
**Internal combustion engines —
Piston rings —**

**Part 2:
Inspection measuring principles**

*Moteurs à combustion interne — Segments de piston —
Partie 2: Principes de mesure pour inspection*

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 34, *Propulsion, powertrain and powertrain fluids*.

This third edition cancels and replaces the second edition (ISO 6621-2:2003), which has been technically revised.

The main changes compared to the previous edition are as follows:

- Oil ring diameter range for ring widths 3,0 mm and 3,5 mm increased up to 160 mm.

A list of all parts in the ISO 6621 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is one of a number of International Standards dealing with piston rings for reciprocating internal combustion engines. Others are ISO 6621-1, ISO 6621-3, ISO 6621-4, ISO 6621-5, ISO 6622, ISO 6623, ISO 6624, ISO 6625, ISO 6626 and ISO 6627 (see Bibliography for details).

The common features and dimensional tables presented in this document constitute a broad range of variables, and the designer, in selecting a particular ring type, should bear in mind the conditions under which it will be required to operate.

It is also essential that the designer refer to the specifications and requirements of ISO 6621-3 and ISO 6621-4 before completing their selection.

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Internal combustion engines — Piston rings —

Part 2: Inspection measuring principles

1 Scope

This document defines the measuring principles to be used for measuring piston rings; it applies to piston rings up to and including 200 mm diameter for reciprocating internal combustion engines.

This document can be used for piston rings for compressors working under analogous conditions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4287, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

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

ISO 6621-1, *Internal combustion engines — Piston rings — Part 1: Vocabulary*

ISO 6624-1, *Internal combustion engines — Piston rings — Part 1: Keystone rings made of cast iron*

ISO 6624-2, *Internal combustion engines — Piston rings — Part 2: Half keystone rings made of cast iron*

ISO 6624-3, *Internal combustion engines — Piston rings — Part 3: Keystone rings made of steel*

ISO 6624-4, *Internal combustion engines — Piston rings — Part 4: Half keystone rings made of steel*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6621-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

h_1

distance between the sides, at any particular point perpendicular to the reference plane measured in millimetres

Note 1 to entry: See Figures 1 and 2.

3.2

h_3

distance between the sides at a specified distance a_6 from the peripheral surface.

Note 1 to entry: See Figure 4.

Note 2 to entry: Alternatively, the ring width is controlled by a_6 at a specified width h_3 (see Figure 6).

3.3

radial wall thickness

a_1

radial distance between the peripheral surface and the inside surface of the ring measured in millimetres

Note 1 to entry: See Figure 7.

3.4

total free gap

m

p

chordal distance between the gap ends of the ring in a free unstressed state, measured at the centre line of the *radial wall thickness* (3.3)

Note 1 to entry: See Figure 10.

Note 2 to entry: For rings with an internal notch for a peg, the total free gap is defined by the chordal distance marked as p in Figure 11.

Note 3 to entry: The total free gap is measured in millimetres.

3.5

closed gap

s_1

distance between the gap ends of the ring measured at the narrowest point, which the ring would have when fitted in a gauge of nominal cylinder bore size

Note 1 to entry: See Figure 12.

Note 2 to entry: The closed gap s_1 is related to the nominal diameter d_1 .

3.6

tangential force

F_t

force necessary to maintain the ring at the *closed gap* (3.5) condition by means of a tangential pull on the ends of a circumferential metal tape or hoop

Note 1 to entry: See Figures 13 to 15.

Note 2 to entry: Tangential force is measured in Newtons.

Note 3 to entry: For single-piece rings, it is not recommended for rings $d_1 < 50\text{mm}$; for these rings, see 4.2.6.

Note 4 to entry: For multi-piece rings, vibration is used to reduce friction during or prior to measurement.

3.7

diametral force

F_d

force, acting diametrically at 90° to the gap, necessary to maintain the ring at the nominal diameter condition measured in the direction of the force

Note 1 to entry: See Figure 20.

Note 2 to entry: This method is only applicable to single-piece rings.

Note 3 to entry: Diametral force is measured in Newtons.

3.8 ovality

U

difference between the mutually perpendicular diameters d_3 and d_4 when the ring is drawn to a *closed gap* (3.5) within a flexible tape

Note 1 to entry: It can be either positive ($d_3 > d_4$) or negative ($d_3 < d_4$) (see Figure 21).

Note 2 to entry: This method is only applicable to single-piece rings.

Note 3 to entry: Ovality is measured in millimetres.

3.9 point deflection

W

deviation of the butt ends from the true circle when restrained in a gauge of nominal cylinder bore diameter

Note 1 to entry: See Figure 22.

Note 2 to entry: Point deflection is measured in millimetres.

3.10 light tightness

ability of the peripheral surface of a ring when mounted in a gauge of nominal cylinder bore diameter to exclude the passage of light

Note 1 to entry: See Figure 23.

Note 2 to entry: Areas of the ring showing pinpoint, burry or fuzzy light shall be considered as light tight.

Note 3 to entry: Light tightness is measured in percentage of ring circumference.

3.11 taper on peripheral surface

intentional angular deviation of the peripheral surface from a line perpendicular to the reference plane

Note 1 to entry: See Figure 24.

Note 2 to entry: In the case of the taper faced peripheral surface with partly cylindrical area both measuring points shall be placed on the taper area.

Note 3 to entry: Taper on peripheral surface is measured in micrometres or degrees.

3.12 barrel on peripheral surface

intentional convex deviation of the peripheral surface from a line perpendicular to the reference plane

Note 1 to entry: See Figure 26 for a symmetrical barrel and Figure 28 for an asymmetrical barrel.

Note 2 to entry: t_2 is used for lower barrel face and t_3 for upper barrel face.

Note 3 to entry: Barrel on a peripheral surface is measured in millimetres.

3.13 land width

h_4

h_5

width of the land which theoretically should be in contact with the cylinder bore

Note 1 to entry: See Figure 29.

Note 2 to entry: Land width is measured in millimetres.

3.14
land offset

displacement of the two peripheral surfaces of a slotted or drilled oil control ring in relation to each other in a radial direction

Note 1 to entry: See Figure 31.

Note 2 to entry: Land offset is measured in millimetres.

3.15
plating/coating thickness

distance between the outer surface of the plating/coating and the surface of the base ring material connected with the different configurations of platings/coatings

Note 1 to entry: See Figure 33.

Note 2 to entry: Plating/coating thickness is measured in millimetres.

3.16
nitrided case depth

thickness of the surface layer with a hardness value ≥ 700 HV 0,1 measured perpendicular to the ring peripheral surface or side faces.

Note 1 to entry: See Figures 34 and 35.

Note 2 to entry: Nitrided case depth is measured in millimetres.

3.17
keystone angle

angle enclosed by the two sides of the ring or alternatively, the sum of both side face angles, i.e. included angle

Note 1 to entry: See Figure 36.

Note 2 to entry: Keystone angle is measured in degrees.

3.18
obliqueness

unintentional deviation of the bisector of the keystone included angle from parallelism with the reference plane

Note 1 to entry: Not applicable to rings with designed *twist* (3.19).

Note 2 to entry: See Figure 42.

Note 3 to entry: Obliqueness is measured in degrees.

3.19
twist

intentional torsional deviation of the section of the ring from the reference plane when the ring is restricted to nominal diameter, as in the case of asymmetrical rings such as those internally or externally stepped or bevelled

Note 1 to entry: See Figure 43.

Note 2 to entry: Twist is measured in millimetres.

3.20**unevenness***T_e*

unintentional deviation of the sides of the ring from parallelism to the reference plane, i.e. twisted or dished rings

Note 1 to entry: See Figures 46 and 48.

Note 2 to entry: Not applicable to rings with designed *twist* (3.19), as covered by 4.2.18.

