International Standard ISO 5436

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Calibration specimens — Stylus instruments — Types, calibration and use of specimens

Échantillons d'étalonnage — Instruments à palpeur — Type, étalonnage et emploi des échantillons

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 5436 was prepared by Technical Committee ISO/TC 57, *Metrology and properties of surfaces*.

Calibration specimens — Stylus instruments — Types, calibration and use of specimens

1 Scope and field of application

This International Standard specifies the characteristics of specimens for the calibration of stylus instruments (see ISO 1880 and ISO 3274) and the annexes give information regarding their calibration and application to the calibration and adjustment in laboratories, standards rooms and workshops.

2 References

ISO 468, *Surface roughness — Parameters, their values and general rules for specifying requirements.*

ISO 1878, *Classification of instruments and devices for measurement and evaluation of the geometrical parameters of surface finish.*

ISO 1879, *Instruments for the measurement of surface roughness by the profile method — Vocabulary.*

ISO 1880, *Instruments for the measurement of surface roughness by the profile method — Contact (stylus) instruments of progressive profile transformation — Profile recording instruments.*

ISO 3274, *Instruments for the measurement of surface roughness by the profile method — Contact (stylus) instruments of consecutive profile transformation — Contact profile meters, system M.*

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 468, ISO 1878, ISO 1879 and ISO 3274, and the following apply.

standard instrument calibration specimen: A specimen having accurately determined standardized characteristics for testing or establishing one or more features of the performance of an instrument.

4 Types and purposes of instrument calibration specimens

The calibration of the existing wide range of instruments in all modes of operation calls for more than one type of calibration specimen.

Each calibrated specimen may have a limited range of application according to its own characteristics and those of the instrument to be calibrated. The validity of the calibration of an instrument will be dependent on the correct association of these characteristics.

To cover the range of requirements, four types of specimens are described, each of which may have a number of variants. Their principal applications are specified in 4.1 to 4.4 and dimensions and tolerances in 7.1 to 7.4.

4.1 Type A

These specimens are for checking the vertical magnification of profile recording instruments having displacement sensitive pick-ups.

4.1.1 Type A1

These specimens have a wide calibrated groove with a flat bottom, or a number of separated grooves of equal or increasing depth, each groove being wide enough to be insensitive to the shape or condition of the stylus tip.

4.1.2 Type A2

These specimens are similar to type A1, except that the grooves have rounded bottoms of sufficient radius to be insensitive to the shape or condition of the stylus tip.

4.2 Type B

These specimens are primarily for checking the condition of the stylus tip.

4.2.1 Type B1

These specimens have a narrow groove or a number of separated grooves proportioned to be increasingly sensitive to the dimensions of the stylus. They are intended for use with instruments having displacement sensitive pick-ups.

4.2.2 Type B2

These specimens have two grids of nominally equal R_a values, one being sensitive and the other insensitive to the dimensions of the stylus tip. These grids are used comparatively for checking the stylus tips of parameter instruments having motion-sensitive pick-ups, the ratio of the R_a values being taken as the criterion.

4.3 Type C

These specimens are primarily intended for checking parameter meters.

They have a grid of repetitive grooves of simple shape (either sinusoidal, triangular or arcuate) which have relatively low harmonic amplitudes. They are used primarily for calibrating parameter meters, but they may also be used for checking horizontal magnification if the spacing of the grooves is held within limits acceptable for this purpose.

An essential requirement of type C calibration specimens is that standardized specimens of differing waveform are nevertheless compatible, in the sense that they will all lead to the same state of instrument calibration or verification, provided they are used correctly.

The declared parameter values issued with each specimen refer to a smooth straight datum and filtered profiles derived from the trace according to ISO 3274. Although the wider grooves are generally insensitive to the dimensions of the stylus tip, sensitivity in this respect may become appreciable for the narrowest grooves; and for this reason the parameter values shall be declared with reference to the stylus tip.

4.3.1 Use for skidless instruments

Each specimen will calibrate a skidless instrument (one which traces the profile with respect to a smooth straight datum) with respect to the particular crest spacing of that specimen.

The purpose of the series of specimens is to enable the transmission characteristic to be checked for a number of spacings and amplitudes.

4.3.2 Use for skid-type instruments

The use of type C specimens for calibrating skid-type instruments is restricted to those for which the generally indeterminate rise and fall of the skid(s) over the crests makes an insignificant contribution to the calibration. This is best assured by using a specimen having the shortest crest spacing permitted by the stylus, as shown in annex B, and this is the general practice.

4.4 Type D

These specimens are for overall check of meter calibration.

They have irregular profiles (for example as obtained by grinding) in the direction of traverse, but they have the convenience of an approximately constant cross-section along their lengths.

The specimens simulate workpieces containing a wide range of crest spacings, but reduce the number of traverses needed to give a good average value. They provide, for reassurance, a final overall check on calibration.

The accuracy obtainable by averaging a few random traverses will generally be less than type C specimens, but may be sufficient for workshop purposes. Higher accuracy can be obtained by averaging a statistically determined number of appropriately positioned traverses.[1)]

5 Materials

The material used shall be hard enough to ensure adequate life in relation to cost. Its surface shall be smooth and flat enough not to affect the evaluation of the grooves. Glass or quartz or materials harder than 750 HV are favoured.

6 Size of specimen

The operative area shall be large enough to provide for the total length of traverse required for all intended determinations.

One or more than one kind of specimen may be provided on a single block. So as to ensure the best possible economic conditions, overall dimensions of specimens are not given.

7 Mechanical requirements

It should be noted that, in the tables which follow, the nominal values carry a wide tolerance, and that these values should not be used as the basis of instrument calibration (see clause 9, notes 1 and 2).

7.1 Type A

7.1.1 Type A1: Wide grooves with flat bottoms (see figure 1 and table 1)

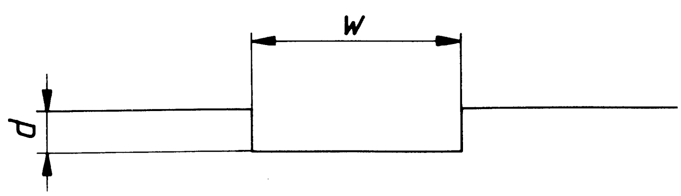


Figure 1 — Type A1 groove

1) To form the subject of a future International Standard.

