SAE International™ SURFACE VEHICLE STANDARD

SAE J1589

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Superseding J1589 APR1998

Internal Combustion Engines—Piston Rings—Inspection Measuring Principles

1. ***Scope***—Differences, where they exist, are shown in Appendix A.

This SAE Standard 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 combustion engines.

These inspection measuring principles may also be used for piston rings for compressors working under analogous conditions.

1.1 Rationale—SAE J1589 is being discontinued because the content of this standard is also contained in ISO 6621-2. Therefore, to eliminate duplication and confusion in coordinating the standards between ISO and SAE, this document will be discontinued. The SAE Piston and Ring Standards Committee will now continue to support ISO in updating the standards as appropriate.

2. ***References***

SAE DESIGNATION	ISO[1] EQUIVALENT	
		INTERNAL COMBUSTION ENGINES—PISTON RINGS
SAE J1588	6621-1	Vocabulary
SAE J1589	6621-2	Measuring principles
SAE J1590	6621-3	Material specifications
SAE J1591	6621-4	General specifications
SAE J1996	6621-5	Quality requirements
		INTERNAL COMBUSTION ENGINES—PISTON RINGS
SAE J1997	6621-1	Rectangular rings
SAE J1998	6622-2 TR	Rectangular rings with narrow ring width
SAE J1999	6623	INTERNAL COMBUSTION ENGINES—PISTON RINGS—SCRAPER RINGS
		INTERNAL COMBUSTION ENGINES—PISTON RINGS
SAE J2000	6624-1	Keystone rings
SAE J2001	6624-2 TR	Half keystone rings

1. TR refers to Technical Report

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SAE J2002	6625	INTERNAL COMBUSTION ENGINES—PISTON RINGS—OIL CONTROL RINGS
SAE J2003	6625	INTERNAL COMBUSTION ENGINES—PISTON RINGS—COIL SPRING LOADED OIL CONTROL RINGS
SAE J2004	6627 TR	INTERNAL COMBUSTION ENGINES—PISTON RINGS—EXPANDER/ SEGMENT OIL CONTROL RINGS
SAE J2226		INTERNAL COMBUSTION ENGINES—PISTON RINGS—STEEL RECTANGULAR RINGS
	ISO 286	ISO SYSTEM OF LIMITS AND FITS

3. Measuring Principles

3.1 General Measuring Conditions—The following general notes are applicable to all measuring principles unless otherwise specified:

a. The ring shall rest on the datum surface in the free or open condition. No additional force shall be applied to load the ring on the datum surface.
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 is towards the datum surface.
c. Measurements shall be made using instruments with a resolution not to exceed 10% of the tolerance of the dimension being measured

3.2 Characteristics and Measuring Principles

TABLE 1—CHARACTERISTICS

Subclause	Characteristics of the Ring	Ring Width
	Principal characteristics of the ring	
3.2.1	Ring Width	
	a) parallel sided rings	h_1
	b) keystone rings	h_3, a_6
3.2.2	Radial wall thickness	a_1
3.2.3	Total free gap	m, p
3.2.4	Closed gap	s_1
3.2.5	Tangential force	F_t
3.2.6	Diametral force	F_d
	Characteristics of ring shape	
3.2.7	Ovality or circularity	U
3.2.8	Point deflection	W
3.2.9	Light tightness	—
	Associated with peripheral surface	
3.2.10	Taper on periphery	—
3.2.11	Barrel on periphery	t_2, t_3, h_8
3.2.12	Land width	h_4, h_5
3.2.13	Land offset	—
3.1.14	Coating/inlay thickness	—
	Associated with sides	
3.2.15	Keystone angle	—
3.2.16	Obliqueness	—
3.2.17	Twist	—
3.2.18	Unevenness	Te_r, Te_u
	Other	
3.2.19	Helix (axial displacement of butt ends)	—
3.2.20	Free flatness	—
3.2.21	Surface roughness	R_a, R_z