3.21**helix**

displacement of the gap ends perpendicular to the reference plane

Note 1 to entry: See Figure 51.

Note 2 to entry: Helix is measured in millimetres.

3.22**free flatness**

relationship between the ring in the free state and a plane parallel to its reference plane

Note 1 to entry: Free flatness is measured in millimetres.

3.23**circumferential waviness**

three or more lobes showing a continuous pattern of peaks and valleys spaced at a set frequency circumferentially around the bottom side face of the ring

Note 1 to entry: Circumferential waviness is measured in micrometres.

4 Measuring principles**4.1 General measuring conditions**

The following general requirements are applicable to all measuring principles unless otherwise specified:

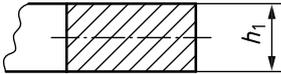
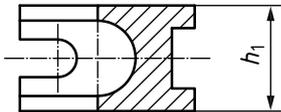
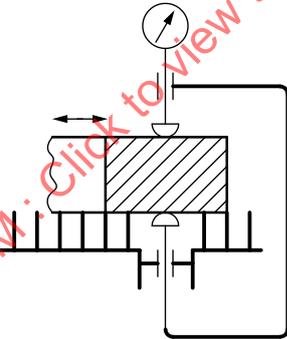
- a) the ring shall rest on the reference plane in the free or open condition. No additional force shall be applied to load the ring on the reference plane; except when measuring "unevenness" in accordance with 4.2.19 or "helix" in accordance with 4.2.20;
- b) certain measurements are made with the ring in the closed condition in a gauge of nominal cylinder bore diameter. When orientated rings are measured in this way, they shall be so placed that the top side of the ring is towards the reference plane;
- c) measurements shall be made using instruments with a resolution not to exceed 10 % of the tolerance of the dimension being measured.

For further terms and definitions see ISO 6621-1.

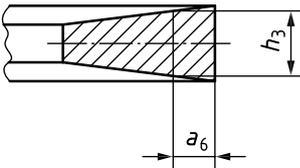
4.2 Characteristics and measuring principles

4.2.1 Ring width

4.2.1.1 Parallel sided rings, h_1 (in millimetres)

Measuring principle	
<p>Measure with spherical measuring probes each of radius 1,5 mm ± 0,05 mm, exerting a measuring force of approximately 1 N (see Figure 3).</p> <p>In the case of slotted oil rings, the measurement shall be made between the slots and not across them (see Figure 2).</p>	
<p>Key h_1 ring width</p>	
<p>Key h_1 ring width</p>	<p>Figure 1</p> 
	<p>Figure 2</p> 
	<p>Figure 3</p>

4.2.1.2 Keystone rings, half keystone rings, h_3

Measuring principle	
<p>Method A</p> <p>This method determines h_3 for a specified value of a_6 (see Figure 4).</p>	
<p>Key h_3 keystone ring width a_6 keystone ring depth</p>	
	<p>Figure 4</p>

Measuring principle

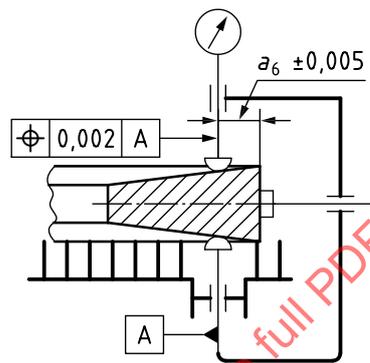
Measure with spherical measuring probes each radius $1,5 \text{ mm} \pm 0,05 \text{ mm}$ exerting a measuring force of approximately 1 N (see Figure 5).

If the measuring equipment is calibrated with parallel gauges instead of keystone gauges, the use of spherical measuring probes for the measurement according to Figure 4 will give rise to an error as follows:

- for 6° keystone angle: $0,004 \text{ mm}$ (Ring types: T, TB, TBA, and TM)
- for 7° keystone angle: $0,012 \text{ mm}$ (Ring types: HK, and HKB)
- for 15° keystone angle: $0,026 \text{ mm}$. (Ring types: K, KB, KBA, and KM)

To obtain the correct measured width of the keystone ring, the above values shall be deducted from the measured values.

Values of a_6 are given in ISO 6624-1 to ISO 6624-4.



Key

a_6 keystone ring depth

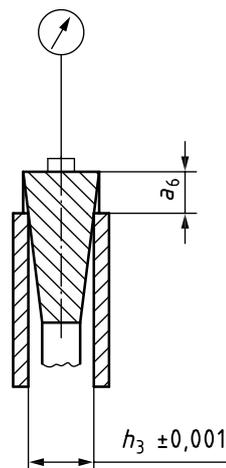
Figure 5

Method B

This method determines a_6 for a specified value of h_3 (see Figure 4).

Measure with a flat face probe exerting a measuring force of approximately 1 N . The ring shall be placed between two sharp-edged (radius $\leq 0,01 \text{ mm}$) circular discs which are spaced apart at the specified gauge width h_3 (see Figure 6).

Values of h_3 are given in ISO 6624-1 to ISO 6624-4.



Key

h_3 keystone ring width

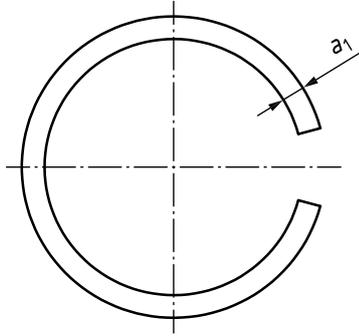
a_6 keystone ring depth

Figure 6

4.2.2 Radial wall thickness, a_1

Measuring principle

1. Measure radially between a flat measuring surface on the peripheral surface and a special measuring surface of the radius approximately 4 mm on the bore, and using a measuring force of 3 N to 10 N (see Figure 8).



Key

a_1 radial wall thickness

Figure 7

2. Measure radially between cylindrical inserts or rollers of radius approximately 4 mm and with a measuring force of 3 N to 10 N. The peripheral surface of the rollers shall be perpendicular to the reference plane.

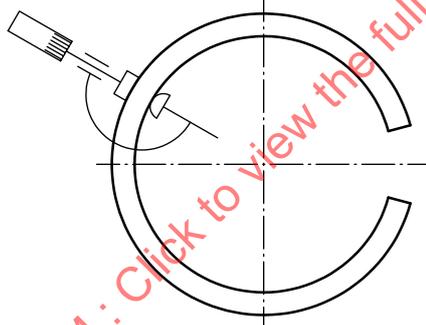


Figure 8

The length of the rollers shall be greater than the axial ring width (see Figure 9).