Table 1 — Nominal values of depth and width for type A1

Values in micrometres

Depth, *d*	0,3	1,0	3,0	10	30	100
Width, *w*	100	100	200	200	500	500

If a skid is used, it shall not cross a groove at the same time that the stylus crosses the groove being measured.

For tolerances, see table 2.

Table 2 — Tolerances for types A1 and A2

Nominal value	Tolerance on nominal value	Uncertainty of measurement in calibrated mean depth		Standard deviation from the calibrated mean
µm	%	%	(µm)	%
0,3	± 20	± 3	(± 0,01)	3
1	± 15	± 2	(± 0,02)	2
3	± 10	± 2	(± 0,06)	2
10	± 10	± 2	(± 0,2)	2
30	± 10	± 2	(± 0,6)	2
100	± 10	± 2	(± 2)	2

7.1.2 Type A2: Wide grooves with rounded bottoms (see figure 2 and table 3)

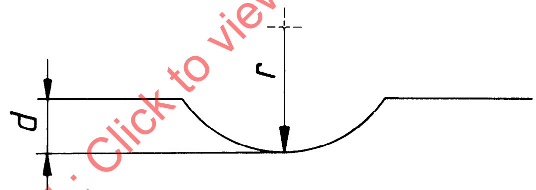


Figure 2 — Type A2 groove

Table 3 — Nominal values of depth and radius for type A2

Depth, *d*, (µm)	1,0	3,0	10	30	100
Radius, *r*, (mm)	1,5	1,5	1,5	0,75	0,75

If a skid is used, it shall not cross the groove at the same time that the stylus crosses the groove being measured.

For tolerances, see table 2.

7.1.3 The basis of assessment for types A1 and A2 is given in 8.1; requirements regarding statements of mean values are given in clause 9; guidance on calibration is given in clauses A.1 and A.2; guidance on use is given in clauses B.1 and B.2.

7.2 Type B grooves for checking stylus tips

7.2.1 Type B1

Development of specimens having single narrow grooves is proceeding, but is not yet sufficiently advanced to permit standardization.

7.2.2 Type B2

These specimens have two grids formed on a common base.

7.2.2.1 Sensitive grid (see figure 3)

Isosceles triangular grooves with sharp peaks and valleys, for testing 10 µm radius tips.

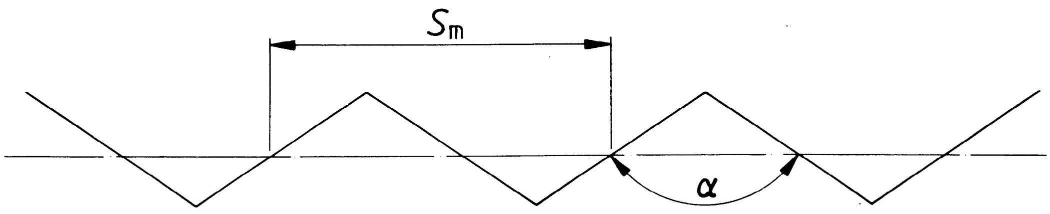


Figure 3 — Type B2 grooves (sensitive grid)

For 10 µm radius tips :

- $\alpha = 150°$
- $R_a = 0{,}5$ µm ± 5 %

S_m shall be determined by α and R_a, and will thus have the mid-limit value of 15 µm.

For tolerances, see table 4.

7.2.2.2 Insensitive grid (see figure 4)

Sinusoidal or arcuate grooves, proportioned to make R_a substantially independent of the stylus tip.

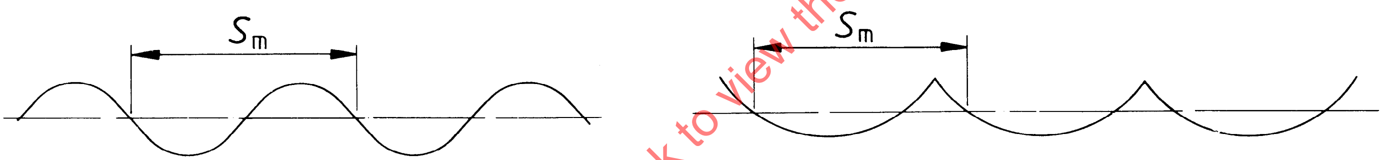


Figure 4 — Type B2 grooves (insensitive grid)

For 10 µm radius tips :

- $R_a = 0{,}5$ µm ± 5 %
- $S_m = 0{,}25$ mm

For tolerances, see table 4.

NOTES

1 Grooves for tips with a radius of less than 10 µm (if such are practical) have still to be developed.

2 For convenience, one or more type C grids may be added for general calibration of R_a. Such grids shall be clearly distinguished from the type B2 pair.

7.2.3 The basis of assessment for type B2 is given in 8.2, tolerances are given in 7.2.2 and table 4, and the method of use is described in B.4.

Table 4 — Tolerances for type B2 sensitive and insensitive grids

Nominal value		Tolerance on nominal value
for sensitive grids	for insensitive grids	%
$\alpha = 150°$ $R_a = 0{,}5$ µm $S_m = 15$ µm	 $R_a = 0{,}5$ µm $S_m = 0{,}25$ mm	± 5
Ratio of mean R_a values		± 2

7.3 Type C

The nominal values given in 7.3.1, 7.3.2 and 7.3.4 are values which assume negligible attenuation by the stylus or filter.

7.3.1 Type C1: Grooves having a sine wave profile (see figure 5 and table 5)

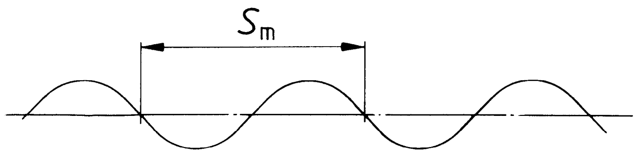


Figure 5 — Type C1 grooves

Table 5 — Nominal values of R_a for type C1

Mean spacing of profile irregularities, S_m, mm			
0,08	0,25	0,8	2,5
R_a, µm			
0,1 0,3 1 3	0,3 1 3 10	1 3 10 30	3 10 30 —

For tolerances, see table 6.

Table 6 — Tolerances for types C1 to C4

Nominal value of R_a	Tolerance on nominal value	Uncertainty of measurement of stated mean value of R_a	Standard deviation from mean value
µm	%	%	%
0,1	± 25	± 3	3
0,3	± 20	± 2	2
1	± 15	± 2	2
3	± 10	± 2	2
10	± 10	± 2	2
30	± 10	± 2	2

NOTE — The sine wave provides an ideal reference for calibrating a frequency-dependent instrument because the perfect sine wave, having no harmonics, is not changed in shape by a wave filter and accords directly with the transmission characteristics defined in ISO 3274.

