SURFACE VEHICLE STANDARD

SAE

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Internal Combustion Engines—Piston Ring-Grooves

RATIONALE

This standard was updated to delete references to the SAE standards because they have been obsoleted and superseded by the ISO documents. Additionally some of the figures were updated for clarity.

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 Publications

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

TO PLACE A DOCUMENT ORDER:	**Tel:**	**877-606-7323 (inside USA and Canada)**
	Tel:	**1+ 724-776-4970 (outside USA)**
	Fax:	**724-776-0790**
	Email:	**CustomerService@sae.org**
SAE WEB ADDRESS:		http://www.sae.org

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/J2275_201001

2.1.1   ISO Publications

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

TR refers to Technical Report.

ISO 6621/1   Internal Combustion Engines—Piston Rings—Vocabulary

ISO 6621/2   Internal Combustion Engines—Piston Rings—Measuring Principles

ISO 6621/3   Internal Combustion Engines—Piston Rings—Material Specifications

ISO 6621/4   Internal Combustion Engines—Piston Rings—General Specifications

ISO 6621/5   Internal Combustion Engines—Piston Rings—Quality Requirements

ISO 6622/1   Internal Combustion Engines—Piston Rings—Rectangular Rings

ISO 6222/2 TR   Internal Combustion Engines—Piston Rings—Rectangular Rings With Narrow Ring Width

ISO 6623   Internal Combustion Engines—Piston Rings—Scraper Rings

ISO 6624/1   Internal Combustion Engines—Piston Rings—Keystone Rings

ISO 6624/2 TR   Internal Combustion Engines—Piston Rings—Half Keystone Rings

ISO 6625   Internal Combustion Engines—Piston Rings—Oil Control Rings

ISO 6626   Internal Combustion Engines—Coil Spring Loaded Oil Control Rings

ISO 6627 TR   Internal Combustion Engines—Expander/Segment Oil Control Rings

ISO 6507/3   Metallic Materials—Hardness Test—Vickers Test—Part 3: Less Than HV 0.2
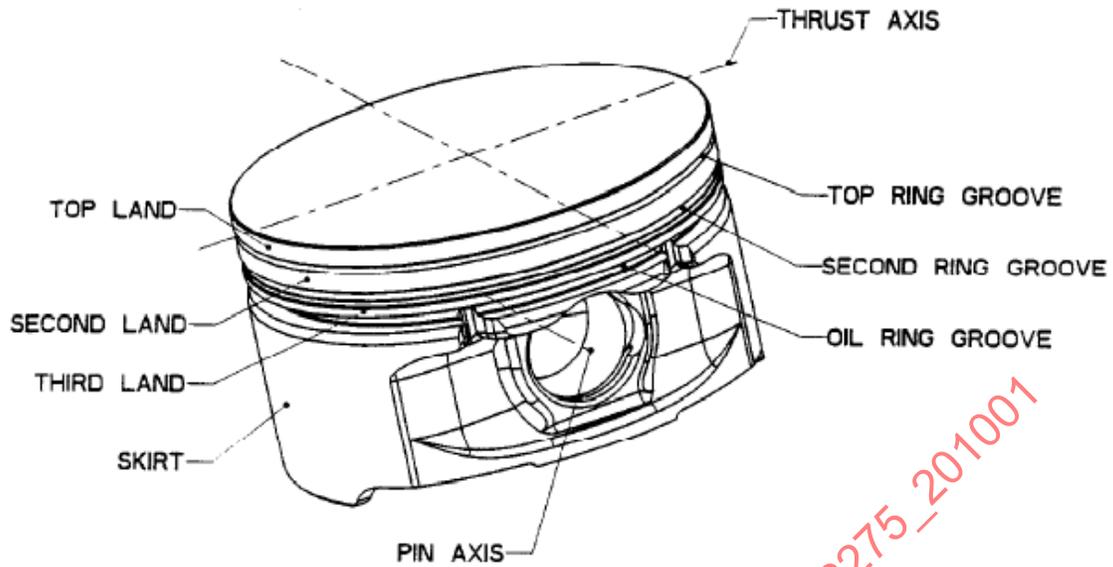
3.   PISTON GROOVE NOMENCLATURE