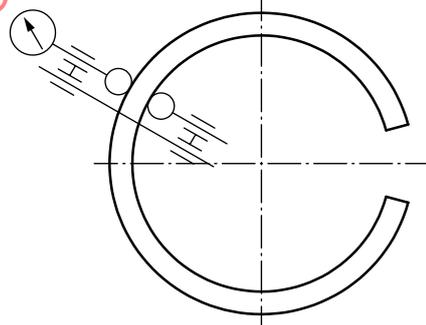
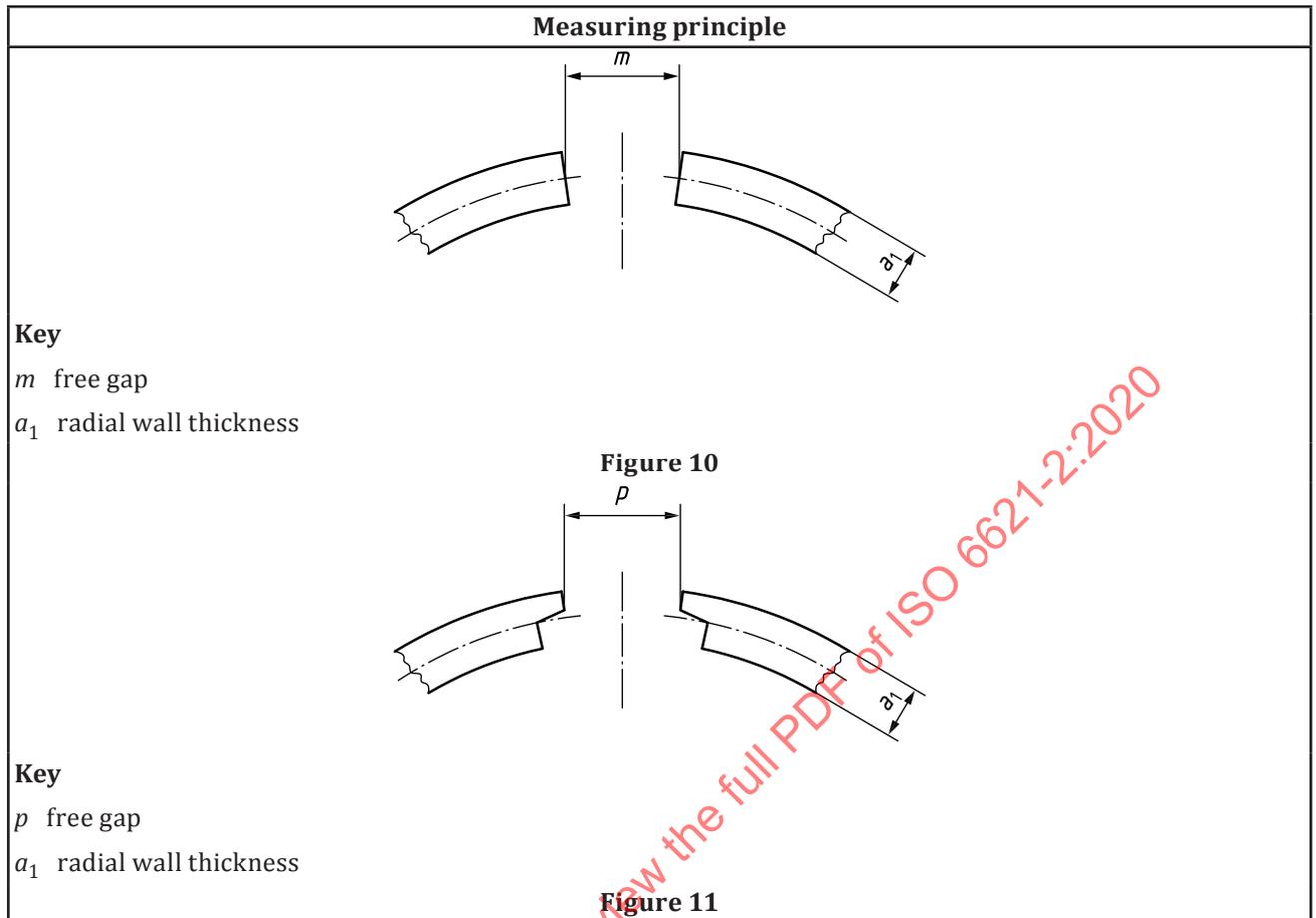


Figure 9

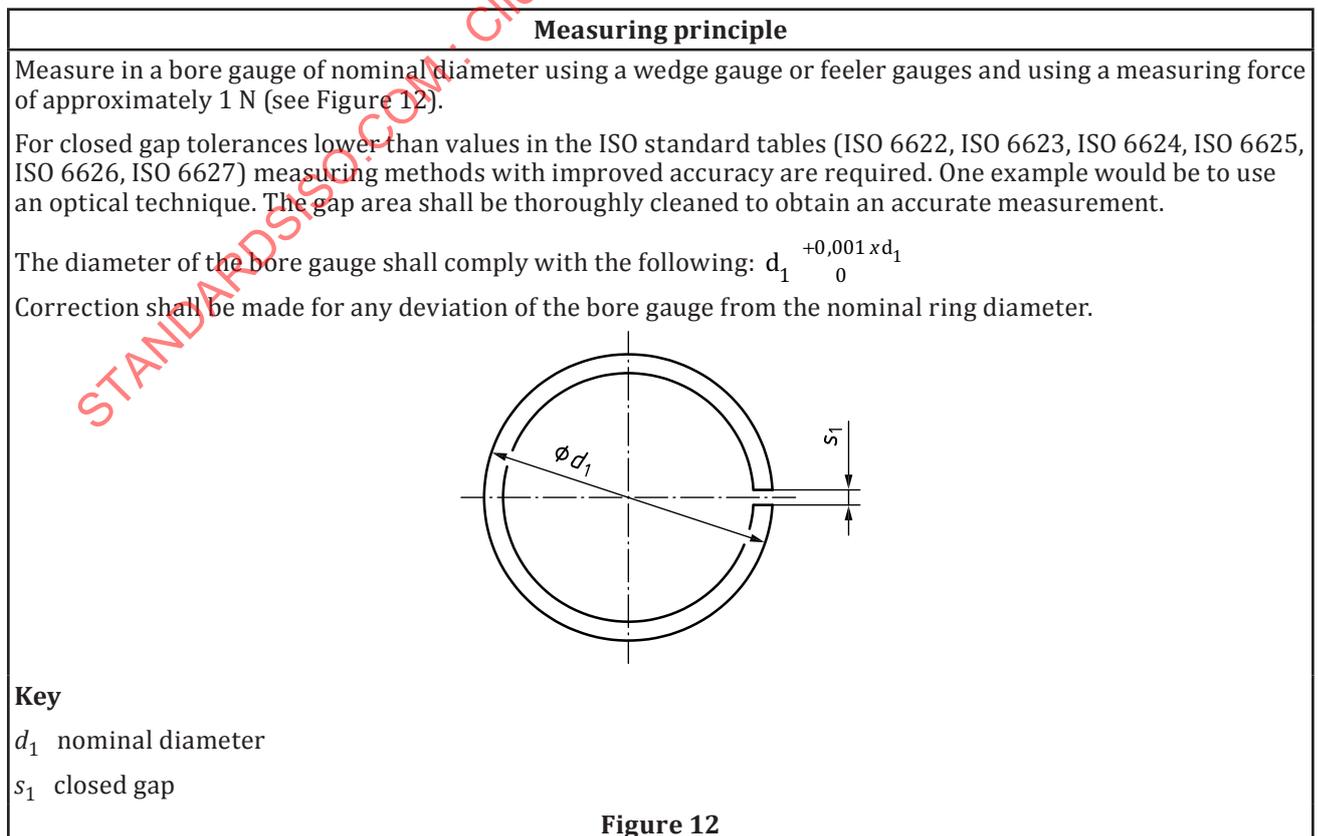
4.2.3 Total free gap m, p

Measuring principle

Measure with a steel rule to the nearest 0,25 mm.
Optionally, this feature can be measured with callipers.