7.3.2 Type C2: Grooves having an isosceles triangular profile (see figure 6 and table 7)

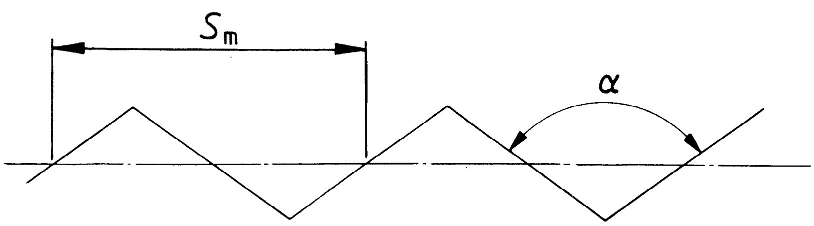


Figure 6 — Type C2 grooves

Table 7 — Nominal values of R_a and α for type C2

Mean spacing of profile irregularities, S_m, mm				α°
0,08	0,25	0,8	2,5	
R_a, µm				
0,1	0,3	1,0	3	178,9
0,3	1,0	3	10	176,4
1,0	3	10	30	168,6
3	10	30	—	144,5

For tolerances, see table 6.

7.3.3 Type C3: Simulated sine wave grooves (see figure 7)

These are simulated sine waves, which include triangular profiles with rounded or truncated peaks and valleys, the total r.m.s. harmonic content of which shall not exceed 10 % of the r.m.s. value of the fundamental.

For tolerances, see table 6.

Figure 7 — Type C3 grooves

NOTE — Specimens of this kind have often been provided by instrument manufacturers for calibrating their own instruments, but without commitment regarding the further use of the specimens.

7.3.4 Type C4: Grooves having an arcuate profile (see figure 8 and table 8)

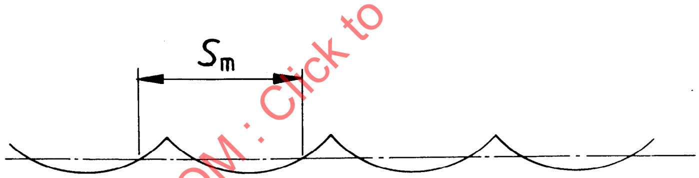


Figure 8 — Type C4 grooves

Table 8 — Nominal unfiltered values of R_a for type C4

Mean spacing of profile irregularities, S_m, mm	
0,25	0,8
R_a, µm	
0,2	3,2
3,2	6,3
6,3	12,5
12,5	25

For tolerances, see table 6.

7.4 Type D: Unidirectional irregular profiles (see figure 9)

These have an irregular ground profile which is repeated every 4 mm in the longitudinal direction of the specimen. Normal to the measuring direction of the specimens, the production grooves on the measuring area have a constant profile form.

The nominal filtered values, R_a, of the specimens, in micrometres, are

0,15; 0,5; 1,5 (cut-off value 0,8 mm)

For tolerances, see table 9.

Table 9 — Tolerances for type D

Nominal value R_a	Tolerance on nominal value	Uncertainty of measurement of stated mean value of R_a 1)	Standard deviation from mean value
µm	%	%	%
0,15	± 30	± 5	4
0,5	± 20	± 3	3
1,5	± 15	± 3	3

1) From 12 evenly distributed readings.

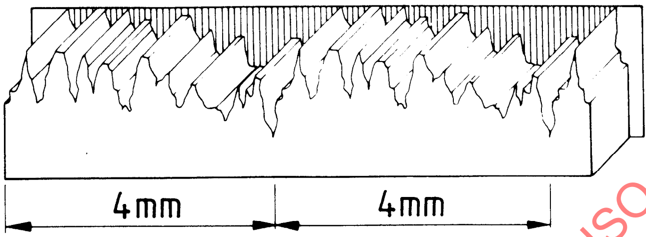


Figure 9 — Type D grooves (profile repetition at 4 mm intervals)

7.5 The basis of assessment for types C and D is given in 8.3. Guidance on calibration is dealt with in clause A.3, while clauses B.3 to B.6 refer to use and other relevant matters.

8 Basis of assessment of calibrated values

8.1 Type A

8.1.1 Type A1

A continuous straight mean line equal in length to three times the width of the groove is drawn over the groove to represent the upper level of the surface and another to represent the lower level, both lines extending symmetrically about the centre of the groove (see figure 10).

To avoid the influence of any rounding of the corners, the upper surface on each side of the groove is to be ignored for a length equal to one-third of the width of the groove. The surface at the bottom of the groove is assessed only over the central third of its width. The portions to be used for assessment purposes are therefore those shown at A, B and C in figure 10.

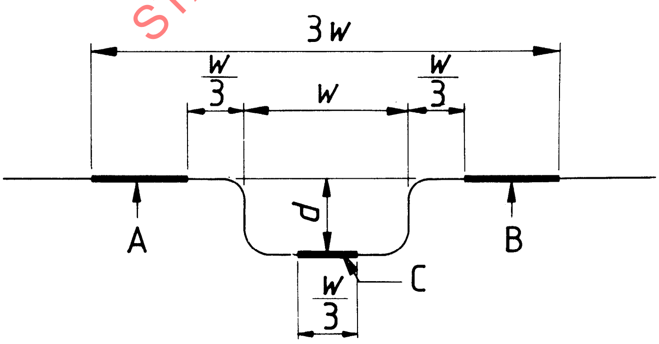


Figure 10 — Assessment of calibrated values for type A1

The depth d of the groove shall be assessed perpendicularly from the upper mean line to the mid-point of the lower mean line.

NOTE — The depth d as defined here will be equal to the mean of the portion C below the upper mean line.

A significant number, not less than five, of evenly distributed traces shall be taken.

8.1.2 Type A2

A mean line representing the upper level is drawn over the groove as described for type A1. The depth shall be assessed from the upper mean line to the lowest point of the groove.

A significant number, not less than five, of evenly distributed traces shall be taken.

8.2 Type B2

The ratio of the mean R_a of the sensitive grid and the mean R_a of the insensitive grid shall be calibrated using a substantially sharp tip (<2 µm nominal radius) and a standard two C-R 1) filter having 0,25 mm cut-off according to ISO 3274. (See clause B.4.)