(See Figure 1.)
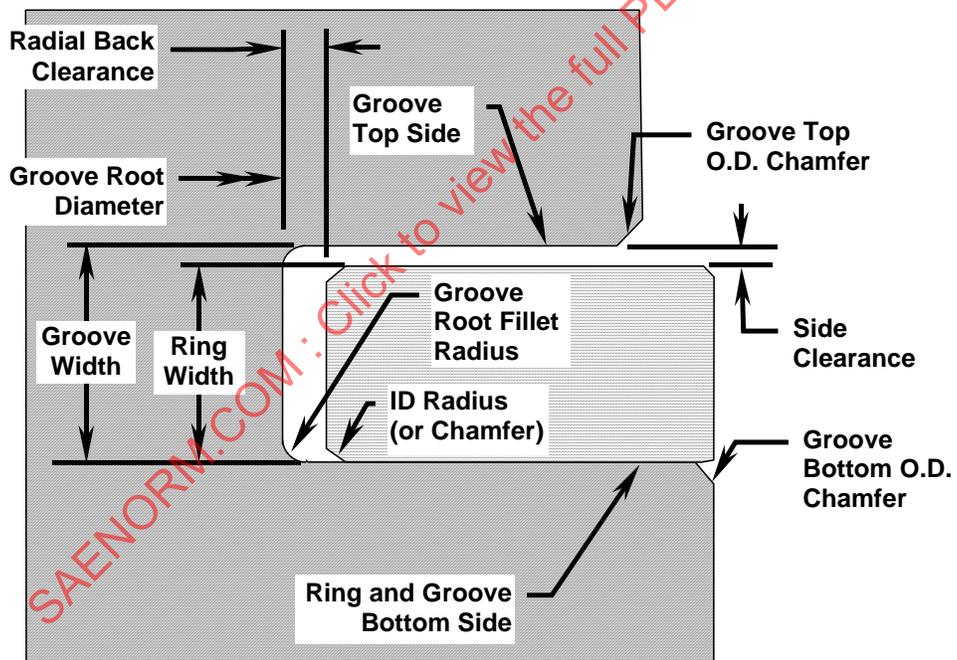
FIGURE 1A - PISTON GROOVE NOMENCLATURE

