SURFACE VEHICLE STANDARD

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Superseding J2275 MAY2018

Internal Combustion Engines - Piston Ring-Grooves

RATIONALE

This revision includes clarifications and corrections for numerous areas. Also included is a new method for specifying piston ring and groove width tolerances for rectangular and oil rings.

1. SCOPE

There is no ISO standard equivalent to this SAE Standard.

This SAE Standard identifies and defines the most commonly used terms for piston ring-groove characteristics, specifies dimensioning for groove widths, and demonstrates the methodology for calculation of piston groove root diameter.

The requirements of this document apply to pistons and rings of reciprocating internal combustion engines and compressors working under analogous conditions, up to and including 200 mm diameter and 4.5 mm width for compression rings and 8.0 mm width for oil rings.

The specifications in this document assume that components are measured at an ambient temperature of 20 °C (68 °F).

Tolerances specified in this document represent practical functional limits and do not imply process capabilities.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein.

2.1.1 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO 6621-2 Internal combustion engines—Piston rings—Part 2: Inspection measuring principles

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https://www.sae.org/standards/content/Pj2275_202402

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

NOTE: "TR" refers to Technical Report.

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

ISO 6621-3 Internal combustion engines—Piston rings—Part 3: Material specifications

ISO 6621-4 Internal combustion engines—Piston rings—Part 4: General specifications

ISO 6621-5 Internal combustion engines—Piston rings—Part 5: Quality requirements

ISO 6622-1 Internal combustion engines—Piston rings—Part 1: Rectangular rings made of cast iron

ISO/TR 6622-2 Internal combustion engines—Piston rings—Part 2: Rectangular rings with narrow ring width

ISO 6623 Internal combustion engines—Piston rings—Scraper rings made of cast iron

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

ISO 6624-3 Internal combustion engines – Piston rings – Part 3: Keystone rings made of steel

ISO/TR 6624-2 Internal combustion engines—Piston rings—Part 2: Half keystone rings

ISO 6625 Internal combustion engines—Piston rings—Oil control rings

ISO 6626 Internal combustion engines—Piston rings—Coil-spring-loaded oil control rings

ISO 6626-2 Internal combustion engines—Piston rings—Part 2: Coil-spring-loaded oil control rings of narrow width made of cast iron

ISO/TR 6627 Internal combustion engines—Piston rings—Expander/segment oil control rings

ISO 6507-3 Metallic materials—Vickers hardness test—Part 3: Calibration of reference blocks

3. PISTON GROOVE NOMENCLATURE

See Figure 1.