Not less than 18 evenly distributed traces shall be taken on each grid, all instrument adjustments remaining constant throughout the determination.

8.3 Types C1 to C4, and D

The profile shall be traced by one or more specified stylus tips with respect to a straight datum, and an R_a value shall be determined, by measurement or computation, after modification of

1) "C" stands for "capacitive", "R" for "resistive".

the traced profile by each of the standard two C-R filters defined in ISO 3274 for which the evaluation length is less than that of the grid, the filter being designated by its cut-off (the wavelength for which it gives 75 % transmission).

A significant number, not less than 12, of evenly distributed traces shall be taken.

If the profile is traced by a 2 µm tip, values for other tips may be derived by computation, this fact being stated.

9 Marking

After each specimen has been individually calibrated, it shall be accompanied by the following statements as and where applicable:

a) type(s) of specimen;

b) the nominal value(s);

c) the effective radius of the stylus tip(s) to which each calibrated value applies;

d) details of calibration:

1) for types A1 and A2, the calibrated mean value of depth of the groove, the standard deviation from the mean, and the number of evenly distributed observations taken;

2) for type B2, the calibrated ratio of the mean R_a value of the sensitive grid to that of the insensitive grid for a sharp tip (of not more than 2 µm nominal radius);

3) for types C and D, the calibrated mean value of R_a for each tip used and for each two C-R transmission characteristic (defined by its 75 % transmission cut-off) for which the specimen may be used, the standard deviation from each mean, and the number of observations taken;

e) the permitted uncertainty in the calibrated mean value, as given in tables 2, 4, 6, and 9;

f) any other reference conditions to which each calibration applies, for example the basis of digital evaluation (ordinate discretization, vertical quantization), and whether the values declared refer to direct measurement or are derived therefrom.

NOTES

1 The nominal value is used only as an aid to identification. It carries a large tolerance as a concession to problems of economic manufacture. The difference between the nominal value and the calibrated value does not constitute an error.

2 The calibrated mean value is the value to be used for calibrating instruments. It is the measured mean value of the appointed number and distribution of traces taken across the operative portion of the specimen, corrected for any predetermined errors in the calibrating equipment, as far as these are known. (See annex C.)

Some degree of uncertainty in the calibrated mean value is permitted to allow for the possibility of residual errors in the calibrating equipment which are unknown and for which correction cannot be made.

3 The stated standard deviation is the standard deviation of the measured values corrected where possible for the estimated standard deviation of the calibrating equipment.

In principle, estimation of the random error of the instrument in the selected mode of use can be made by traversing a specimen a number of times over precisely the same track. To ensure that wear of the track does not occur and progressively alter its value, it is generally acceptable to use several closely adjacent tracks and assume they are identical. For example five tracks spaced 0,1 mm apart may each be traversed five times.

As far as possible the required information specified here shall be marked on each specimen; but, if there is insufficient space, the values may be stated separately and uniquely identified with the specimen, for example by means of a serial number.

Annex A

Calibration of instrument calibration specimens

A.1 General procedure for type A specimens

A stylus instrument having displacement-sensitive pick-up, or an optical interferometer can be used.

The interferometric results are directly traceable to the wavelength of light, but are generally limited to the shallower grooves unless the instrument is built to allow for optical desensitization. The surface may have to be metallized to ensure adequate reflectivity, and the quality of the fringes may limit the attainable accuracy.

The stylus method is indirectly traceable to the wavelength of light, but it can cover the whole range of specimens without difficulty.

In theory, a very small divergence between the two methods is possible. There may be differences in the mechanical and optical properties of the upper and lower surfaces, and while the stylus method measures normal cross-sections, the optical method generally measures oblique cross-sections which assume uniformity within the length of the groove occupied by the obliquity. In practice, such effects are generally negligible.

A.2 Procedure for type A specimens using a stylus instrument

The vertical magnification of the instrument is first calibrated. For this purpose a step, as nearly as possible equal in size to that of the specimen, may be formed by two gauge blocks wrung down on an optical flat. The instrument is then used as a comparator to compare the specimen step with that of the gauge block. In this way residual errors in the instrument tend to cancel out. For highest accuracy, at least five equally spaced traverses should be taken along the marked length of the groove, and a corresponding number across the gauge block step.

The adjacent sides of the gauge blocks used are preferably manufactured so that the corners are sharp enough to produce a clearly defined step on the profile graph, as shown in figure 11.

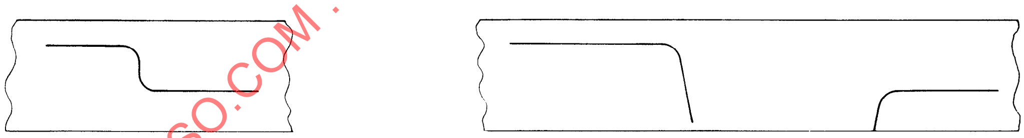


Figure 11 — Profile graphs

A number of gauge blocks can be wrung down to provide a series of steps, as shown in figure 12, attention being paid to the flatness, smoothness and parallelism of the surfaces. The steps can be calibrated directly by interferometry.

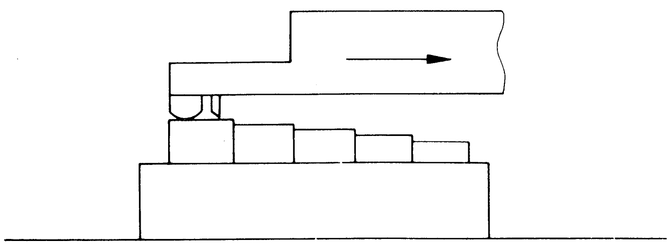


Figure 12 — Gauge blocks providing a series of steps

Gauge block steps over 2 µm can be used directly, but for smaller displacements the calibration error of the gauge block step itself may represent an excessively large proportion of the step height. Small displacements down to 0,2 µm can be produced by scaling down larger gauge block steps with an accurate reducing lever. Reductions of 10 or 20 times are used.

A.3 Procedures for type C specimens (C1 to C4)

A.3.1 Determination of R_a value for the traced profile

Since type C specimens are periodic and are formed on a base that is substantially straight in the direction of measurement, an R_a value for the profile traced by a given stylus can be determined by application of the procedures for graphical determination described in ISO 468, ISO 1878 and ISO 1880. In practice, it is necessary only for the traced profile to be evaluated with sufficient accuracy. The R_a value of the trace will refer to the specimen itself, without involving the transmission characteristics of an instrument.