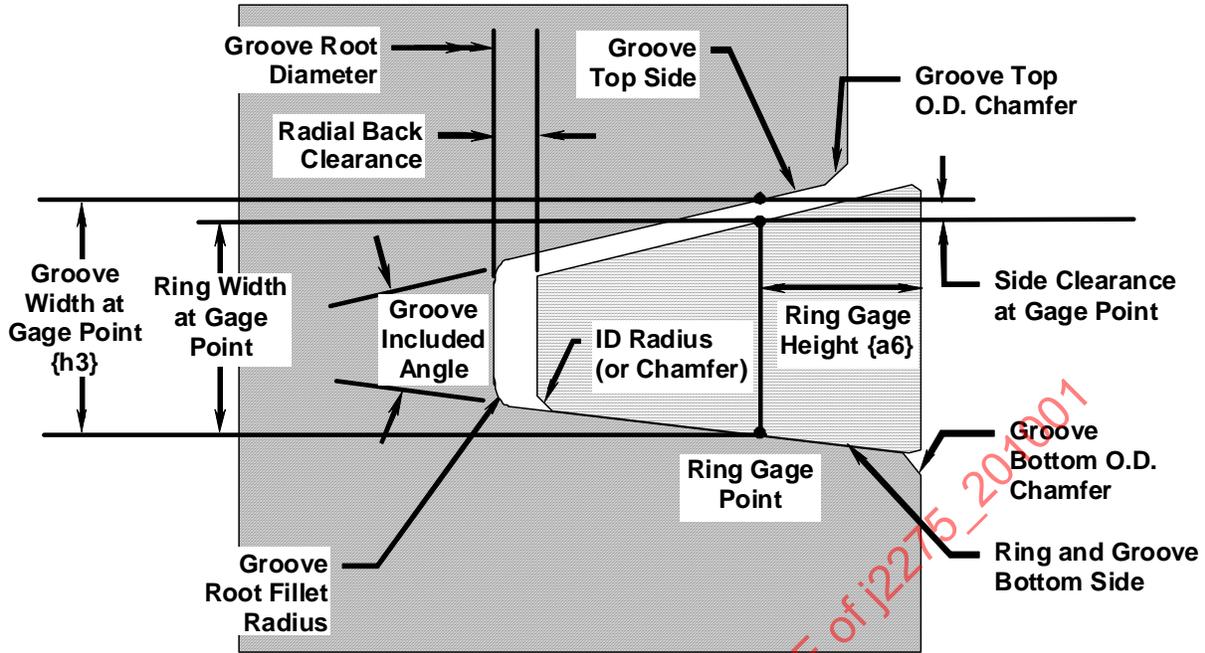FIGURE 1B - PISTON RECTANGULAR GROOVE NOMENCLATURE

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 8 points with 4 target points on each of two datum planes. See Figure 2.
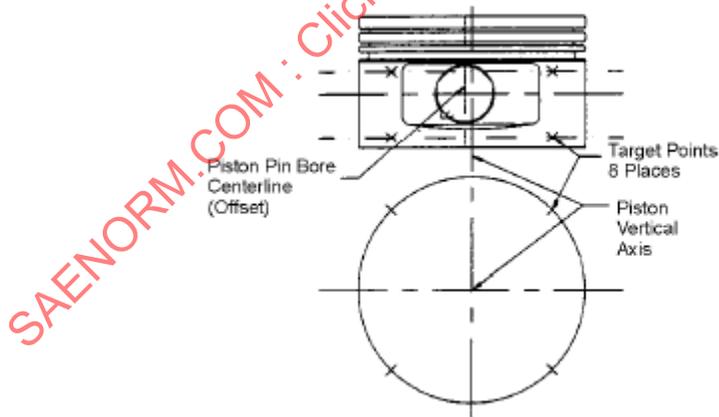

FIGURE 2 - PISTON VERTICAL AXIS

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.
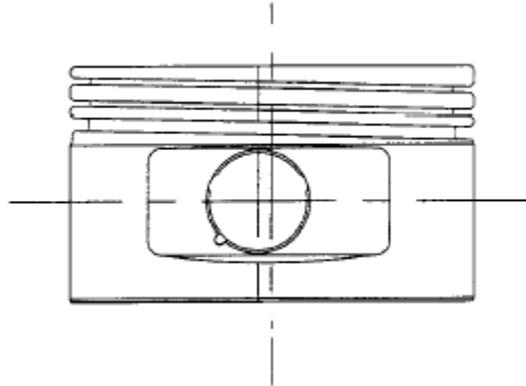

FIGURE 3 - WIND (ALSO "WINDE")

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.
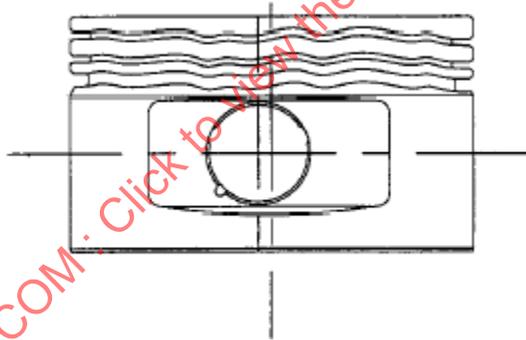

FIGURE 4 - CIRCUMFERENTIAL GROOVE WAVINESS (ALSO "WAVE")