4.2.4 Closed gap, s_1

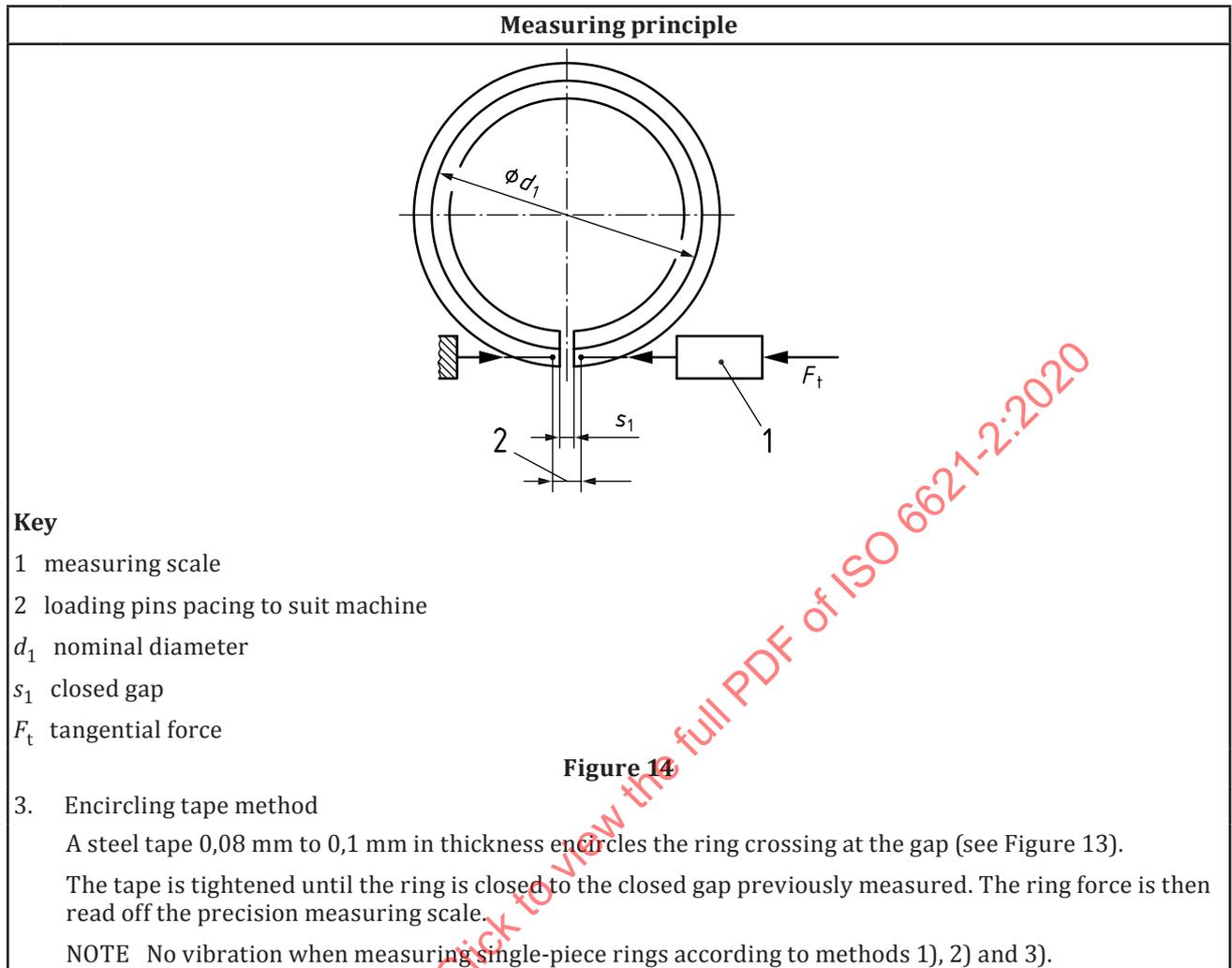


4.2.5 Tangential force, F_t (in Newton)

4.2.5.1 For single-piece rings

NOTE Not recommended for rings $d_1 < 50\text{mm}$; for these rings, see 4.2.6.

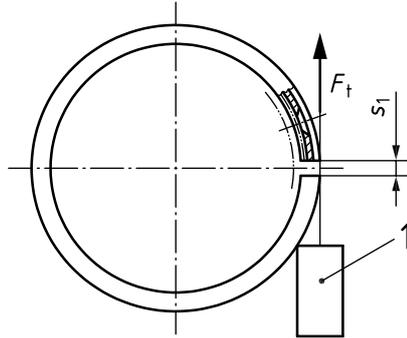
Measuring principle	
<p>1. Tape method (see Figure 13)</p> <p>The encircling steel tape of thickness 0,08 mm to 0,10 mm is carried around 10 mm diameter rollers set 20 mm apart (see Figure 13). In tightening the tape, the ring is closed to the point where the gap ends touch and then open to the closed gap dimension previously measured. The ring force is then read off from the precision measuring scale. The gap of the ring shall be symmetrically disposed between the rollers.</p> <p>An alternative method to set up the tangential loading of the force measuring instrument is using a solid disc of nominal bore diameter $\pm 0,005\text{ mm}$ to set up the length of the tape. The gauge disc is inserted into the tape and the tape length adjusted until the specified mean limit tangential force is indicated.</p>	
<p>Key</p> <p>1 measuring scale</p> <p>2 diameter of rollers 10 mm</p> <p>s_1 closed gap</p> <p>F_t tangential force</p>	
<p>Figure 13</p>	
<p>2. Hoop method (see Figure 14)</p> <p>The ring is placed in a correctly sized hoop with its gap aligned to the gap of the hoop. The hoop is then closed in a precision loading machine until the loading pins are at a predetermined distance apart at which point the hoop is precisely at the cylinder bore diameter appropriate to the ring (see Figure 14). The force is then read off from the display.</p>	



4.2.5.2 For multi-piece rings

Measuring principle
<p>For the measurement of coil spring loaded rings or similar rings where the spring is supported in the bore of the ring, the gap of the spring shall be positioned at 180° to the gap of the ring.</p> <p>For the measurement of expander/segment oil control rings, the ring assembly shall be mounted in a carrier simulating the piston ring groove. The gap of the spring element is placed at 180° to the gap of the rails, both of which shall be in line. Choice of ring carrier type (see Table 1) shall be decided between manufacturer and client.</p> <p>For the measurement of a ring provided with a wavy spring, or other spring which is groove root supported, the ring assembly shall be mounted in a carrier simulating the groove, the root diameter of which is equal to the mean diameter of the piston ring groove in which the ring will be used.</p> <p>Tolerance on carrier root diameter $\pm 0,02$ mm. The gap of the wavy spring shall be at 180° to the gap of the ring.</p>

Measuring principle



Key

- 1 measuring scale
- s₁ closed gap
- F_t tangential force

Figure 15

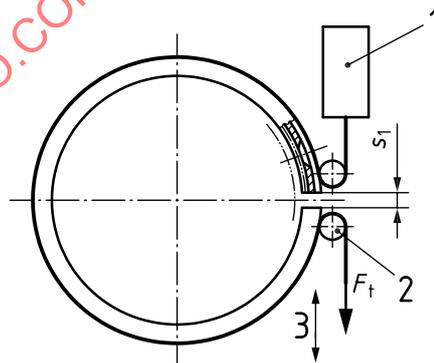
Table 1 — Alternative ring carriers

Dimensions in millimetres

Types	Carrier groove width	
		Tolerance
I	$h_1 + 0,01$	+0,02 0
II	$h_1 + 0,02$	
III	$h_1 + 0,03$	
$h_1 = \text{nominal ring width}$		

1. Tape method with circumferential vibration

Identical procedures are used as for single piece rings but an appropriate vibration shall be applied to the tape loading mechanism to relieve forces of friction (see Figure 16). A suitable level is 40 Hz to 50 Hz at an amplitude of ±0,15 mm.