A.3.2 Determination of R_a value for modified profile

If the traced profile is passed through a defined wave filter, there will emerge a modified (or transformed) profile which will also have an R_a value. This R_a value will refer to the profile plus filter, and will thus involve the transmission characteristics of the instrument.

However, when the cut-off wavelength of the filter is around 10 times the wavelength of the specimen (see annex B and figure 16) the R_a value of the modified profile will differ so little from that of the unfiltered profile that for practical purposes the difference can be neglected.

As the wavelength of the specimen approaches the cut-off wavelength, the filtered R_a value will become less than the unfiltered value, to an extent that is shown by the transmission curves in figure 16.

A.3.3 Calibration of periodic (type C) specimens with respect to a straight mean line drawn through each sampling length

In principle, the specimen is traced by a defined (generally sharp) stylus relative to a straight datum, and a profile graph or digital record is taken at an accurately known vertical magnification, using a displacement-sensitive recording system (a system that is uniformly responsive to all frequencies from zero to the highest that is significant). A straight mean line is drawn through each sampling length parallel to the peaks and valleys of the graph, such that the average values of the departures on each side of it, over a whole number of periods, are equal. The total length of the periods taken should as nearly as possible be equal to the sampling length, which should then be adjusted to fit a whole number of periods (figure 13). A number of consecutive sampling lengths should be included in each trace and according to the uniformity of the defined area several evenly distributed traces are taken and averaged. Thus the mean R_a is found for the given sampling length, without electrical filtering.

The graphical method can generally be simulated, with greater ease and precision, by digital methods.

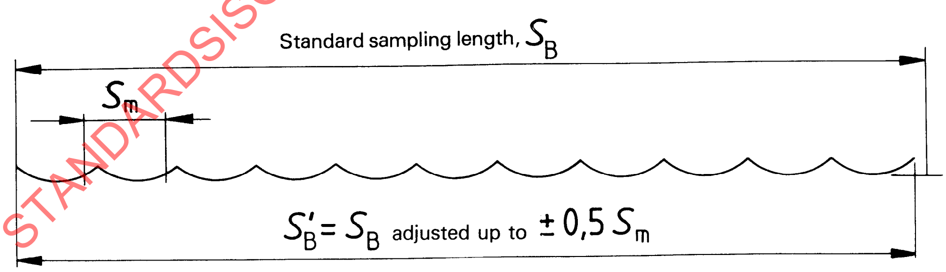


Figure 13 — Choice of sampling length

A.3.4 Calibration of type C and D specimens with respect to the filter characteristics defined in ISO 3274

A.3.4.1 Calibration by comparison

Calibration can sometimes be carried out with acceptable accuracy by direct comparison with a specimen having the same waveform, wavelength and comparable R_a value, this value being accurately known.

Precise calibration of the instrument will then be of secondary importance as it is used only as a comparator.

A.3.4.2 Calibration using digital methods

A displacement sensitive pick-up having a defined stylus is used, and the vertical magnification of the instrument is accurately calibrated from gauge blocks or from a specially calibrated type A specimen.

The required number of fairly distributed traces is taken, each trace being longer than the traversing length appropriate to the intended meter cut-off. The profile of each trace is recorded digitally, relative to a straight datum, the ordinate density and quantization being sufficient to represent the waveform and give the required accuracy. Use of on-line logging of ordinates is advantageous.

Taking the digitally recorded ordinates of each trace in turn, the mean line of the filter to be simulated, and from it the R_a value of the corresponding modified profile, can be computed both for periodic and for irregular profiles according to definitions in ISO 3274.

The filtered R_a value is taken to be the mean value of a sufficient number of evenly distributed modified profiles obtained with the stated stylus and filter.

Annex B

Use of instrument calibration specimens

B.1 General

It is convenient to discuss separately the correct use of:

a) type A specimens for calibrating graphic or digital profile recording instruments (see ISO 1880);

b) type C specimens for calibrating parameter indicating instruments of consecutive profile transformation.

B.2 Use of type A specimens (wide single grooves)

These specimens are used for calibrating the vertical magnification of a recording instrument having a displacement-sensitive pick-up.

B.2.1 If a spherical skid is used, care should be taken to see that at the moment when the stylus traverses the groove to be measured, the skid slides only on a smooth part of the surrounding surface, and does not traverse the same groove, or any other groove of significant width.

B.2.2 A sufficient number of traverses across the calibrated part of the length of the groove should be taken and averaged.

B.2.3 The horizontal magnification should be large enough, and hence give sufficient time, for the stylus and recording pen to indicate clearly that the bottom of the groove has been reached (see figure 14).

Figure 14 — Effects of horizontal magnification

B.3 Use of type C specimens (grids) for calibrating parameter meters

B.3.1 These specimens are normally used for calibrating the parameter meter of a pick-up and amplifying system incorporating a filter network which transmits a limited range of wavelengths. Such a filter is required for the measurement of workpieces. Its purpose is to select, from the great range of wavelengths found on the surfaces of most workpieces, a waveband representing the surface roughness.