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.
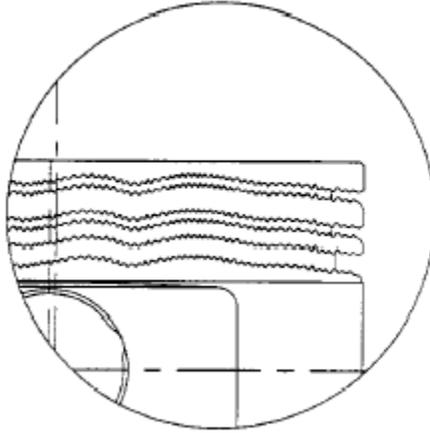
FIGURE 5 - RING GROOVE CHATTER (ALSO "CHATTER")

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.
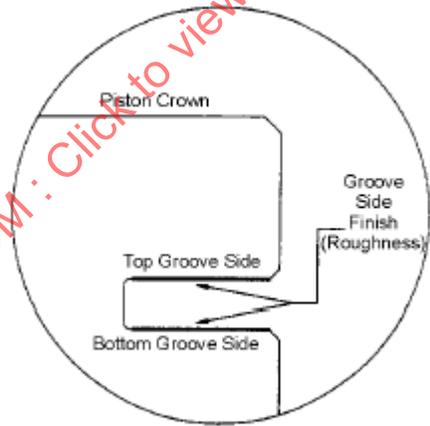
FIGURE 6 - GROOVE SIDE SURFACE FINISH (ALSO "ROUGHNESS")

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 2/3's 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")

Is 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.

FIGURE 8 - EXAMPLE OF RADIAL UPWARD TILT (ALSO "INCLINATION")
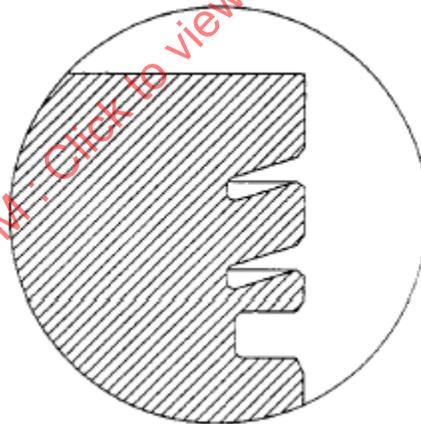
Example of
Upward Tilt

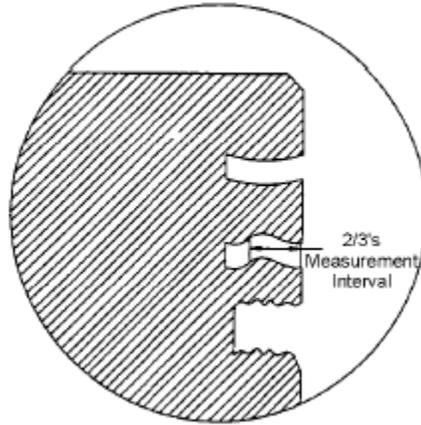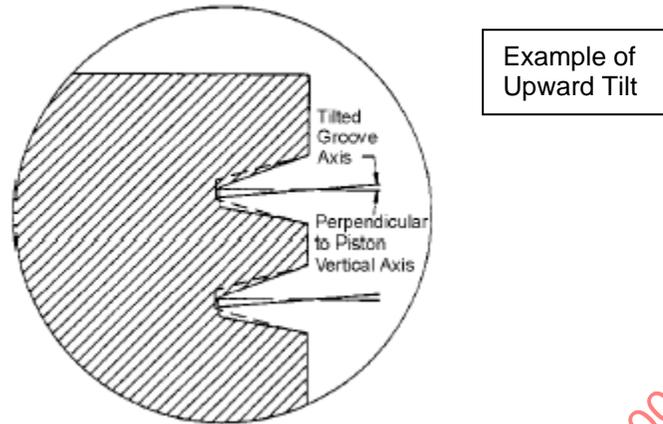FIGURE 9 - EXAMPLE OF UPWARD RADIAL TILT KEYSTONE GROOVES (ALSO "INCLINATION")