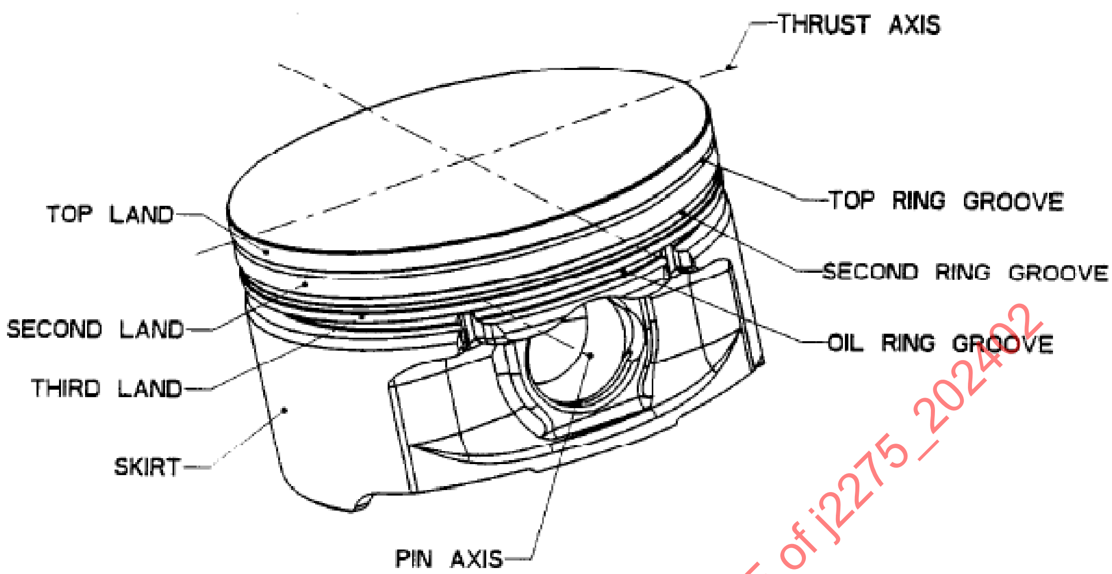


Figure 1A - Piston groove nomenclature

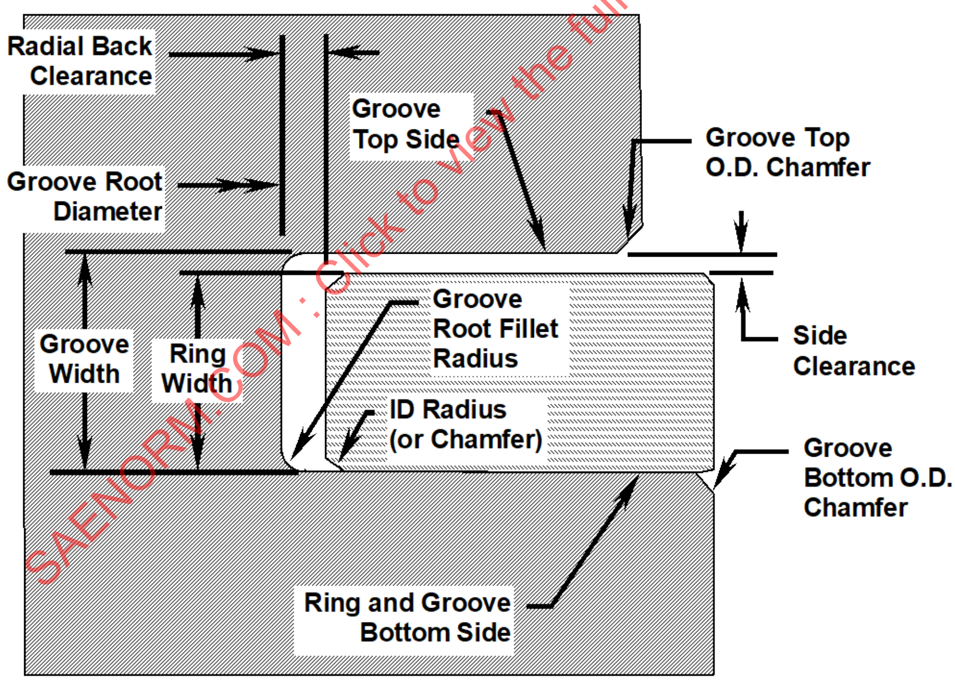


Figure 1B - Piston rectangular groove nomenclature

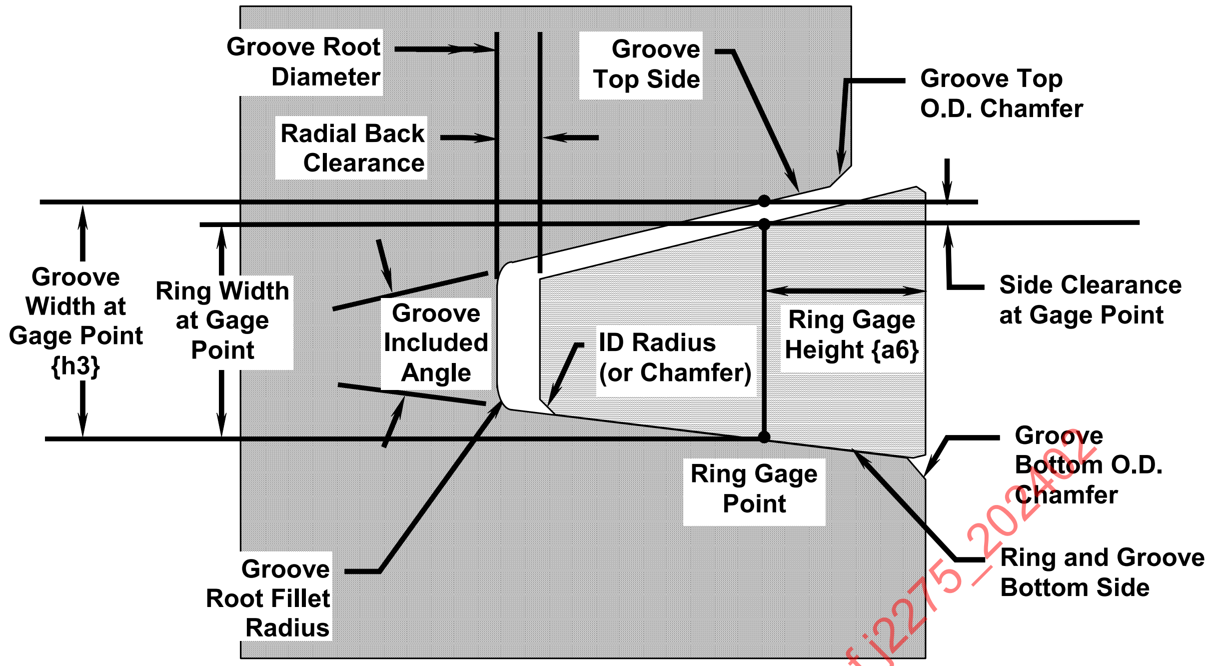


Figure 1C - Piston keystone groove nomenclature

4. PISTON GROOVE TERM DEFINITIONS

4.1 Piston Vertical Axis

The geometric axis of the piston skirt. To establish the piston vertical axis, it requires alignment of a minimum of eight points with four target points on each of two datum planes. See Figure 2.

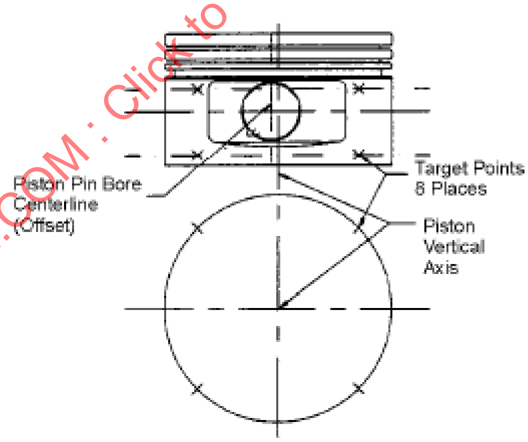


Figure 2 - Piston vertical axis

4.2 Wind (also “Winde”)

This term means the planar tilt of the ring groove sides to the piston vertical axis, or ring groove squareness over a given distance to the piston vertical axis. See Figure 3.

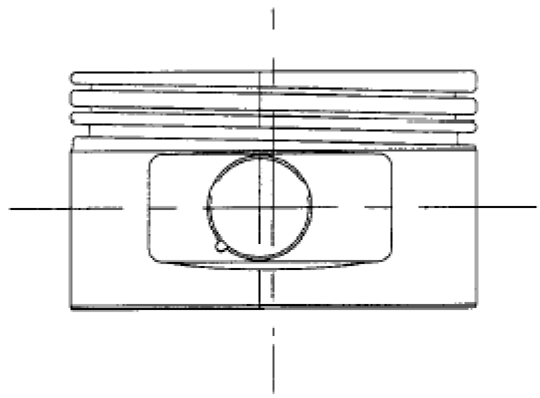


Figure 3 - Wind (also “winde”)

4.3 Circumferential Groove Waviness (also “Wave”)

Ring groove axial undulations are measured circumferentially over 360 degrees of the ring groove and frequently specified over shorter defined intervals. See Figure 4.

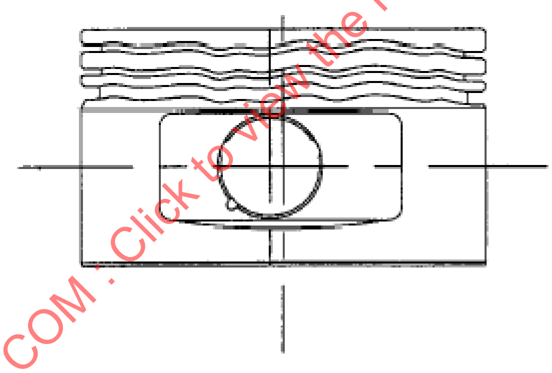


Figure 4 - Circumferential groove waviness (also “wave”)

4.4 Ring Groove Chatter (also "Chatter")

Tool marks in the surface of the groove sides. These are of a higher frequency than waviness yet lower than surface roughness. See Figure 5.