TABLE 2—MEASURING PRINCIPLES

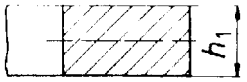
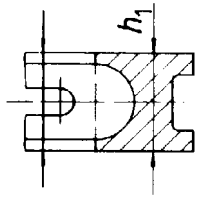
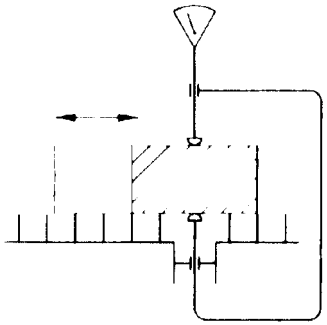
Term	Definition	Measuring Principles	Ilustration of measuring principles
3.2.1 Ring width (in millimeters)			
a) Parallel sided rings, h_1	The distance between the sides, at any particular point perpendicular to the datum surface (see Figures 1 and 2).	Measure with spherical measuring probes each of radius 1,5 ± 0,05 mm, exerting a measuring force of approximately 1 N (see Figure 3). In the case of slotted oil rings, the measurement shall be made between the slots and not across them (see Figure 2).	 FIGURE 1—  FIGURE 2—  FIGURE 3—

TABLE 2—MEASURING PRINCIPLES (CONTINUED)

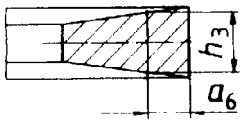
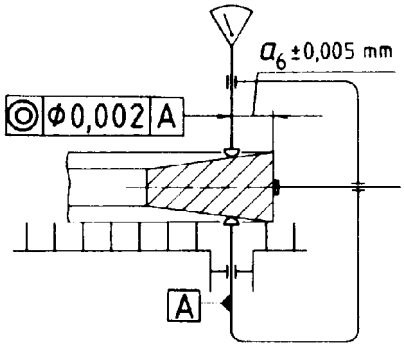
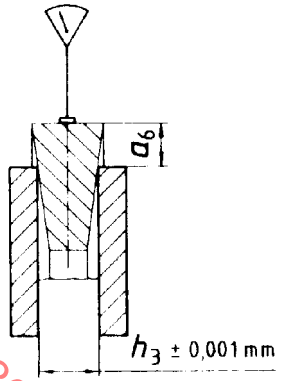
Term	Definition	Measuring Principles	Illustration of measuring principles
b) Keystone rings, h_3	The distance between the sides at a specified distance a_6 from the peripheral surface (see Figure 4).	a) Method A This method determines h_3 (see Figure 4) for a specified value of a_6. Measure with speherical measuring probes each of radius 1,5 ± 0,05 mm exerting a measuring force of approximately 1 N (see Figure 5). If the measuring equipment is set up with parallel gauges instead of keystone gauges the use of spherical measuring probes will give rise to an error as follows: for 6° keystone angle: 0,004 mm for 15° keystone angle: 0,026 mm. 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. b) Method B This method determines a6 for a specified width 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 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.	 FIGURE 4—h_3 AND a_6  FIGURE 5—SPHERICAL MEASURING PROBES  FIGURE 6—FLAT FACE MEASURING PROBE

TABLE 2—MEASURING PRINCIPLES (CONTINUED)

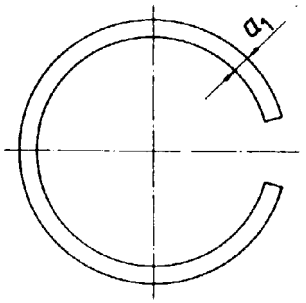
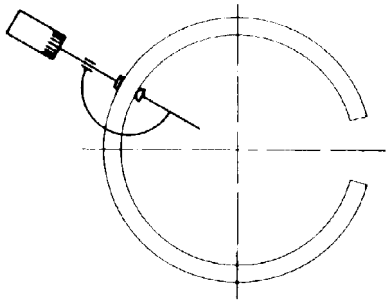
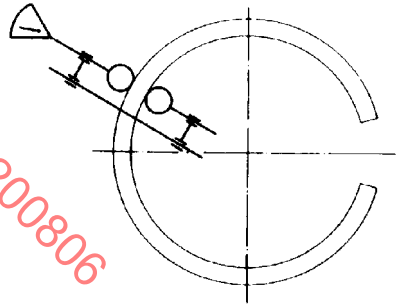
Term	Definition	Measuring Principles	Illustration of measuring principles
3.2.2 Radial wall thickness, a_1 (in millimeters)	The radial distance between the periphery and the inside surface of the ring (see Figure 7).	a) Measure radially between a flat measuring surface on the periphery and a spherical measuring surface of radius approximately 4 mm on the inside surface, and using a measuring force of 3 to 10 N (see Figure 8). b) Measure radially between cylindrical inserts or rollers of radius approximately 4 mm and with a measuring force of 3 to 10 N. The length of the rollers shall be greater than the ring width (see Figure 9).	 FIGURE 7—a_1  FIGURE 8—METHOD a  FIGURE 9—METHOD b