4.8   Ring Groove Depth

Is 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.
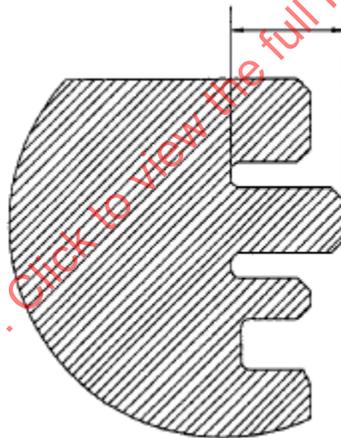
FIGURE 10 - RING GROOVE DEPTH

4.9   Groove Root Runout

Relative to the piston vertical axis. See Figure 11.

Groove Root Deviation from Piston Vertical

Groove Root Trace

Piston Vertical Axis

Rmin

Rmax

Runout = Rmax - Rmin
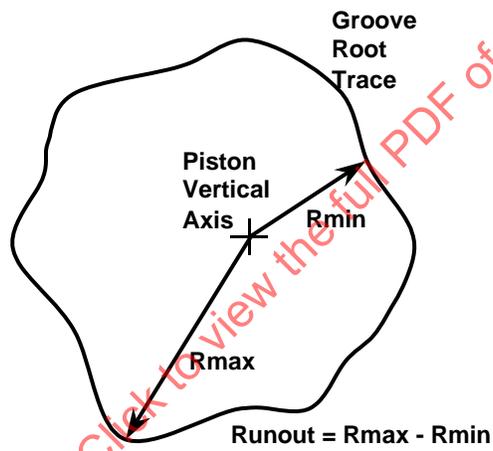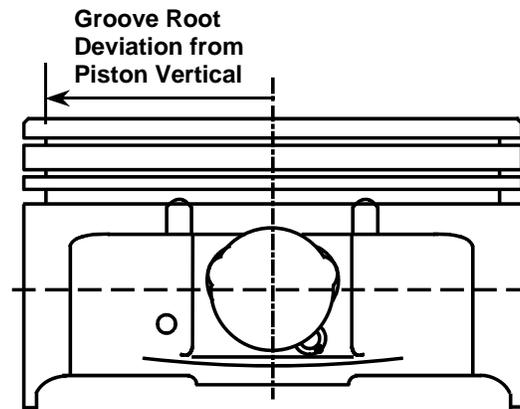
FIGURE 11 - GROOVE ROOT RUNOUT

4.10   Groove Root to Land Runout

This refers to the Ring Groove Root Diameter runout to the adjacent land diameter. See Figure 12.

**Piston Land
Deviation from
Groove Root
Vertical Axis**

**Piston
Land
Trace**

**Groove Root
Vertical Axis**

Rmin

Rmax

Runout = Rmax - Rmin
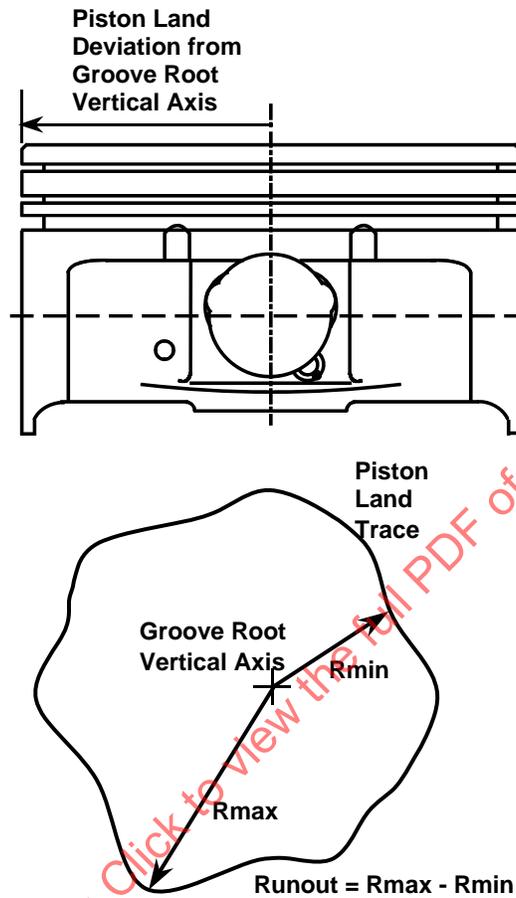
FIGURE 12 - GROOVE ROOT TO LAND RUNOUT