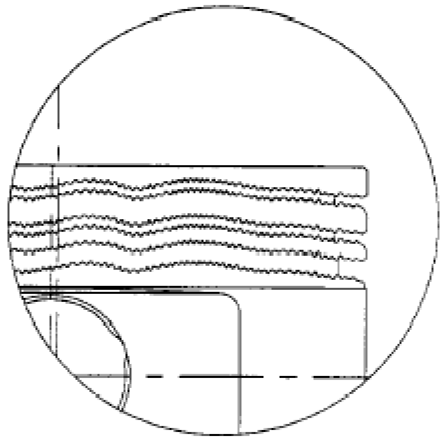


Figure 5 - Ring groove chatter (also "chatter")

4.5 Groove Side Surface Finish (also "Roughness")

The surface texture of the top and bottom sides of the ring grooves. Generally measured radially in the ring groove to factor out wave and chatter contribution. See Figure 6.

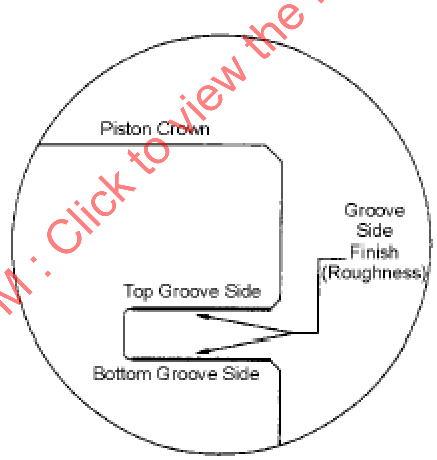


Figure 6 - Groove side surface finish (also "roughness")

4.6 Groove Radial Profile (also "Groove Profile")

This refers to the radial straightness of the ring groove sides usually measured over a minimum of two-thirds of the radial depth of the ring groove side. See Figure 7.

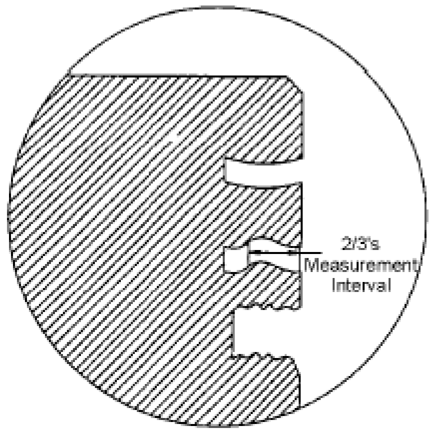
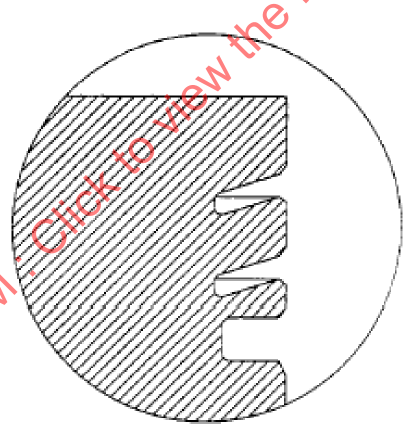


Figure 7 - Groove radial profile (also "groove profile")

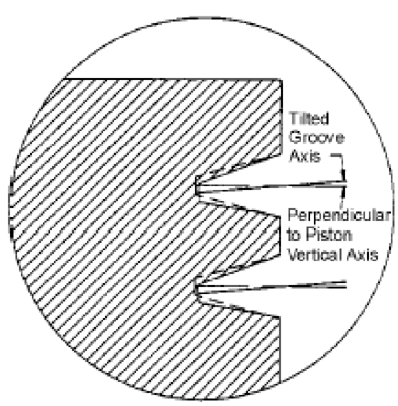
4.7 Radial Tilt (also "Inclination")

The downward, zero, or upward slope of the ring grooves. This can be intentionally specified to enhance ring performance. Illustrated is upward tilt of compression grooves. See Figures 8 and 9.



Example of Upward Tilt

Figure 8 - Example of radial upward tilt (also "inclination")



Example of Upward Tilt

Figure 9 - Example of upward radial tilt keystone grooves (also "inclination")

4.8 Ring Groove Depth

The radial distance from the root of the ring groove to the largest adjacent land. Ring groove depth can vary with runout differences of the ring groove root and land diameters to the piston vertical axis, ring groove root or land roundness variation, or addition of land ovality. See Figure 10.

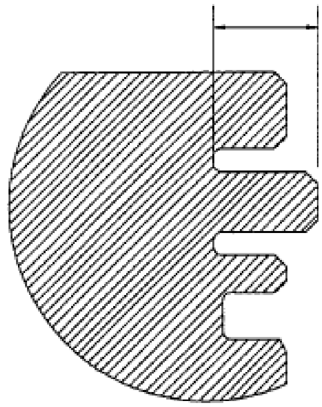


Figure 10 - Ring groove depth

4.9 Groove Root Runout

Relative to the piston vertical axis. See Figure 11.

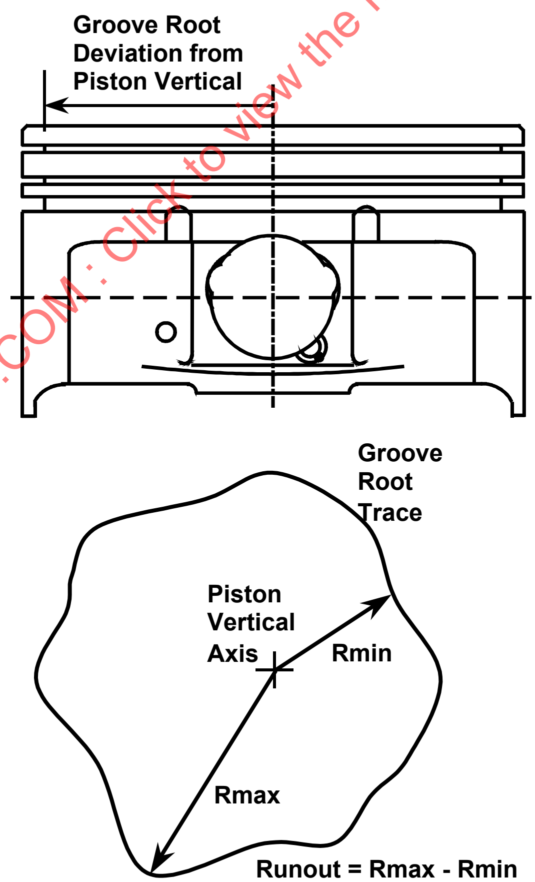


Figure 11 - Groove root runout

4.10 Groove Root to Land Runout

This refers to the ring groove root diameter runout to the adjacent land diameter. See Figure 12.