TABLE 2—MEASURING PRINCIPLES (CONTINUED)

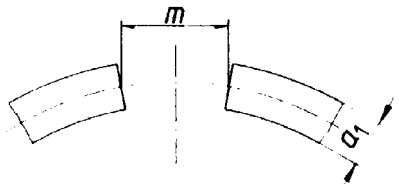
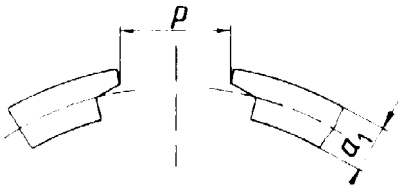
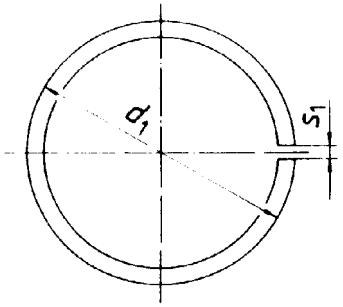
Term	Definition	Measuring Principles	Illustration of measuring principles
3.2.3 Total free gap m, p (in millimeters)	The chordal distance between the butt ends of the ring in a free, unstressed state, measured at the centerline of the radial wall thickness (see Figure 10). For rings with an internal notch for a peg, the total free gap is defined by the chordal distance marked as p in Figure 11.	Measure with a steel rule to the nearest 0,25 mm.	 FIGURE 10—m AND a_1  FIGURE 11—p AND a_1
3.2.4 Closed gap, s_1 (in millimeters)	The gap at the butt ends of the ring, measured at the narrowest point of the gap, which the ring would have when fitted in a gauge of nominal cylinder bore size (see Figure 12). The closed gap s_1 is related to the nominal diameter d_1.	Measure in a bore gauge of nominal diameter using a wedge gauge or feeler gauges and using a measuring force of approximately 1 N (see Figure 12). The diameter of the bore gauge shall comply with the following deviations from the nominal ring diameter: Tolerance: $^{+0,001}_{0}$ d_1 Correction shall be made for any deviation of the bore gauge from the nominal ring diameter	 FIGURE 12—s_1 AND d

TABLE 2—MEASURING PRINCIPLES (CONTINUED)

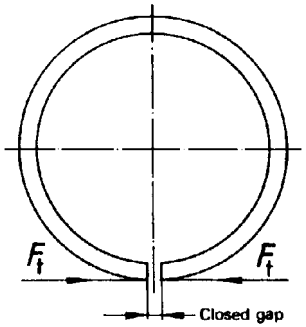
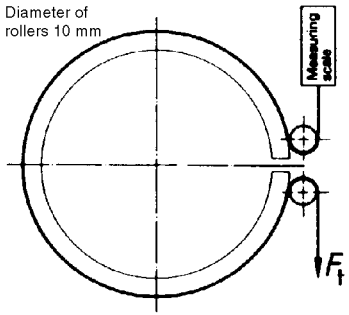
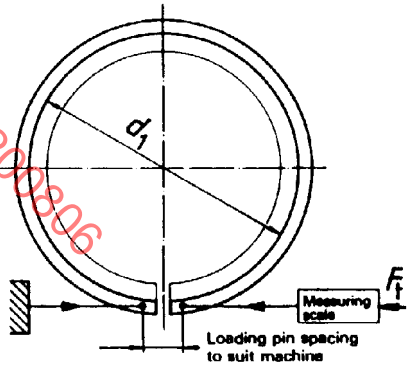
Term	Definition	Measuring Principles	Ilustration of measuring principles
3.2.5 Tangential force, F_t (in Newtons)			
a) For single-piece rings	The force necessary to maintain the ring at the closed gap condition by means of a tangential pull on the ends of a circumferential metal tape or hoop (see Figure 13).	a) Tape method (see Figure 14) The encircling steel tape of thickness 0,08 to 0,10 mm is carried round 10 mm diameter rollers set 20 mm apart (see Figure 14). In tightening the tape, the ring is closed to the point where the butt ends touch and the opened to the closed gap dimension previously measured. The ring force is then read of from the precision measuring scale. The gap of the ring shall be symmetrically disposed between the rollers. b) Hoop method (see Figure 15) 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 15). The force is then read off from the display.	 FIGURE 13—F_t  FIGURE 14—TAPE METHOD  FIGURE 15—HOOP METHOD