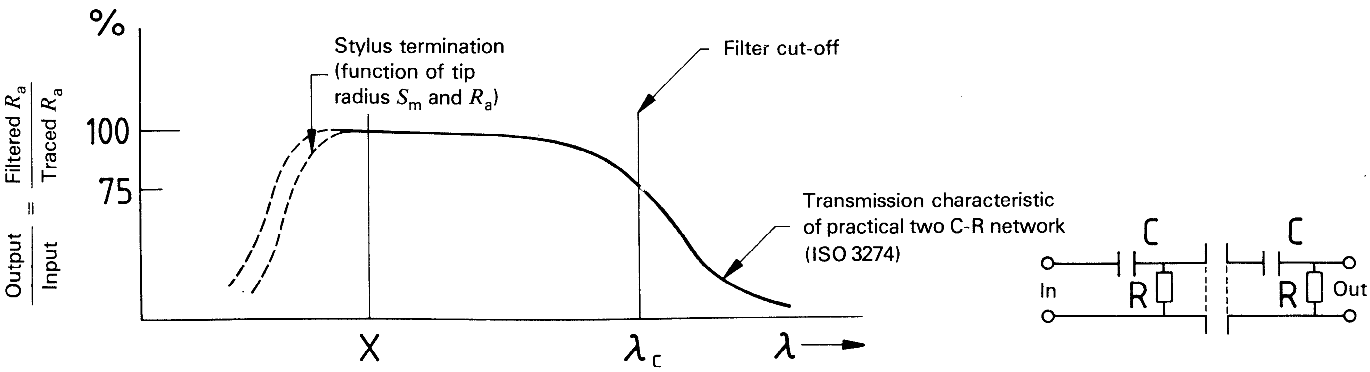


Figure 15 — Transmission characteristic for calibration

B.3.2 It is usual to calibrate instruments with a periodic specimen (triangular or approximately sinusoidal) calibrated with respect to a straight mean line and having a spacing short enough to come well on to the flat portion of the characterization, as at X in figure 15, where there is substantially no attenuation caused either by the stylus or by the electric filter, and where the filtered R_a value is substantially equal to the unfiltered value of the profile. The instrument is then deemed to be calibrated for the measurement of workpiece profiles (which may contain a wide range of crest spacing represented by a corresponding range of sinusoidal frequencies) according to the chosen transmission characteristic which is assumed to comply with ISO 3274.

B.3.3 If, to make sure of avoiding stylus losses, a specimen having a spacing which comes nearer to the cut-off is used, corresponding allowance shall be made for the transmission of the instrument as shown by the transmission curves in figure 16, where the ratio of the filtered to unfiltered value of R_a is plotted against wavelength for four filter network characteristics defined in ISO 3274 and for the three periodic waveforms defined in this International Standard.

By way of example, for a sinusoidal specimen having a spacing equal to one third of the cut-off, the instrument transmission will be 96 % of its maximum value, and the correct reading for this specimen, if it has been calibrated from a straight mean line without regard for attenuation, would be 4 % below the marked value.

If, however, the calibration specimen has been calibrated for each of the transmission characteristics for which it is serviceable, as required in clause 9 d), the correct reading taking its waveform and the attenuation into account will be marked on it so that the instrument can be adjusted (or checked) to give this reading directly.

B.3.4 It follows from B.3.3 that the R_a-meter of a correctly calibrated instrument will give the value of the modified profile of the calibration specimen, according to the filter used.

B.3.5 There is an important distinction to be drawn between the measurement of calibration specimens having a pure or approximately pure sinusoidal waveform, and the measurement of workpieces having irregular profiles (such as are produced by grinding). The former contain a single wavelength the value of which is directly influenced by the shape of the filter transmission, while the latter contain a range of wavelengths distributed through and often beyond the pass band, the attenuation at each end of which affects only some of the included components of the profile, and may thus have a smaller overall effect on R_a.

The measurement of workpieces having substantially periodic profiles (such as are made by processes like turning) can, however, be affected by the shape of the filter transmission, the more so as the grooves becomes "clean-cut"; but it then becomes easier to identify the wavelength which will be equal to the traverse feed and to select a filter transmission having a cut-off wavelength that is long enough to avoid error.

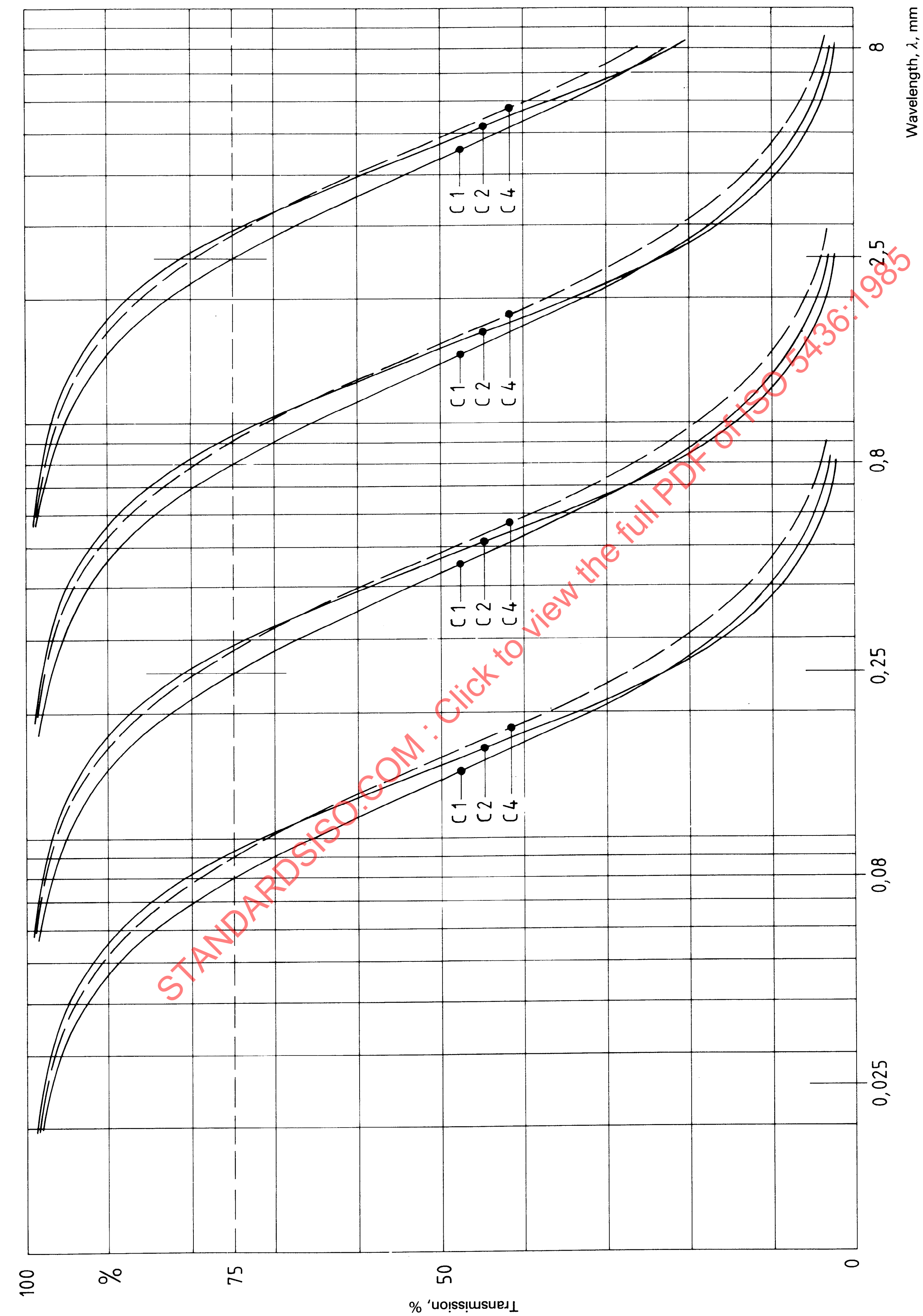


Figure 16 — R_a transmission curves characteristic of types C1, C2 and C4 specimens conforming to ISO 3274

B.4 Consideration of stylus wear

Use tends to produce a small wear patch truncating the tip and reducing its effectiveness (figure 17).