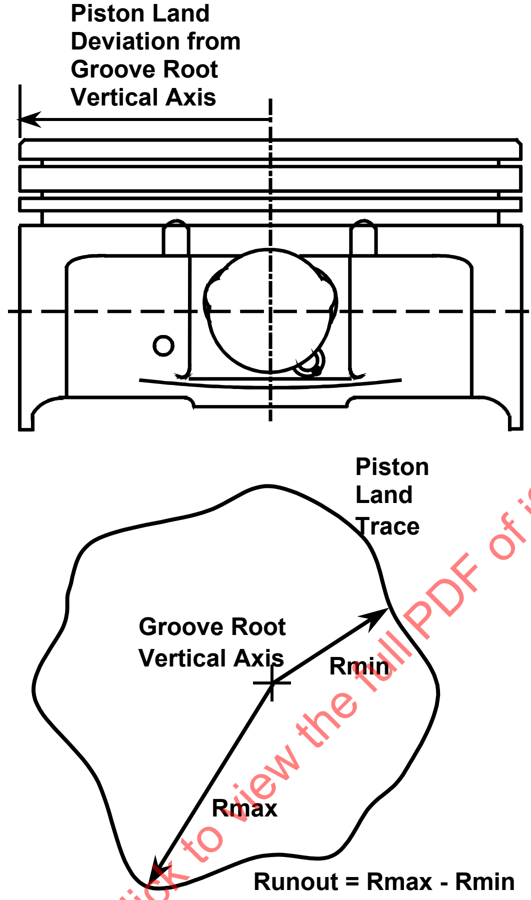


Figure 12 - Groove root to land runout

4.11 Ring Groove Side Parallelism (Rectangular Grooves Only)

All points of one groove side are equidistant from the perpendicular corresponding points on the other groove side. See Figure 13.

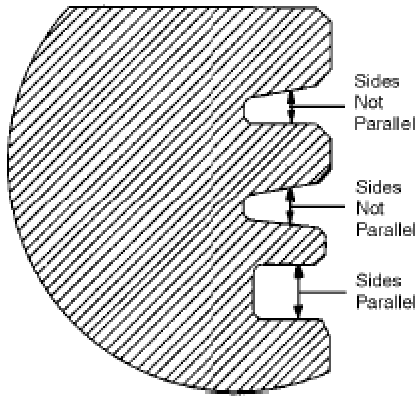


Figure 13 - Ring groove side parallelism

4.12 Land Runout

This term is the piston land diameter runout to the piston vertical axis. See Figure 14.

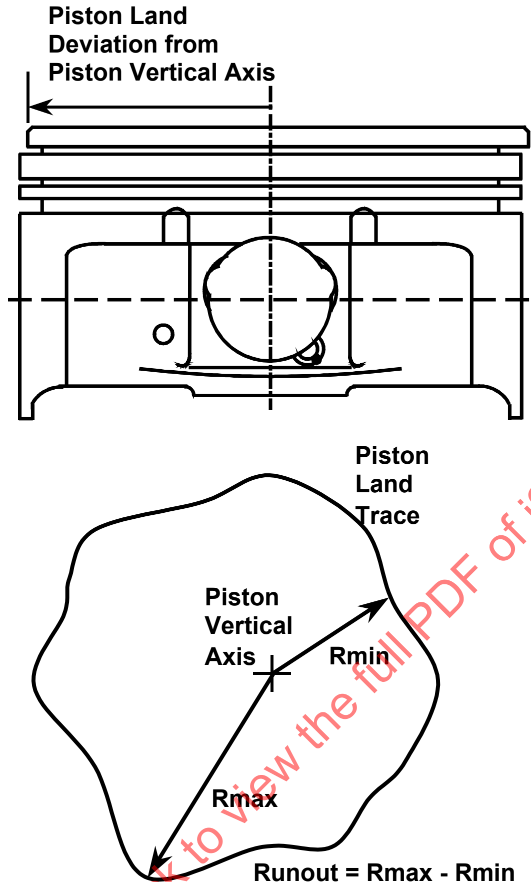


Figure 14 - Land runout

4.13 Land Offset

This term refers to the intentional offset of the ring land vertical axis to the piston vertical axis for any number of ring lands. May be added as a design feature. See Figure 15.

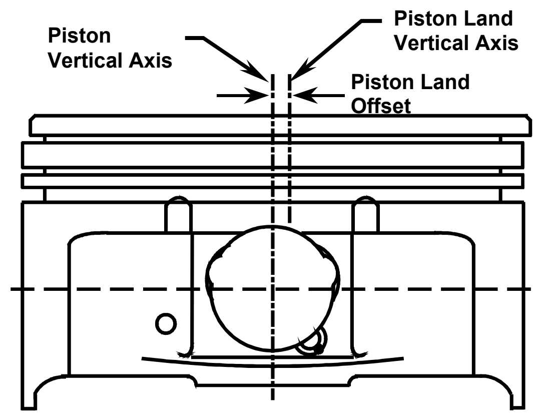


Figure 15 - Land offset

4.14 Land Profile

This refers to the vertical shape of the ring lands of a piston. There may be a design feature (i.e., taper, barrel, etc.) that accommodates for thermal expansion, and mechanical clearance, of the ring lands. See Figure 16.

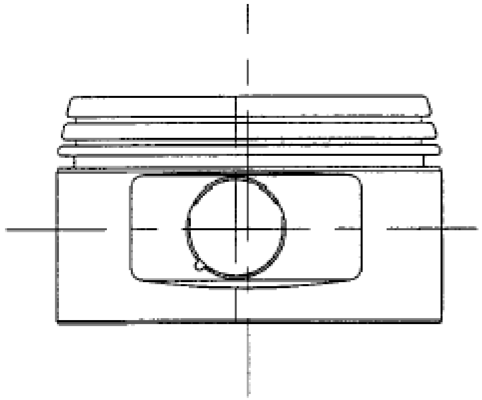


Figure 16 - Land profile

4.15 Land Ovality

Land ovality is a design feature that will compensate for cylinder bore and piston shape changes due to thermal conditions. Ovality is defined as the major minus the minor diameter of the land (positive ovality is shown in Figure 17). There are applications with asymmetric and non-oval circumferential profiles. See Figure 17.