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.

Sides
Not
Parallel

Sides
Not
Parallel

Sides
Parallel
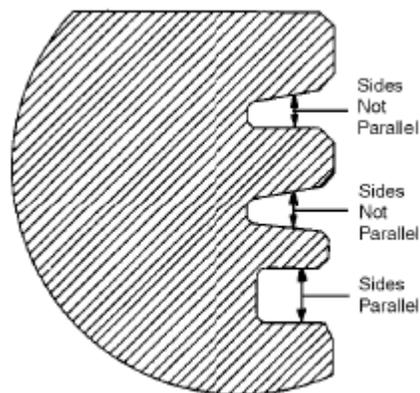
FIGURE 13 - RING GROOVE SIDE PARALLELISM

4.12   Land Run Out

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

Piston Land
Deviation from
Piston Vertical Axis

Piston
Land
Trace

Piston
Vertical
Axis   **Rmin**

Rmax

Runout = Rmax - Rmin
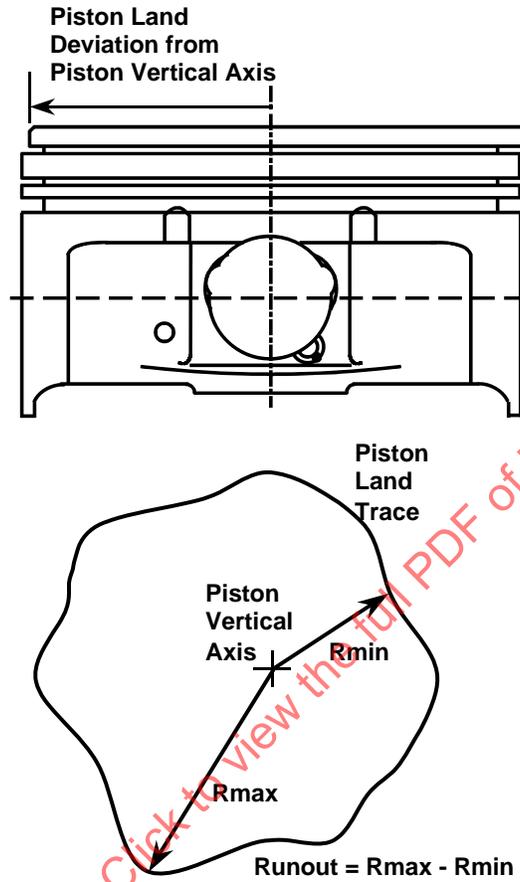
FIGURE 14 - LAND RUNOUT

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.

Piston   **Piston Land**
Vertical Axis   **Vertical Axis**

                            Piston Land
                            Offset
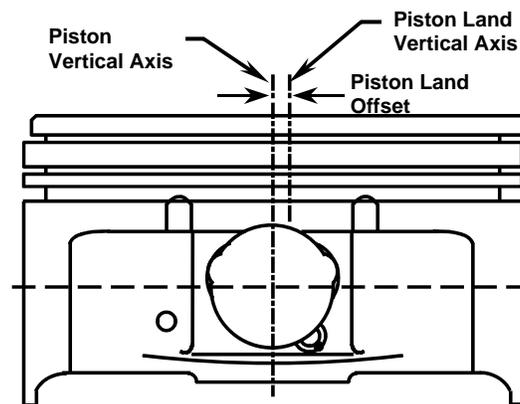
FIGURE 15 - LAND OFFSET