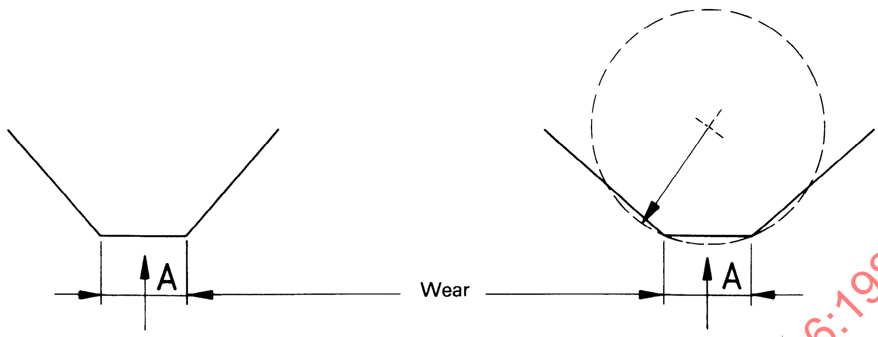


Figure 17 — Stylus wear

Wear can best be measured by looking directly at the end of the tip (in the direction of the arrow A in figure 17) with a microscope of adequate performance. Apart from mechanical requirements for mounting the pick-up, a suitable microscope will be equipped with a 4 mm objective, a X10 objective with graticule, a vertical illuminator, a mechanical stage, and a rotating objective turret fitted with a second objective of lower power with which to locate and approximately focus the tip, because at the higher magnification required for measuring the flat, the image of the flat will generally be invisible until it is simultaneously in focus and centred in the field. Some skill and experience is required in using such a microscope without letting the tip touch the easily scratched objective, and in interpreting what is seen. Although effective, and applicable to all types of pick-up, this method cannot be recommended for the workshop.

For checking tips in the workshop, test specimens having both widely and closely spaced grids of nominally the same R_a value, serviceable for 10 µm tips, have become available (see 7.2.2). The more widely spaced grid is proportioned to be insensitive to tip condition, while the grid of closer spacing is proportioned so that some loss can be expected even for a tip in good condition.

The usual mode of use is first to calibrate the instrument using the insensitive grid, and then compare the reading given by the tip under test with the value it should have given if in good condition. This method calls for very precise determination of the R_a values both for the sharp tip and the tip under test.

In a second mode of use, envisaged in this International Standard, errors are minimized by using the instrument as a comparator, and basing the determination on the ratios of the mean R_a values of the grids found by the two tips — noting that by definition the mean R_a value of the insensitive grid is independent of the tip. In this way, small errors in magnification and in the attenuation of the filter can be made to cancel out.

Thus, if the ratio of the R_a values found for the stylus under test is U_1, and the calibrated ratio of the R_a values for a sharp tip is U_2, the ratio of U_1/U_2, compared with the nominal ratio, provides a criterion for evaluating the tip condition. This criterion will not distinguish between wear and permitted variations in the tip radius unless the initial values of U_1/U_2 determined before wear has begun is known. In practice, however, the distinction may not be important, and knowledge of the ratio including both factors may suffice. For example, if for a perfect 10 µm spherical tip, the ratio of the R_a values from two grids is U_1, and the ratio for a sharp tip is U_2, then U_1/U_2 will be 0,91.

If the instrument tip is spherical, but has a radius larger than the intended value, the ratio of U_1/U_2 will be less than the expected value; but if smaller the ratio will be greater. As wear proceeds, the ratio will fall from its initial value.

The spacing and R_a value given for the grid in 7.2.2 were laid down for a 12,5 µm tip; they are serviceable with some loss of sensitivity for a 10 µm tip; but would have little use for 5 µm tips and none for 2 µm tips. Grids fine enough for these tips call for further development.

The behaviour of a stylus tip that has been fractured will depend on the detailed shape of the fracture in relation to the texture of the surface being traced to such an extent that useful prediction is generally not possible.

A spherical tip sheared off as shown in figure 18 might act as one sharper or blunter than the original according to whether the fractured edge lay along or, to some extent, across a groove, as shown respectively in a) and b). Even though the tip might sometimes reach to the full depth of the groove, the waveform could still be distorted. A generally irregular fracture may exhibit a number of small local peaks, any one of which on a fine surface could sometimes act as a sharp tip regardless of orientation. A pyramid sheared from corner to corner could also behave as a sharp tip.

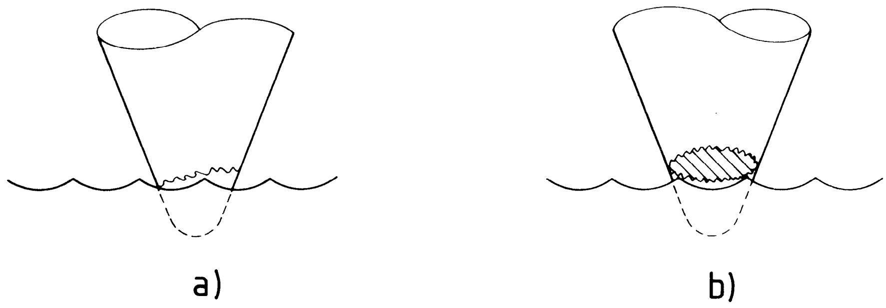


Figure 18 — Sheared off spherical tip

B.5 Considerations of skid devices (if used)

B.5.1 The locus of the skid device, as it slides over the surface, is used to provide a datum from which the excursions of the stylus are measured. If the device rises and falls as it slides over the peaks of the irregularities, these movements will combine with those of the stylus and introduce an error in the traced profile.

Many arrangements of single and multiple skid devices are known. In the case of multiple skids, all skid elements shall touch the surface simultaneously to be effective.