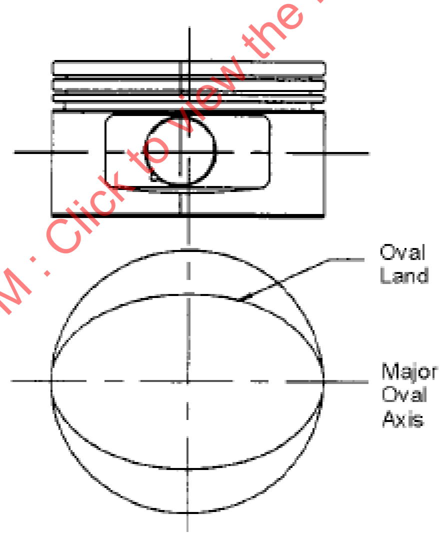


Figure 17 - Land ovality

5. PISTON RING AND GROOVE WIDTH

5.1 Widths of Rectangular Compression Rings, Oil Control Rings, and Mating Piston Grooves

5.1.1 Rectangular Compression Rings

Typical nominal rectangular ring and groove widths that may be used are (mm):
0.80, 1.00, 1.20, 1.50, 1.75, 2.00, 2.50, 3.00, 3.50, 4.00, 4.50

Table 1 - Basic top rectangular compression piston ring and groove width tolerance

	Typical Piston Ring Width Tolerance (millimeters)	Typical Piston Ring Groove Width Tolerance (see Note 3) (millimeters)		
Nominal Ring Width		d ≤ 80	80 < d ≤ 125	d > 125
≤2.0	-0.010/-0.030	+0.020/+0.040	+0.030/+0.050	+0.040/+0.060
>2.0	-0.010/-0.035	+0.030/+0.055	+0.040/+0.065	+0.050+0.075

NOTE 1: For all engine applications, the second piston ring groove width tolerance is typically 0.010 mm lower than in Table 1.

NOTE 2: For small IDI diesel engines with top ring groove protectors, top piston ring groove width tolerances are typically 0.010 mm larger than in Table 1.

NOTE 3: Dimensions apply to uncoated rings and untreated ring grooves. Applications with coating and groove treatment must be considered on a case-by-case basis.

5.1.2 Three-Piece Oil Rings

Typical nominal ring and groove widths that may be used are (mm):
2.00, 2.50, 3.00, 3.50, 4.00

Typical groove width tolerance:
+0.030/+0.050 mm

5.1.3 One- and Two-Piece Oil Rings

Typical nominal ring and groove widths that may be used are (mm):
2.00, 2.50, 3.00, 3.50, 4.00, 4.50, 5.00, 6.00, 7.00, 8.00

Table 2 - Basic one- or two-piece oil piston ring and groove width tolerance

	Typical Piston Ring Width Tolerance (millimeters)	Typical Piston Ring Groove Width Tolerance (see Note 3) (millimeters)		
Nominal Ring Width		d ≤ 80	80 < d ≤ 125	d > 125
≤2.0	-0.010/-0.030	+0.010/+0.030	+0.010/+0.030	+0.030/+0.060
>2.0	-0.010/-0.040	+0.020/+0.050	+0.020/+0.050	+0.030/+0.060

5.2 Widths of Keystone Rings and Mating Piston Grooves

5.2.1 Keystone Ring Width Definition, Measurement Method

Measurement methods for keystone ring width should be in accordance with ISO 6621-2.

5.2.2 Keystone Groove Width Definition, Measurement Method

Typically specified on the print as a diameter measured over gage pins. The measurement is then translated into a vertical width dimension, W. See Figure 18.

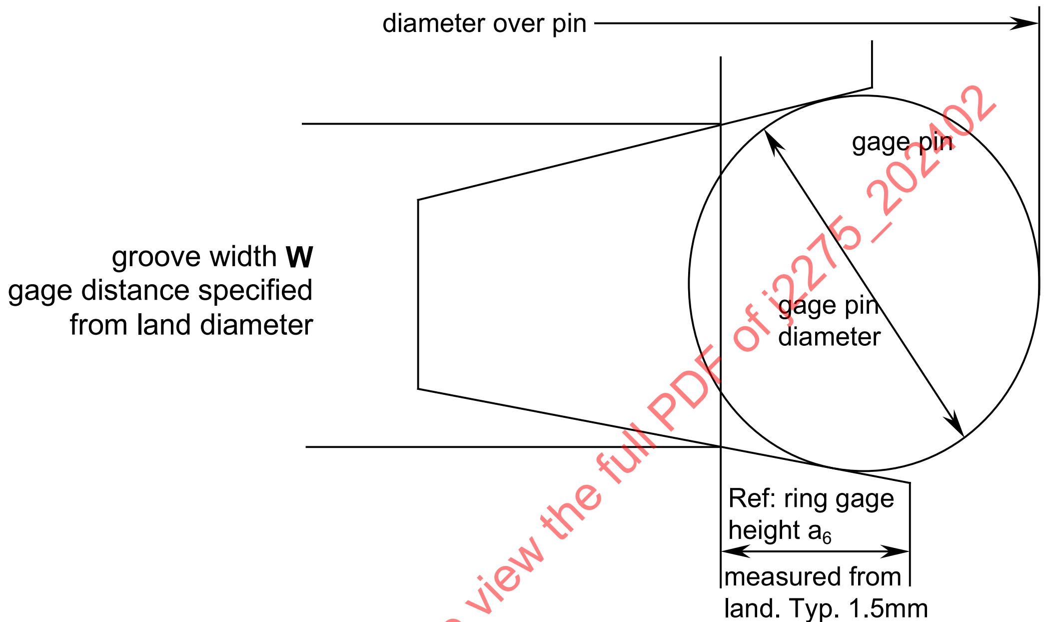


Figure 18 - Keystone groove width definition

Where a nominal groove width dimension is specified on the print, it is recommended that the datum for the gage distance (typical 1.5 mm) is the largest adjacent land, not the cylinder bore diameter. See Figure 18.

5.2.3 Keystone Ring-to-Groove Clearance, Calculation

Clearance should be calculated and specified in the vertical plane.

Typical ring and groove designs have asymmetrical angles; therefore, the clearance could be specified at the ID, OD, and gage point of the ring/groove. See Figure 19.