Key

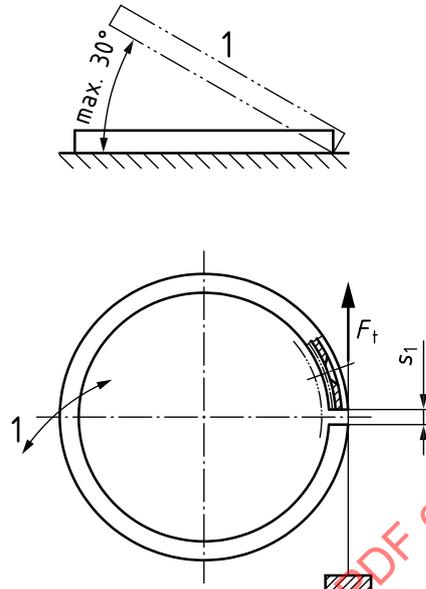
- 1 measuring scale
- 2 diameter of rollers 10 mm
- 3 vibration
- s₁ closed gap
- F_t tangential force

Figure 16

2. Encircling tape method with axial vibration

Measuring principle

Identical procedures are used as for the single piece rings (encircling tape method) except that a carrier may be used and vibration (slapping) is applied to the encircled ring or encircled ring with carrier to reduce friction (see Figure 17). A suitable level of slapping is 1 to 3 times per second.



Key

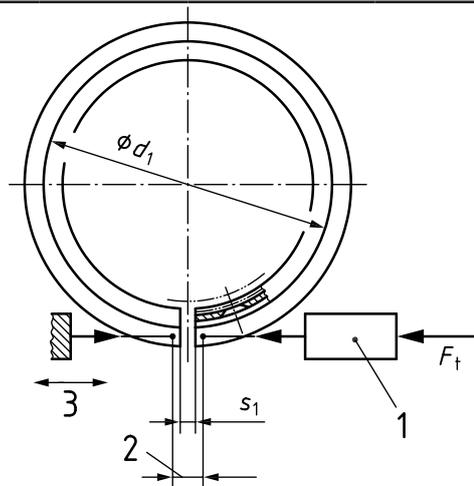
- 1 slapping
- s_1 closed gap
- F_t tangential force

Figure 17

3. Hoop method with circumferential vibration

Identical procedures are used as for single-piece rings but an appropriate vibration shall be applied to the hoop loading mechanism to relieve all forces of friction (see Figure 18).

Measuring principle



Key

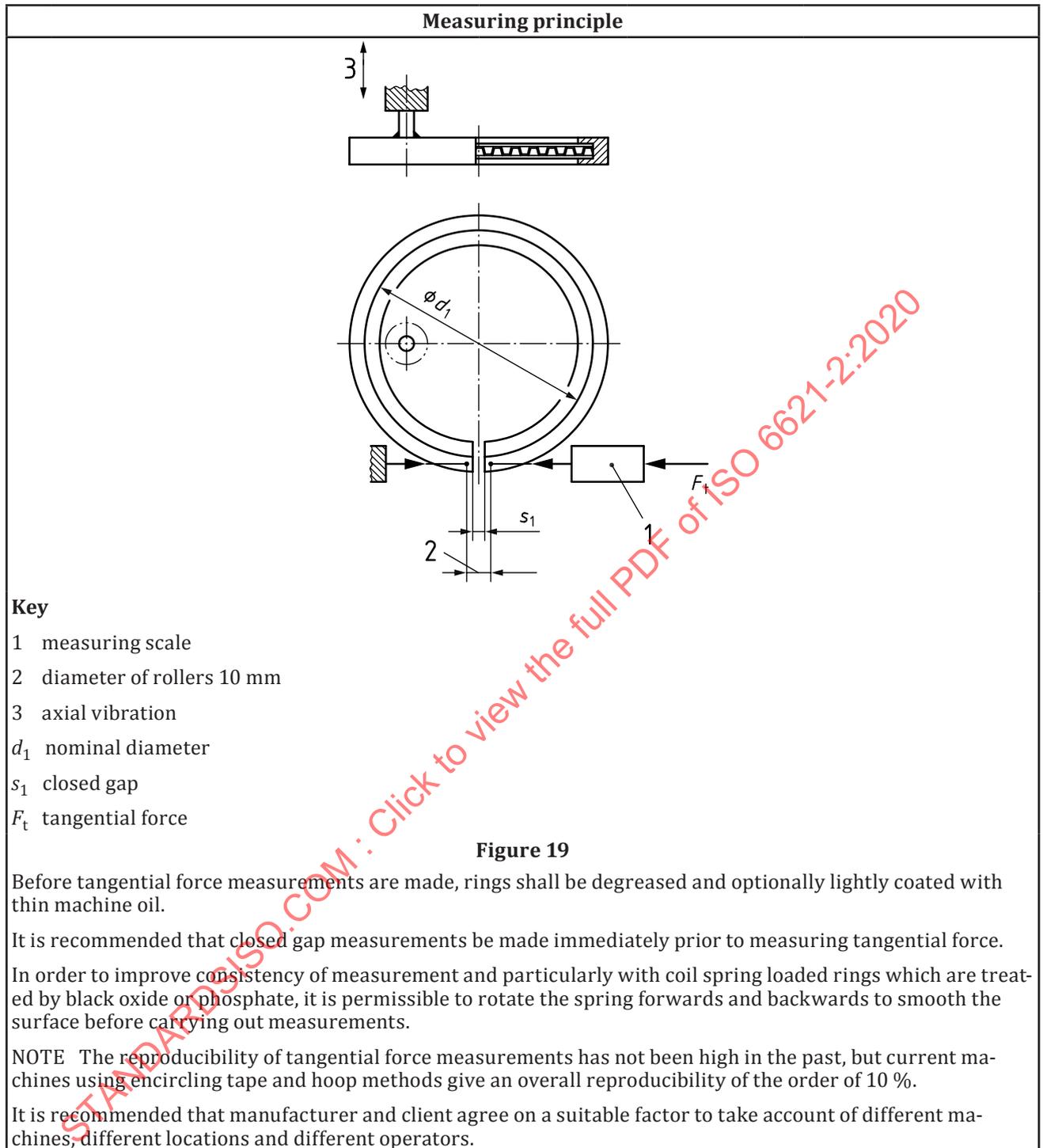
- 1 measuring scale
- 2 loading pin spacing to suit machine
- 3 circumferential vibration
- d_1 nominal diameter
- s_1 closed gap
- F_t tangential force

Figure 18

Tape- or Hoop-method with axial vibration

Identical procedures are used as for single-piece rings but an appropriate axial vibration shall be applied to the carrier which is simulating the ring groove to relieve forces of friction.

A suitable level of vibration is 420 Hz (\approx equal to 25 000 cycles per minute). The axial vibration shall have an amplitude that the exerted force on the carrier will reach approximately ± 18 N. (see Figure 19).

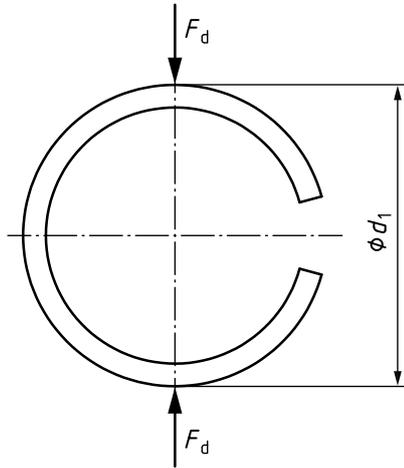


4.2.6 Diametral force, F_d (in Newton)

NOTE This method is only applicable to single-piece rings.

Measuring principle

Diametral force is measured in purpose-built machines which incorporate flat plates for closing the rings (see Figure 20).



Key

- F_d diametral force
- d_1 nominal diameter

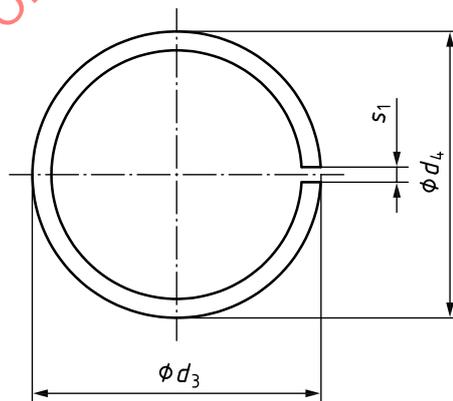
Figure 20

4.2.7 Ovality, U (in millimetres)

NOTE This method is only applicable to single-piece rings.