TABLE 2—MEASURING PRINCIPLES (CONTINUED)

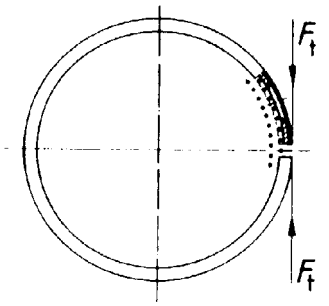
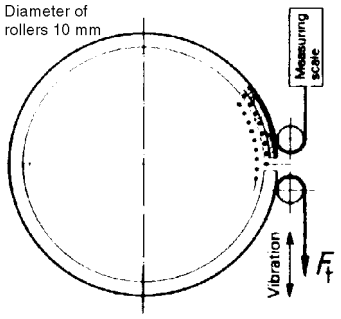
Term	Definition	Measuring Principles	Ilustration of measuring principles
b) For multi-piece rings	The force which is necessary to maintain the ring at the closed gap condition by means of a tangential pull on the ends of a circumferential metal tape of hoop whilst vibrating the butt ends of the ring (see Figure 13a).	For the measurement of coil spring loaded rings or similar rings where the spring is supported in the inside grooved surface of the ring, the gap of the spring shall be positioned at 180 degrees to the gap of the cast iron part. For the measurement of multi-piece steel rail oil control rings, the ring assembly shall be mounted in a carrier simulating the ring groove. The gap of the spring element is placed at 180 degrees to the gap of the rails, both of which shall be in line. 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. Tolerance on carrier root diameter ±0,02 mm. The gap of the wavy spring shall be at 180° to the gap of the cast iron part. a) Tape method 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 14a). A suitable level is 40 to 50 Hz at an amplitude of 0,15 mm.	 FIGURE 13a)—F_t (MULTI-PIECE)  FIGURE 14a)—TAPE METHOD (MULTI-PIECE)

TABLE 2—MEASURING PRINCIPLES (CONTINUED)

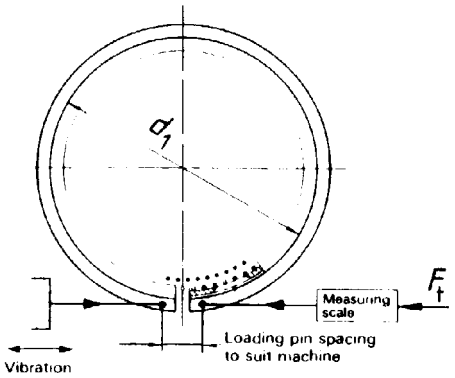
Term	Definition	Measuring Principles	Ilustration of measuring principles
		b) Hoop method Identical procedures are used as for single-piece rings but an appropriate vibration shall be applied to the hoop loading mechanism to relieve all forces of friction (see Figure 15a). NOTES: 1. Before tangential force measurements are made, rings must be degreased and lightly coated with thin machine oil. 2. It is recommended that closed gap measurements be made immediately prior to measuring tangential force. 3. In order to improve consistency of measurement and particularly with coil spring loaded rings which have been oxided or phosphated it is permissible to rotate the spring forwards and backwards to smooth the surface before carrying out measurements. 4. The reproducibility of tangential force measurements has not been high in the past but current machines using hape and hoop methods give an overall reproducibility of the order of 6,5%. It is recommended that customer and supplier agree on a suitable factor to take account of different machines, different locations and different operators.	 FIGURE 15a)—HOOP METHOD (MULTI-PIECE)

TABLE 2—MEASURING PRINCIPLES (CONTINUED)