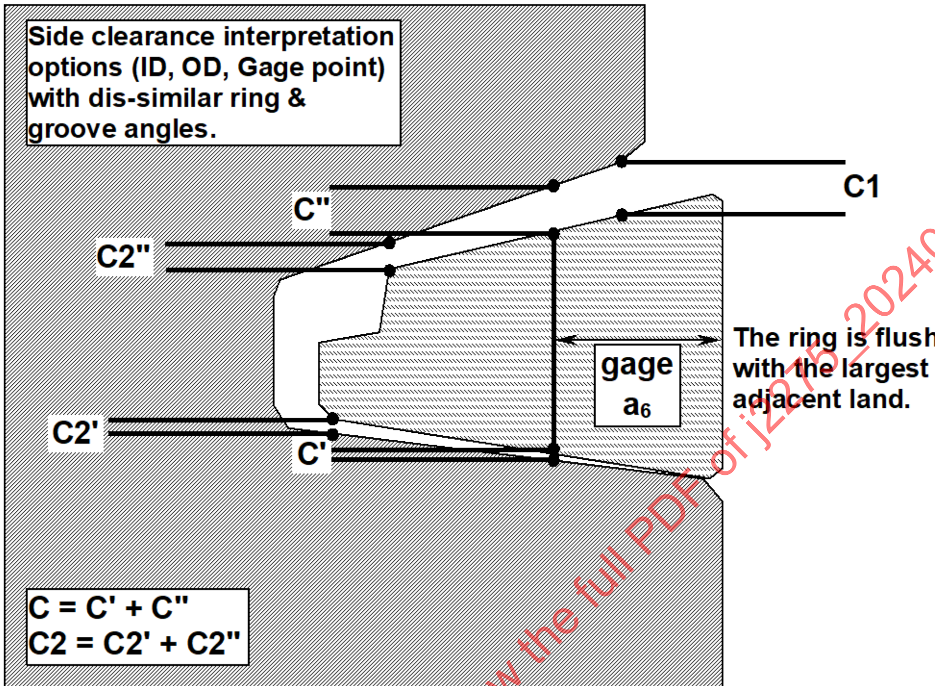


Figure 19 - Keystone ring-to-groove clearance

The ID and OD clearances (C1 and C2) method should assume maximum material conditions (MMC). Minimum clearance may occur at either C1 or C2. The clearance at the gage point should be checked at nominal dimensions. Recommended clearances are specified in Table 3. See Figure 19.

5.2.3.1 Keystone Ring Groove Clearance Calculation

See Figure 20 for an example calculation.

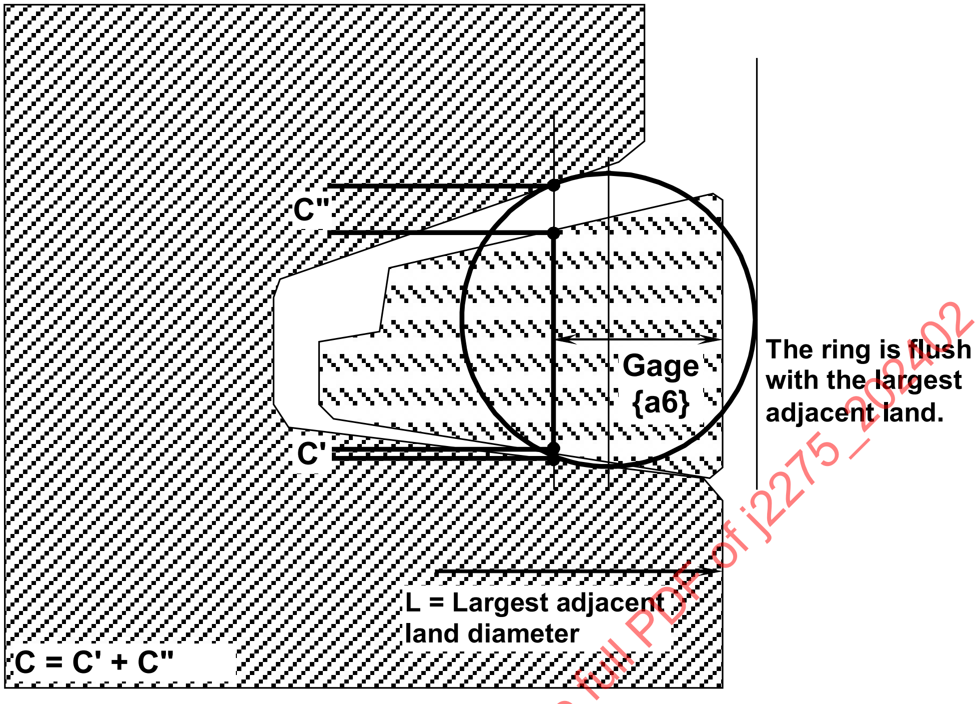


Figure 20 - Keystone ring groove clearance (example calculation)

vz = Radial Distance from Center of Pin to Gage Point = (D-d)/2 - (L/2 - g) (Eq. 1)
az = Radial Gage Point to Tangent Point = (d/2)sin(A/2)
vk = Axial Distance From Tangent Point to Gage Point = (vz - az)tan(A/2)
cz = Axial Height from Pin Center to Tangent Point = (d/2)cos(A/2)
kx = Width of Groove at Gage Point = 2(cz-vk)
C = Clearance at Gage Point = kx-jx

The resultant reference clearance C should then fall within the recommended limits.

Recommended clearances should not be the starting point of ring or groove dimension calculations.

5.2.4 Keystone Groove Reference Clearance Recommendations

For keystone compression ring tolerances, refer to ISO 6624-1 and ISO 6624-3. Piston groove dimensions, typical tolerances, 15-degree included angle:

- Diameter over pin: ±0.12
- Piston land diameter: ±0.10
- Land runout to piston axis: 0.05
- Keystone groove, bottom side angle: ±0.083 degree (5 minutes)
- Keystone groove, included angle: ±0.125 degree (7.5 minutes)

- Keystone ring, bottom side angle: ±0.2 degree (12 minutes)
- Keystone ring, included angle: ±0.2 degree (12 minutes)
- Ring groove runout to piston axis: 0.10

Heavy-duty engine applications (100 to 200 mm), typical 15-degree included angle. Measured at the ring gage distance {a_6} from largest adjacent land diameter. See Table 3.

Table 3 - Nominal keystone groove clearance at gage point (heavy-duty applications)

	Reference Clearance Range Min	Reference Clearance Range Max
Top Keystone	0.090	0.140
2nd Keystone	0.060	0.110

Small bore engine applications, typical 15-degree included angle. Measured at the ring gage distance {a_6} from largest adjacent land diameter. See Table 4.