Measuring principle

Measure with the ring drawn to its closed gap in a flexible steel tension tape or band of thickness 0,08 mm to 0,10 mm using a diametral measuring device exerting a measuring force of ≤ 1 N (see Figure 21). With the ring closed within the tape, it is an acceptable alternative to clamp it between plates and then remove the tape prior to measuring the diameters d_3 and d_4 . However, clamping of the ring between plates is not applicable to oil control rings with slots.

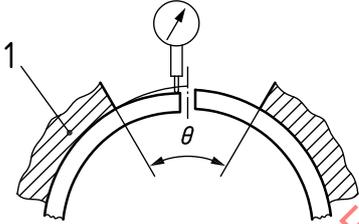


Key

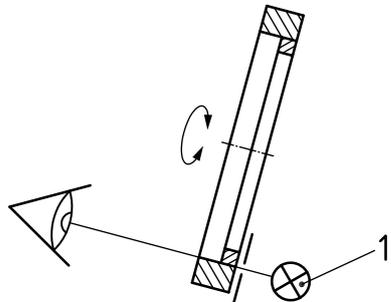
- d_3 diameter in the direction of the gap
- d_4 diameter 90° to the gap
- s_1 closed gap

Figure 21

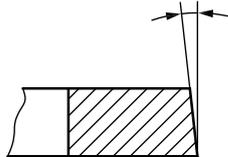
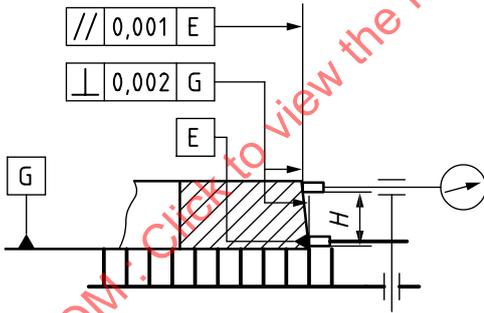
4.2.8 Point deflection, W (in millimetres)

Measuring principle	
<p>Measure with a probe of spherical radius of $1,5 \text{ mm} \pm 0,05 \text{ mm}$ with measuring force of approximately 1 N, the ring being mounted in a gauge of nominal cylinder bore diameter relieved over the gauge angle, θ, (see Figure 22).</p> <p>Point deflection W and the gauge angle, θ, shall be agreed between the manufacturer and the client.</p> <p>The following gauge tolerances apply for this test:</p> <ul style="list-style-type: none"> — Angle θ: $\pm 1^\circ$ — Diameter: $d_1 \begin{smallmatrix} +0,001 \times d_1 \\ 0 \end{smallmatrix}$ — Circularity: max. $0,000 1 \times d_1$ 	
	<p>Figure 22</p>
<p>Key</p> <p>1 gauge</p>	

4.2.9 Light tightness (percentage of ring circumference)

Measuring principle	
<p>Measure in a gauge equipped with a suitable light source and determine the percentage of the ring circumference which will allow light to pass (see Figure 23).</p> <p>It is permissible to rotate the ring in the gauge to remove any slight surface roughness on the peripheral surface. Unless otherwise specified examination and measurement should be made without magnification and with normal eyesight. It is important to avoid errors of parallax and to protect the viewer against stray light penetration.</p> <p>Illuminance behind the ring shall be 400 lux to $1\,500 \text{ lux}$ above the ambient conditions. The following gauge tolerances apply for this test:</p> <ul style="list-style-type: none"> — Diameter: $d_1 \begin{smallmatrix} +0,001 \times d_1 \\ 0 \end{smallmatrix}$ — Circularity: max. $0,000 1 \times d_1$ 	
	<p>Figure 23</p>
<p>Key</p> <p>1 lamp</p>	

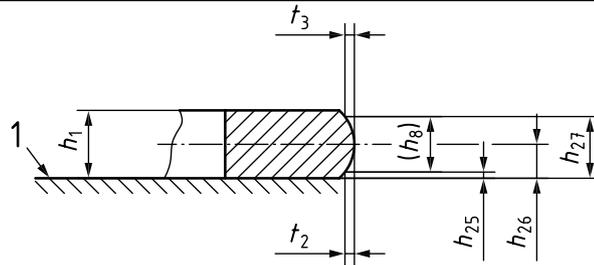
4.2.10 Taper on peripheral surface (in micrometres or degrees)

Measuring principle	
<p>Method A</p> <p>Measure at the back of the ring perpendicular to the reference plane using flat faced probes exerting a force of approximately 1 N (see Figure 25).</p> <p>The measurement recorded is the difference in radial dimension of the ring peripheral surface between two points, near the top and near the bottom, distance H apart. The dimension H shall be approximately two-thirds of the total axial width of the ring's peripheral surface and the recorded measurement may be converted to the taper angle in degrees or minutes.</p>	
<p>Figure 24</p>	
<p>Method B</p> <p>The ring shall be placed on a reference plane and the peripheral surface of the back of the ring graphed, perpendicular to the reference plane, using a profile measuring machine.</p> <p>Magnification used shall be clearly indicated.</p> <p>NOTE The same methods can be used to determine the unintentional taper which can be present on, for example, a nominally straight-faced rectangular ring.</p>	
<p>Figure 25</p>	

4.2.11 Barrel on peripheral surface, t_2, t_3 (in millimetres)

Measuring principle	
<p>Method A</p> <p>Measure at the back of the ring perpendicular to the reference plane using flat faced probes exerting a force of approximately 1 N (see Figure 27).</p> <p>The measurement recorded is the difference in radial dimension of the ring peripheral surface between two points, one at the peak of the barrel (at or near the centre line of the ring) and the second at a distance $h_8/2$ from the centreline of the nominal ring width h_1.</p> <p>Alternatively, the difference in radial dimension can be measured at gauge points h_{25} and h_{27} from the bottom of the ring.</p>	

Measuring principle



Key

- 1 reference plane
- h_1 ring width
- h_8 gauge width
- h_{25} lower barrel measurement position
- h_{26} barrel peak axial position
- h_{27} upper barrel measurement position
- t_2 lower barrel face
- t_3 upper barrel face