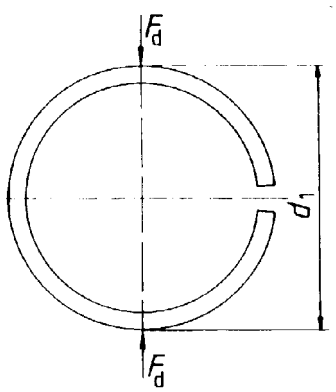
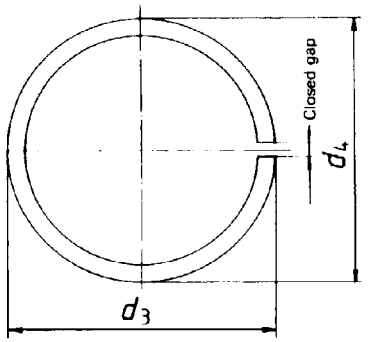
Term	Definition	Measuring Principles	Ilustration of measuring principles
3.2.6 Diametral force, F_d (in Newtons) NOTE—This method is only applicable to single-piece rings.	The force, acting diametrically at 90 degrees to the gap, necessary to maintain the ring at the nominal diameter condition measured in the direction of the force (see Figure 16).	Diametral force is measured in purpose built machines which incorporate flat plates for closing the rings (see Figure 16).	 FIGURE 16—F_d AND d_1
3.2.7 Ovality or circularity, U (in millimeters) NOTE—This method is only applicable to single-piece rings.	The difference between the mutually perpendicular diameters d_3 and d_4 when the ring is drawn to closed gap within a flexible tape. It may be either positive ($d_3 > d_4$) or negative ($d_3 < d_4$) (see Figure 17).	Measure, with the ring drawn to true closed gap in a flexible steel tension tape or band of thickness 0,08 to 0,10 mm using a diametral measuring device with a measuring force of not more than 1 N (see Figure 17). 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. NOTE—Clamping of the ring between plates is not applicable to oil control rings with slots.	 FIGURE 17—d_3 AND d_4

TABLE 2—MEASURING PRINCIPLES (CONTINUED)

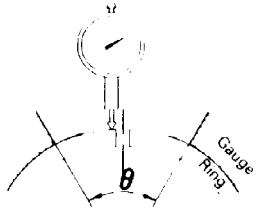
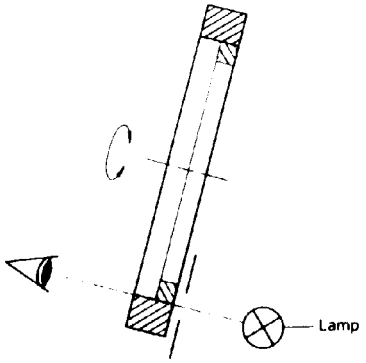
Term	Definition	Measuring Principles	Illustration of measuring principles
3.2.8 Point deflection, W (in millimeters)	The deviation of the butt ends from the true circle when restrained in a gauge of nominal cylinder bore diameter (see Figure 18).	Measure with a probe of spherical radius of 1,5 mm ± 0,05 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 18). The gauge angle, θ , shall be agreed between manufacturer and customer. It normally relates to port angle. The following gauge tolerances apply for this test: Angle θ: ± 1 degrees Diameter: $^{+0,001}_{0}$ d_1 Circularity: 0,0001 d_1 max.	 FIGURE 18—POINT DEFLECTION
3.2.9 Light tightness (percentage of ring circumference)	The ability of the periphery of a ring when mounted in a gauge of nominal cylinder bore diameter to exclude the passage of light (see Figure 19). A ring showing only pin point, blurry or fuzzy light shall be considered as light tight.	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 19). It is permissible to rotate the ring in the gauge to remove any slight surface roughness on the periphery. 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. Illumination behind the ring to be 400 to 1 500 lux above the ambient conditions. The following gauge tolerances apply for this test: Diameter: $^{+0,001}_{0}$ d_1 Circularity: 0,0001 d_1 max.	 FIGURE 19—LIGHT TIGHTNESS

TABLE 2—MEASURING PRINCIPLES (CONTINUED)

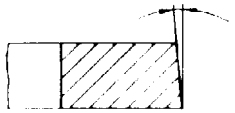
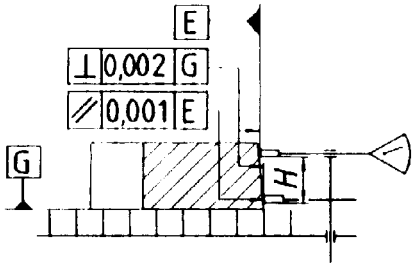
Term	Definition	Measuring Principles	Illustration of measuring principles
3.2.10 Taper on periphery (in micrometers or degrees)	Taper is the intentional deviation of the periphery from a line perpendicular to the datum surface (see Figure 20).	a) Method A Measure at the back of the ring perpendicular to the datum surface using flat faced probes exerting a force of approximately 1 N (see Figure 21). 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 width of the ring and the recorded measurement may be converted to the taper angle in degrees or minutes. b) Method B The ring shall be mounted on a datum surface and the peripheral surface of the back of the ring graphed perpendicular to the datum surface using a profile recorder. Magnification used shall be clearly indicated. NOTE—The same methods may be used to determine the unintentional taper which may be present on, for example, a nominally straight faced rectangular ring.	 FIGURE 20—TAPER  FIGURE 21—METHOD A