Table 4 - Nominal keystone groove clearance at gage point (small bore engine application)

	Reference Clearance Range Min	Reference Clearance Range Max
Top Keystone	0.060	0.110

5.2.5 Half-Keystone Reference Groove Clearance Recommendations

Typical 7.5-degree included angle. Measured at the ring gage distance {a_6} from largest adjacent land diameter. See Table 5.

Table 5 - Nominal half-keystone at gage point groove clearance

	Reference Clearance Range Min	Reference Clearance Range Max
Top Half Keystone	0.060	0.110

Add +0.025 mm typical after maximum material calculation to achieve recommended range.

5.2.6 Keystone Groove Up-Tilt Recommendation

To compensate for thermal and mechanical deformation of the piston lands and grooves.

Used in conjunction with symmetrical angle (preferred), nonsymmetrical angle, or twist section keystone compression rings. See Figure 21.

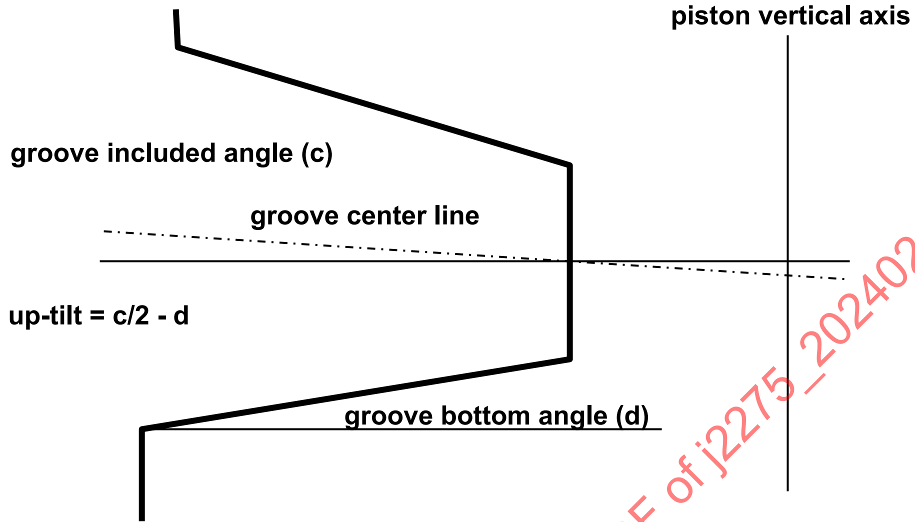


Figure 21 - Keystone groove up-tilt

Heavy-duty engine applications (100 to 200 mm), typical for 15-degree included angles. Recommended nominal range of uptilt: +15 to +25 minutes.

5.2.7 Keystone Ring-to-Groove Contact Bias

See Figure 22.

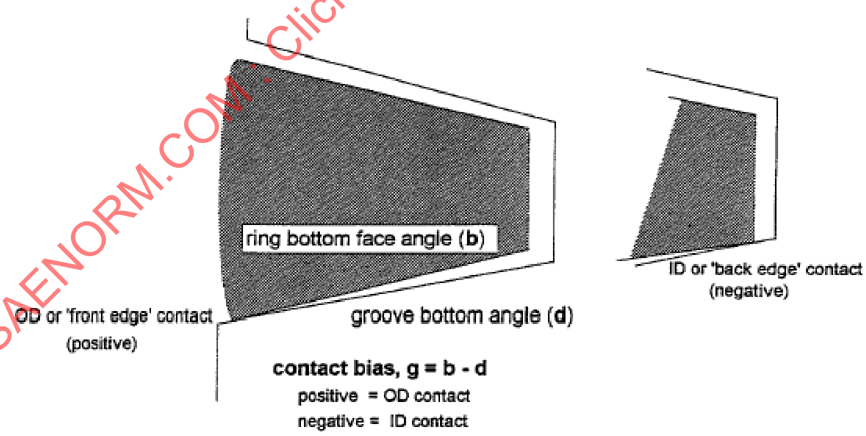


Figure 22 - Keystone ring-to-groove contact bias

Heavy-duty engine applications (100 to 200 mm), typical for 15-degree included angles.

Typical nominal ranges, nominal values, g.

a. Top groove: +30 minute (OD contact) to -10 minute (ID contact)

b. 2nd groove: +35 minute (OD contact) to -30 minute (ID contact)

Excludes the effects of ring twist.

6. GROOVE ROOT DIAMETER CALCULATION

6.1 Piston and Ring Assembly

See Figure 23.