Figure 26

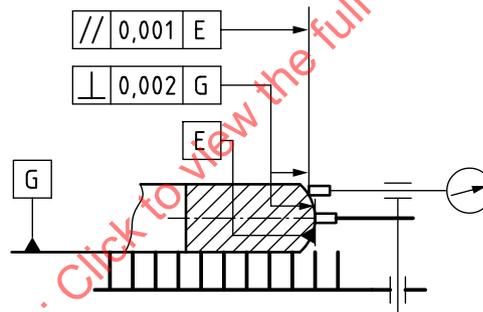


Figure 27

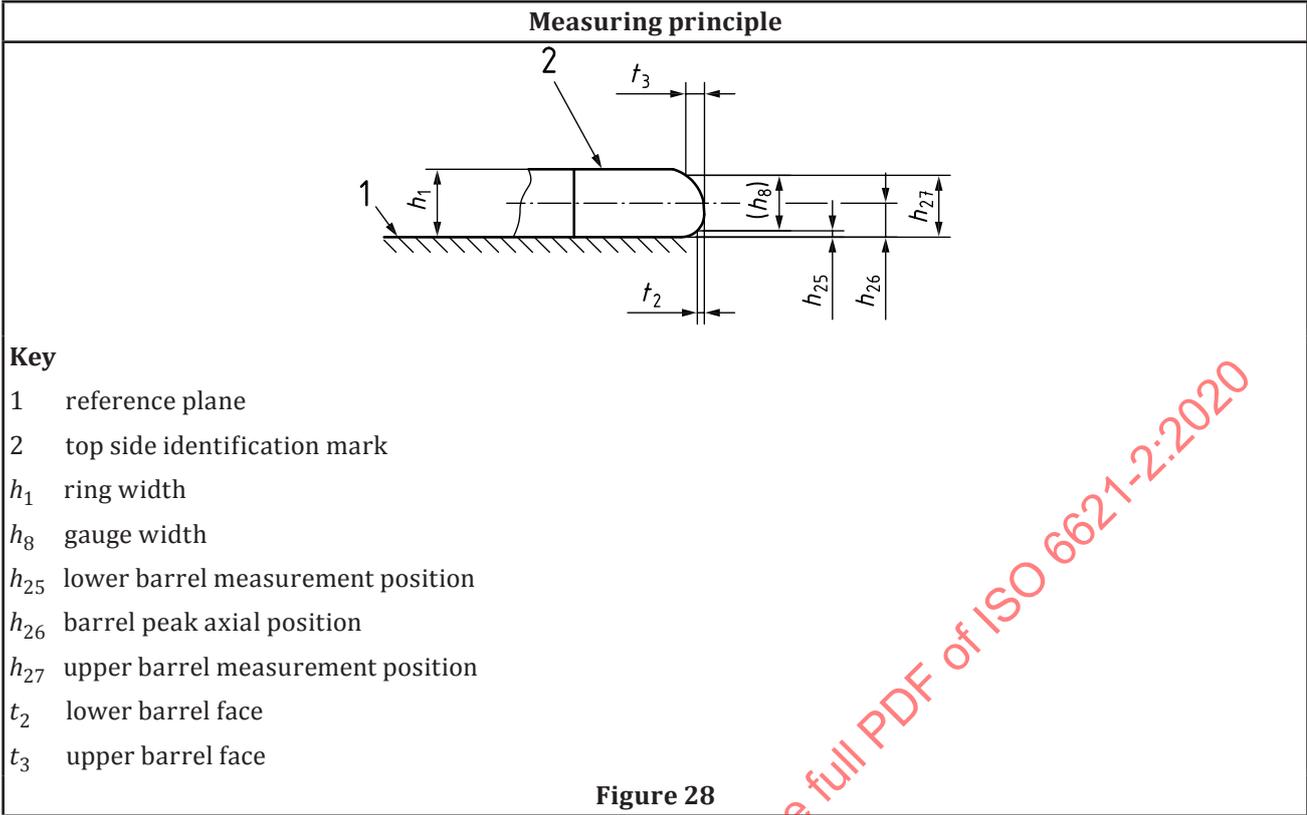
Method B

The ring shall be mounted on a reference plane and the peripheral surface of the back of the ring graphed, perpendicular to the reference plane, using a profile measuring machine.

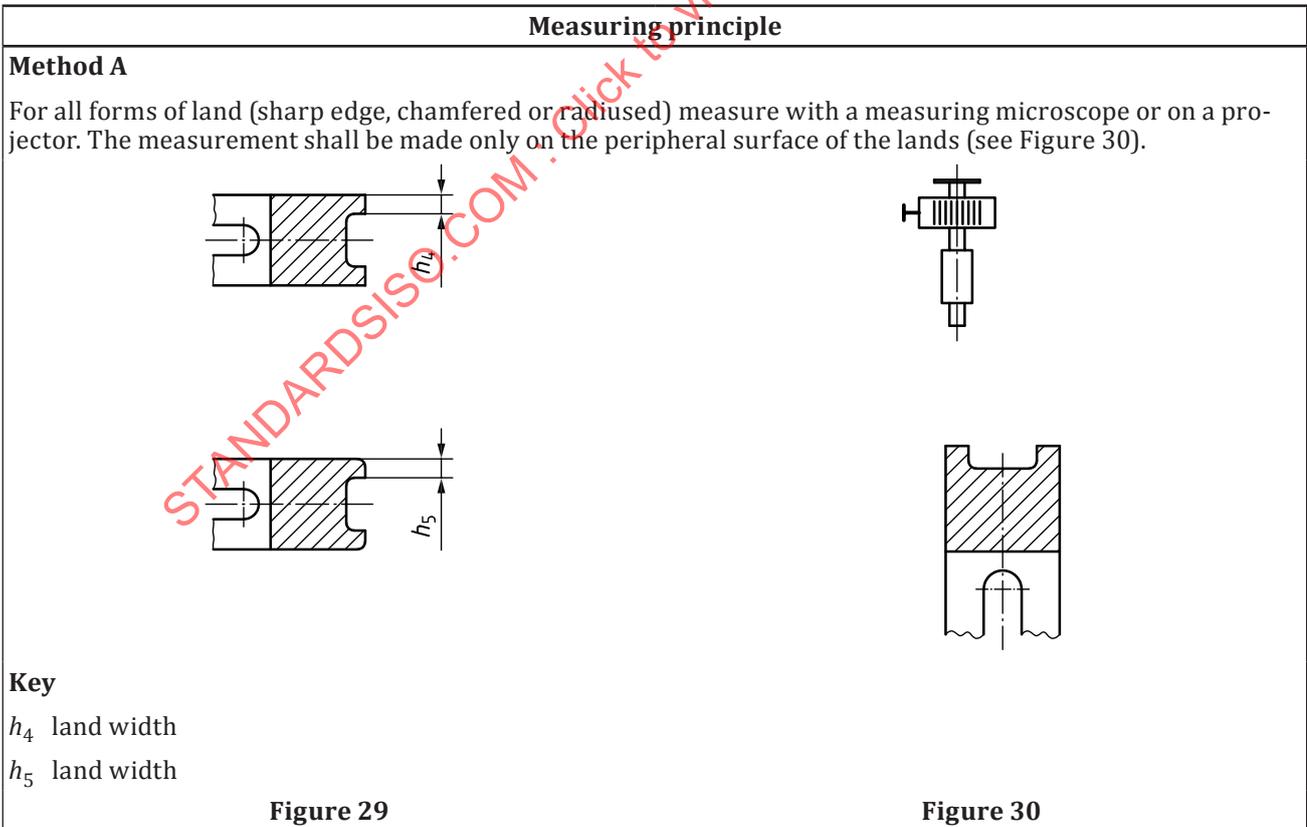
Magnification used shall be clearly indicated (recommended ratio between vertical and horizontal magnifications 10 or 25).

NOTE The same methods can be used to determine the unintentional barrel which can be present on, for example, a nominally straight-faced rectangular ring.

Gauge width (h_8) is only informative.