TABLE 2—MEASURING PRINCIPLES (CONTINUED)

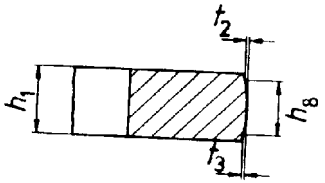
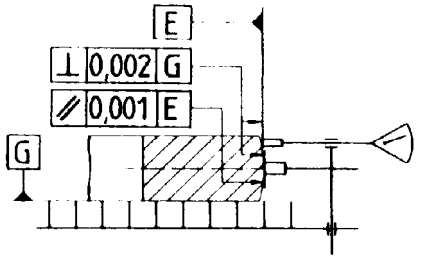
Term	Definition	Measuring Principles	Illustration of measuring principles
3.2.11 Barrel on periphery. t_2, t_3, h_8 (in millimeters)	The barrel is the intentional convex deviation of the peripheral surface from a line perpendicular to the datum surface (see Figure 22).	a) Method A Measure at the back of the ring perpendicular to the ring datum surface using flat ended probes exerting a force of approximately 1 N (see Figure 23). 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 center line of the ring) and the second at half gauge width $\frac{h_8}{2}$, from the peak. b) Method B The ring shall be mounted on a datum surface and the peripheral surface of the back of the ring graphed, perpendicular to the datum surface, using a profile recorder. Magnification used shall be clearly indicated. (Recommended ratio between vertical and horizontal magnifications 10 or 25.) NOTE—The same methods may be used to determine the unintentional barrel which may be present on, for example, a nominally straight faced rectangular ring.	 FIGURE 22—t_2, t_3 AND h_8  FIGURE 23—METHOD A

TABLE 2—MEASURING PRINCIPLES (CONTINUED)

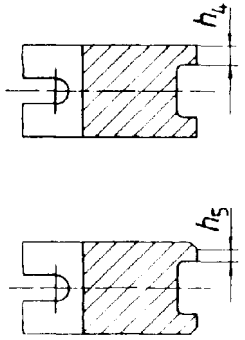
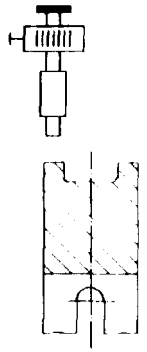
Term	Definition	Measuring Principles	Illustration of measuring principles
3.2.12 Land width, h_4, h_5 (in millimeters)	The width of the land which theoretically should be in contact with the cylinder bore (see Figure 24).	a) Method A For all forms of land (sharp edge, chamfered or radiused) measure with a measuring microscope or on a projector. The measurement shall be made only on the periphery of the lands (see Figure 25). b) Method B For all forms, the ring shall be mounted on a datum surface and the lands shall be graphed on a profile recorder. Magnification used shall be clearly stated. NOTE—Land offset, (see 3.2.13), can be included and obtained from this measurement at the back of the ring.	 FIGURE 24—h_4 AND h_5  FIGURE 25—METHOD A

TABLE 2—MEASURING PRINCIPLES (CONTINUED)

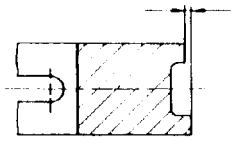
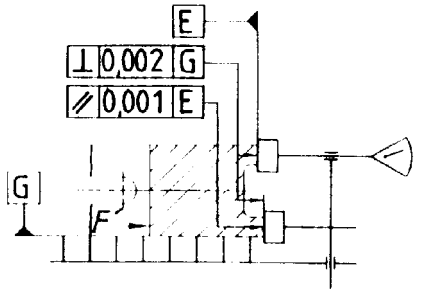
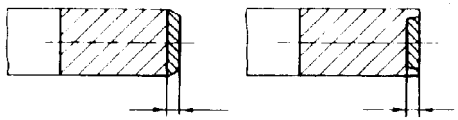
Term	Definition	Measuring Principles	Illustration of measuring principles
3.2.13 Land Offset (in millimeters)	The displacement of the two peripheral surfaces of a slotted or drilled oil control ring in relation to each other in a radial direction (see Figure 26).	a) Method A Measure at the back of the ring from a line perpendicular to the datum surface (see Figure 26) 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 27). Value of force F to be in the range of 3 to 5 N. b) Method B See Method B in 3.2.12.	 FIGURE 26—LAND OFFSET  FIGURE 27—METHOD A
3.2.14 Coating/inlay thickness (in millimeters)	The distance between the outer surface of the coating/inlay and the surface of the base ring material (see Figure 28).	Measure non-destructively in the middle of the width of coating using a calibrated inductive thickness measuring instrument. The calibration shall be made using a ring of equal dimension and material to the ring being tested. Specific points for measuring shall be at the back of the ring and at 15 mm from each butt end.	 FIGURE 28—COATING/INLAY THICKNESS