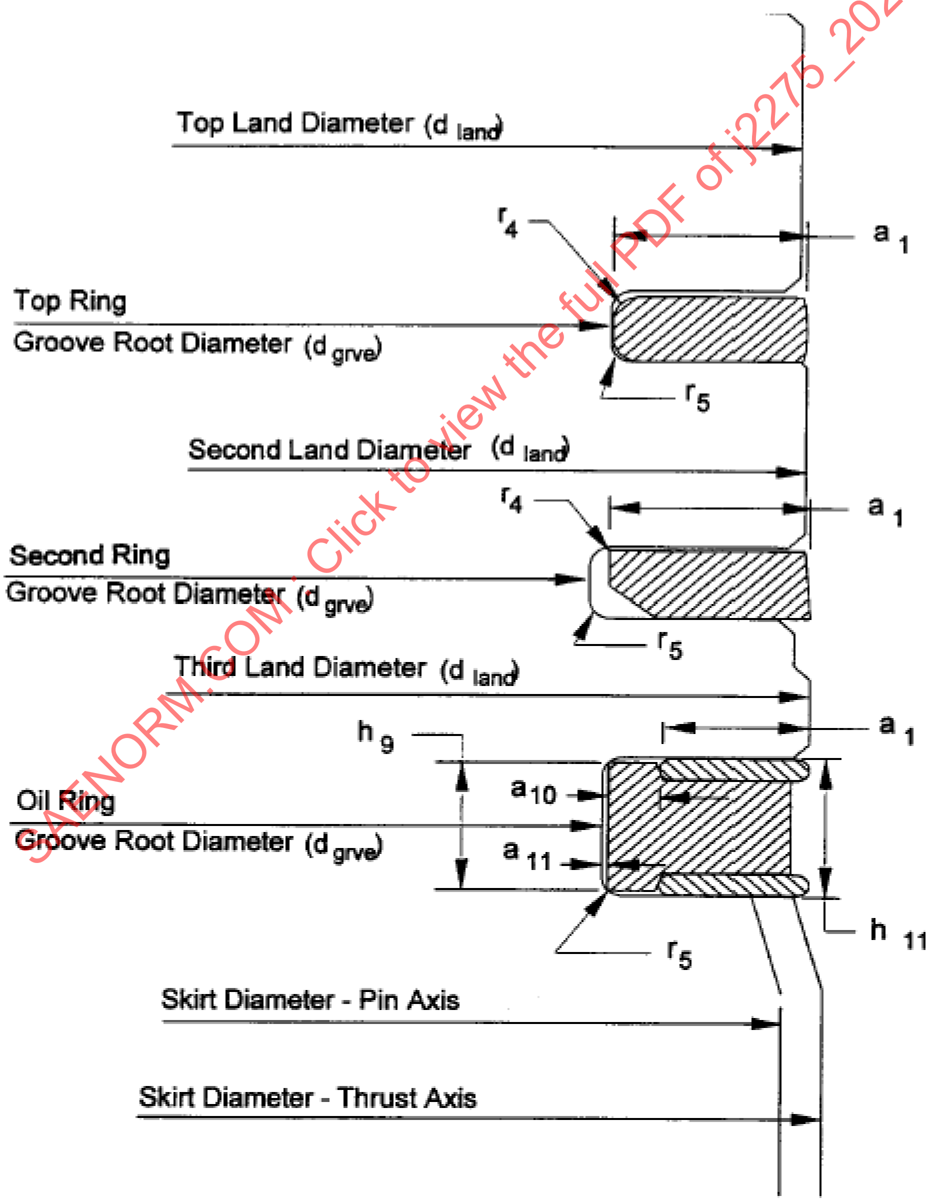


Figure 23 - Piston and ring assembly

6.1.1 Coil-Spring-Loaded Oil Ring

See Figure 24.

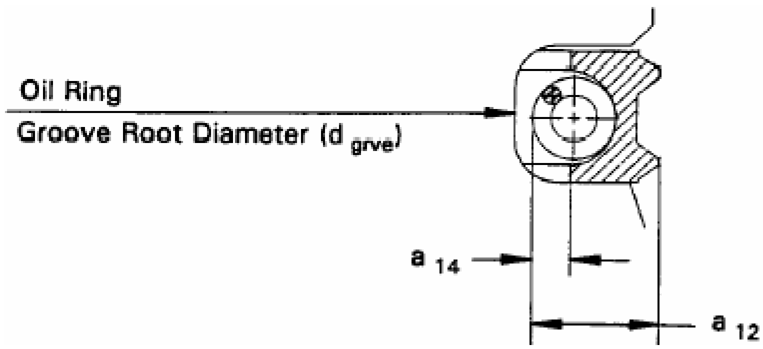


Figure 24 - Coil-spring-loaded oil ring

6.2 Compression Ring Groove

See Figure 25.

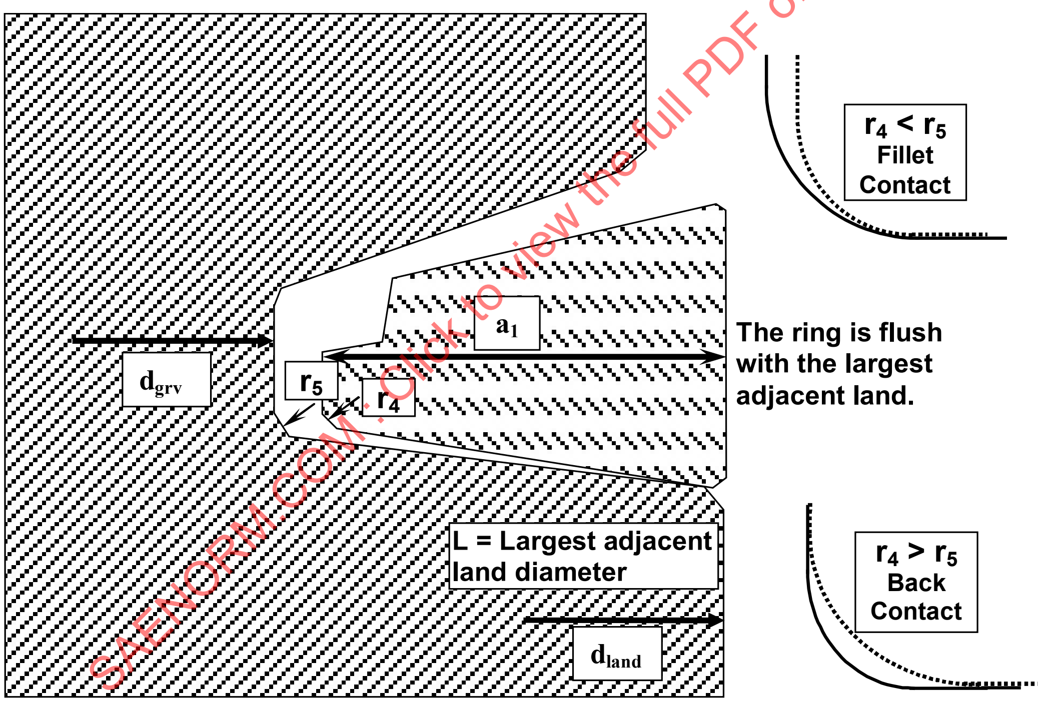


Figure 25 - Compression ring back clearance

If $r_4 > r_5$, then the contact is at the back of the ring.

$$d_{grve}max_1 = (d_{land}\ min) - (a_{ro}\ max) - 2(a_1\ max) \qquad \text{(Eq. 2A)}$$

If $r_4 < r_5$, then the contact is at the fillet radius.

$$d_{grve}max_1 = (d_{land}min) - (a_{ro}max) - 2(a_1max) - 2(r_5max) + 2(r_4min) \qquad \text{(Eq. 2B)}$$

where:

d_{grve} = top or second ring groove root diameter

d_{land} = ring land diameter (see NOTE 2)

a_{ro} = groove root to ring land runout

a_1 = top or second ring radial wall thickness

r_5 = groove root radius

r_4 = top or second ring ID radius or chamfer

NOTE 1: Minimized ring radial back clearance is achieved by applying statistical methods to the previous calculation.

NOTE 2: Low limit of the largest land diameter adjacent to the groove. Includes effect of land ovality when present.

NOTE 3: Equation 1 yields zero back clearance.

NOTE 4: In the absence of known land diameters, the minimum bore diameter may be substituted. However, an appropriate allowance for estimated land clearance should be included in the back clearance calculation.