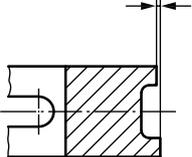
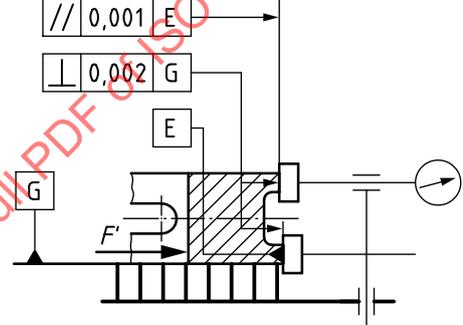


4.2.12 Land width, h_4, h_5 (in millimetres)

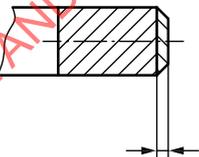
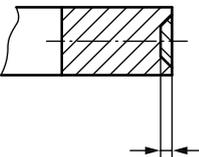
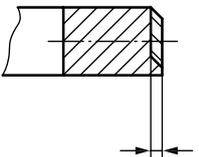


Measuring principle
<p>Method B</p> <p>For all forms of land, the ring shall be placed on a reference plane and the lands shall be graphed on a profile measuring machine.</p> <p>Magnification used shall be clearly stated.</p> <p>NOTE Land offset, (see 4.2.13), can be included and obtained from this measurement at the back of the ring.</p>

4.2.13 Land offset (in millimetres)

Measuring principle
<p>Method A</p> <p>Measure at the back of the ring from a line perpendicular to the reference plane (see Figure 31) using flat measuring probes exerting a force of approximately 1 N. The ring shall be loaded against the measuring instrument in the direction of and in the position of the force F (see Figure 32). Value of force F shall be in the range of 3 N to 5 N.</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>Figure 31</p> </div> <div style="text-align: center;">  <p>Figure 32</p> </div> </div> <p>Method B</p> <p>See method B in 4.2.12.</p>

4.2.14 Plating/coating thickness (in millimetres)

Measuring principle
<p>Measure non-destructively in the middle of the width of plating/coating using a calibrated inductive thickness measuring instrument. The calibration shall be made using a master ring being tested.</p> <p>Suggested points for measuring shall be at the back of the ring and at 15 mm from each gap end.</p> <p>The plating/coating thickness shall fulfil the specification at any particular point of the peripheral surface.</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>a) Fully faced</p> </div> <div style="text-align: center;">  <p>b) Inlaid</p> </div> <div style="text-align: center;">  <p>c) Semi inlaid</p> </div> </div> <p style="text-align: center;">Figure 33</p>

4.2.15 Nitrided case depth (in millimetres)

Measuring principle	
<p>To be measured on prepared cross sections of the ring. The micro-hardness HV 0,1 shall be measured at various distances from the peripheral or side face surfaces. Recommended increments are 0,01 / 0,015 / 0,02.</p> <p>The hardness values should be plotted against the perpendicular distance from the surface (see Examples 1 and 2) and the hardness characteristic curve drawn through the points in accordance with proper mathematical principles.</p> <p>The diagrams in Figures 34 and 35 show typical shapes of hardness curves.</p> <p>EXAMPLE 1 Nitrided case depth 0,05 mm (NT050) EXAMPLE 2 Nitrided case depth 0,25 mm (NS020)</p>	
<p>Key Y hardness HV 0,1 X measuring distance</p>	<p>Key Y hardness HV 0,1 X measuring distance</p>
Figure 34	Figure 35
<p>The depth at which the hardness characteristic curve crosses the 700 HV 0,1 line is the case depth.</p> <p>Measure hardness "HV 0,1" in accordance with the appropriate ISO Standard i.e. ISO 6507-3 and using any suitable hardness measuring machine.</p> <p>Suggested positions for establishing the cross-sections for the hardness measurements are at the back of the ring and at 15 mm from each gap end.</p> <p>For thinner nitrided case depths where it is impractical to apply the hardness measurement method (e.g. on expanders or segments), an alternative method (e.g. micro analysis of the etched ring cross section) may be agreed between the manufacturer and the client.</p> <p>NOTE Reliable non-destructive measuring principles for determining the "Nitrided case depth" of nitrided piston rings are not known up to now. Nitrided case depth shall fulfil the specification at any particular point of the peripheral surface and/or the ring side faces.</p>	

4.2.16 Keystone angle (in degrees)

Measuring principle	
<p>Method A</p> <p>Measure, in a true radial direction at the back of the ring, the difference in ring width at two points of known distance apart, using spherical probes each of radius 1,5 mm ± 0,05 mm exerting a force of approximately 1 N.</p> <p>The keystone angle can then be calculated as the sum of both side angles (see Figure 37).</p>	
<p>Key 1 included angle</p>	
Figure 36	

Measuring principle

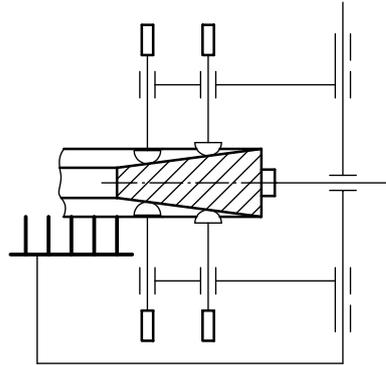


Figure 37

Method B

Measure, in a true radial direction at the back of the ring, the difference in ring width, using two probe systems formed as knife edges, each probe exerting a force of approximately 1 N.

The keystone angle can then be calculated as the sum of both side angles (see Figure 38).

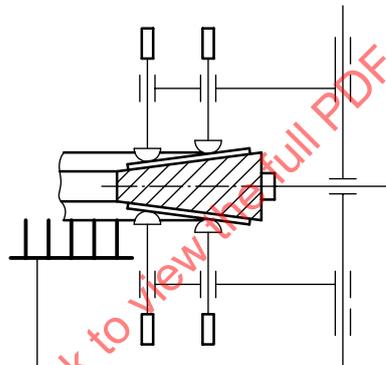


Figure 38

Methods C and D

Both methods involve the use of a probe which traverses in a true radial direction, a known distance across the side face at the back of the ring. The probe has a spherical radius of $1,5 \text{ mm} \pm 0,05 \text{ mm}$ and exerts a force of approximately 1 N. The reference plane plate on which the ring rests for measurement is provided with a location to ensure that the line of measurement is truly radial (see Figure 41).

1) Method C

The reference plane plate is inclined at an angle equal to the nominal side face angle of the ring and hence the contact surface of the probe traverses a path nominally parallel to the axis of the motion of the probe.

The probe measures any deviation of the side face from parallel and allows the actual angular deviation to be calculated. Hence the actual side face angle can be determined.

The ring is measured on both sides and the sum of the side face angles gives the keystone angle (see Figure 39).

2) Method D

The reference plane plate is parallel to the axis of motion of the probe and the ring side face lies at an angle to the reference plane equal to the nominal side face angle of the ring. The contact surface of the probe in traversing the side face describes the full movement equivalent to the side face angle: the latter can then be calculated directly.

The ring is measured on both sides and the sum of the side face angles gives the keystone angle (see Figure 40).

Measuring principle

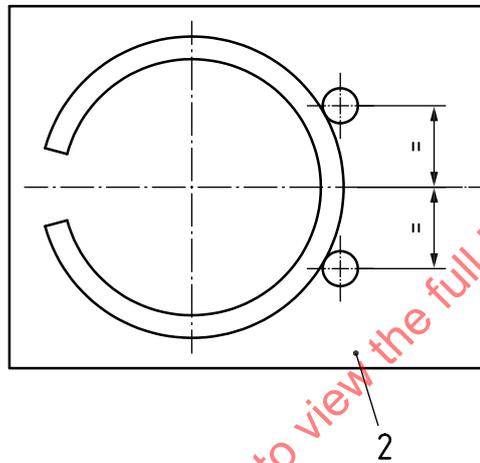


Key

- 1 side horizontal
- 2 nominal angle of side face

Figure 39

Figure 40



Key

- 1 line of measurement
- 2 reference plane plate

Figure 41

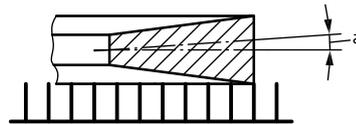
4.2.17 Obliqueness (in degrees)

Measuring principle

The measuring principles are identical with those given for keystone angle, see 4.2.16.

When each side face angle is available, obliqueness is one half the difference between the two side face angles, for example, with a 15° included angle ring where one side is 7°40' and the other is 7°20', the obliqueness is 10'.

When the deviation from each side angle is available, the obliqueness is one half the sum of the two deviations; in the above example, the two side face deviations are each 10' and therefore the obliqueness is 10'.



a Obliqueness.

Figure 42