TABLE 2—MEASURING PRINCIPLES (CONTINUED)

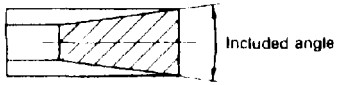
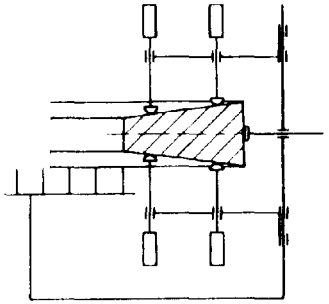
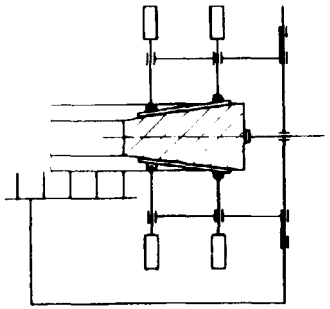
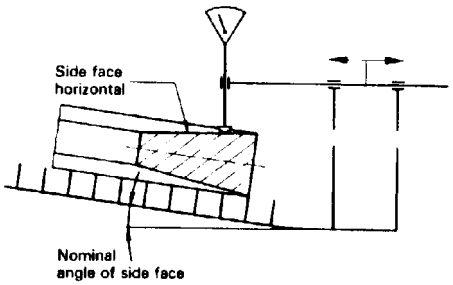
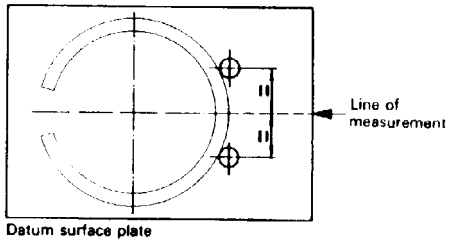
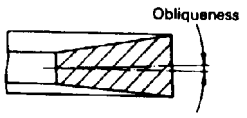
Term	Definition	Measuring Principles	Illustration of measuring principles
3.2.15 Keystone angle (in degrees)	The angle enclosed by the two sides of the ring (see Figure 29). Alternatively, the sum of both side face angles, i.e., included angle.	a) Method A Measure, in a true radial direction at the back of the ring, the difference in ring width at two points of known distance apart, using spherical probes each of radius 1,5 ± 0,05 mm exerting a force of approximately 1 N. The keystone angle can then be calculated as the sum of both side angles (see Figure 30). b) 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 31). c) 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 ± 0,05 mm and exerts a force of approximately 1 N. The datum surface 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 33). 1) Method C The datum surface 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 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.	 FIGURE 29—KEYSTONE ANGLE  FIGURE 30—METHOD A  FIGURE 31—METHOD B

TABLE 2—MEASURING PRINCIPLES (CONTINUED)

Term	Definition	Measuring Principles	Illustration of measuring principles
		The ring is measured on both sides and the sum of the side face angles gives the keystone angle (see Figure 32). 2) Method D The datum surface plate is parallel to the axis of motion of the probe and the ring side face lies at an angle to the datum surface equal to the 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.	 FIGURE 32—METHOD C  FIGURE 33—DATUM SURFACE PLATE
3.2.16 Obliqueness (in degrees)	The unintentional deviation of the bisector of the keystone included angle from parallelism with the datum surface (see Figure 34). Not applicable to rings with designed twist.	The measuring principles are identical with those given for keystone angle, see 3.2.15. 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 degrees 40' and the other is 7 degrees 20', the obliqueness is 10'.	 FIGURE 34—OBLIQUENESS