B.5.2 Figure 19 shows how a substantially straight datum is provided by a skid device which incorporates the stylus and transducer and has two co-planar flat skids, one at each end. Each flat shall span the width of at least one groove. Errors should arise only from irregularities in the level of adjacent peaks.

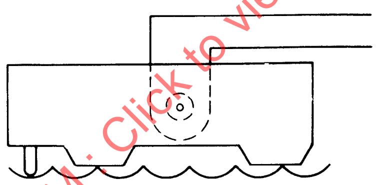


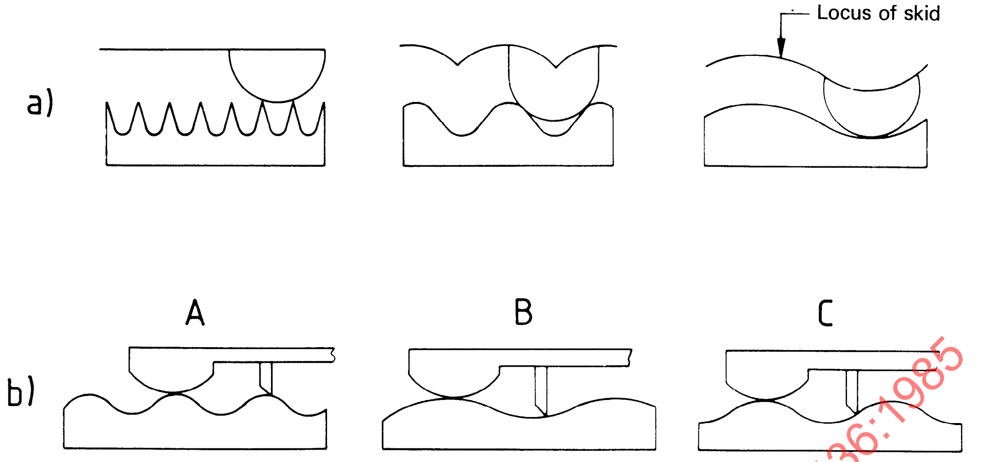
Figure 19 — Centrally relieved flat skid

B.5.3 Figure 20a) shows the approximately arcuate locus of the commonly used single spherical or toroidal skid sliding over periodic profiles of different crest spacing. This locus constitutes the datum from which the specimen profile is measured.

Figure 20b) shows that if the spacing of the specimen happens to be such that skid and stylus engage peaks simultaneously, they will move up and down together, i.e. in phase, and the movement of the stylus relative to the skid reveals less than the true magnitude of the profile. If, on the other hand, the skid is on a peak when the skid is over a valley, their movements will be out of phase, and the apparent movement will reveal more than the true magnitude.

In the case of periodic profiles, the error will be constant throughout the traverse. It may lie anywhere between the maximum positive and maximum negative values, and for some intermediate phase it will be zero.

In the case of irregular profiles, the phase will fluctuate as the pick-up traverses the surface. Both positive and negative values are then likely to be encountered, with the result that the average skid error may be close to zero. (It is because of this that single skids, even of short radius, have been able to find such widespread workshop acceptance.)



A Skid and stylus in phase giving minimum assessment

B Skid and stylus out of phase giving a maximum assessment

C Intermediate phase giving no error

Figure 20 — Skid errors

B.5.4 Figure 21 shows how the profile traced by a spherical skid combines with that of a sinusoidal specimen when fully out of phase and fully in phase. If the ordinates of the skid profile are added to or subtracted from those of the specimen profile, there will emerge in each case a new profile, shown by dashed lines, which represents the original profile as distorted by the skid, and referred to a straight crest line. This is the signal that will emerge from the pick-up for amplification, graphing or parameter assessment.

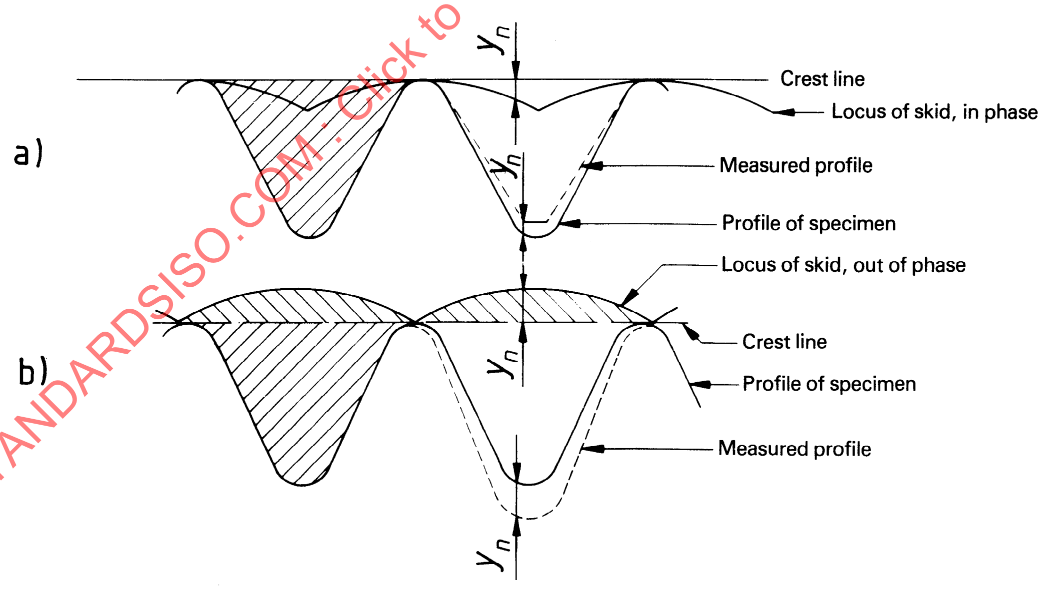


Figure 21 — Profiles traced by a spherical skid on a sinusoidal specimen

B.5.5 The magnitude of the skid error can be found by summing the ordinates of the skid locus and the corresponding ordinates of the specimen profile in any desired phase relation, determining the mean line of the combination, finding from this the parameter value of the combination, and then finding the error as the difference between this value and the true value of the specimen. Without the aid of a computer this process would be tedious.

There are, however, two simple ways of roughly estimating the maximum skid error for the instrument calibration specimens defined in this International Standard. One of these considers simply the effect on the maximum peak-to-valley height, but takes no account of any effect on the shape of the flanks. The other compares the area enclosed between a straight crest line and the skid locus, with the area enclosed between the crest line and the specimen profile, see figure 21.