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.
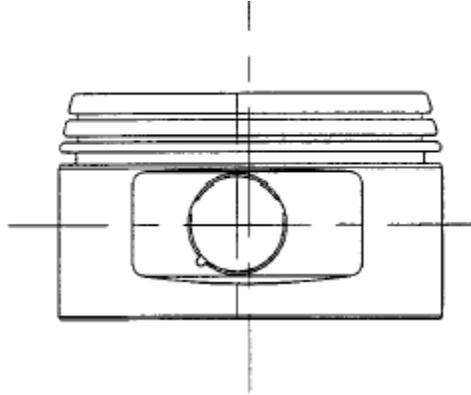
FIGURE 16 - LAND TAPER

4.15 Land Ovality

Land ovality is a design feature that will compensate for cylinder bore and piston shape changes due to thermal conditions. The major axis of the ovality may be designed on an axis other than the skirt or pin axis. Ovality is defined as the major minus the minor diameter of the land (positive ovality is shown in the figure). 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 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

Typical Ring Width Tolerance: Typical Groove Width Tolerance (See Note 4)
         -0.010/-0.030 mm   +0.030/+0.050 mm (Spark Ignition Engines)
         -0.010/-0.040 mm   +0.040/+0.060 mm (Compression Ignition Engines)
         -0.010/-0.030 mm   +0.040/+0.060 mm (Two Stroke Engines)

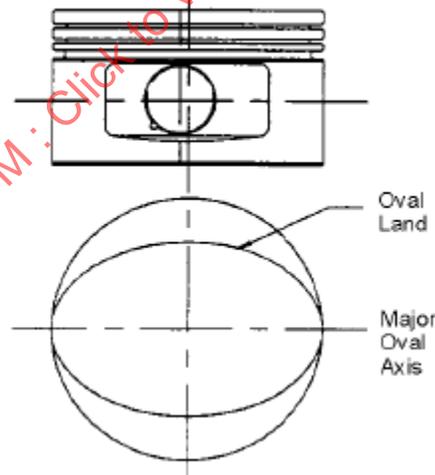Typical Minimum Ring to Groove Clearance for Uncoated Rings (Min Groove Width - Max Ring Width):
         0.040 mm (Bore $\leq$ 125mm, Spark Ignition Engines)
         0.050 mm (Bore $\leq$ 125mm, Compression Ignition Engines)
         0.060 mm (Bore > 125mm)

NOTE 1: For all engine applications, the second ring to groove clearance is typically 0.010 mm narrower than the clearances above.

NOTE 2: For small bore engine applications (approximately 80 mm or less) or compressor applications, the ring to groove clearance is typically 0.010 mm narrower than the clearances above.

NOTE 3: For small IDI diesel engines with top ring groove protector, top ring to groove clearance are typically 0.010 mm wider than the clearances above.

NOTE 4: 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 width 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 width 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

Typical Ring Width Tolerance: Typical Groove Width Tolerance:
         -0.010/-0.030   +0.030/+0.050 (Spark Ignition Engine)
         -0.010/-0.040   +0.030/+0.055 (Compression Ignition Engine)

Minimum Ring to Groove Clearance (Min Groove Width - Max Ring Width):
         0.020 mm (Bore $\leq$ 125 mm, Nominal Ring/Groove Width <3.0)
         0.040 mm (Bore $\leq$ 125 mm, Nominal Ring/Groove Width >3.0)
         0.040 mm (Bore > 125 mm)

Maximum Ring to Groove Clearance (Min Groove Width - Max Groove Width):
         0.060 mm (Bore $\leq$ 125mm, Nominal Ring/Groove Width <3.0)
         0.080 mm (Bore $\leq$ 125mm, Nominal Ring/Groove Width >3.0)
         0.095 mm (Bore > 125mm)

5.2   Widths of Keystone Rings and Mating Piston Grooves

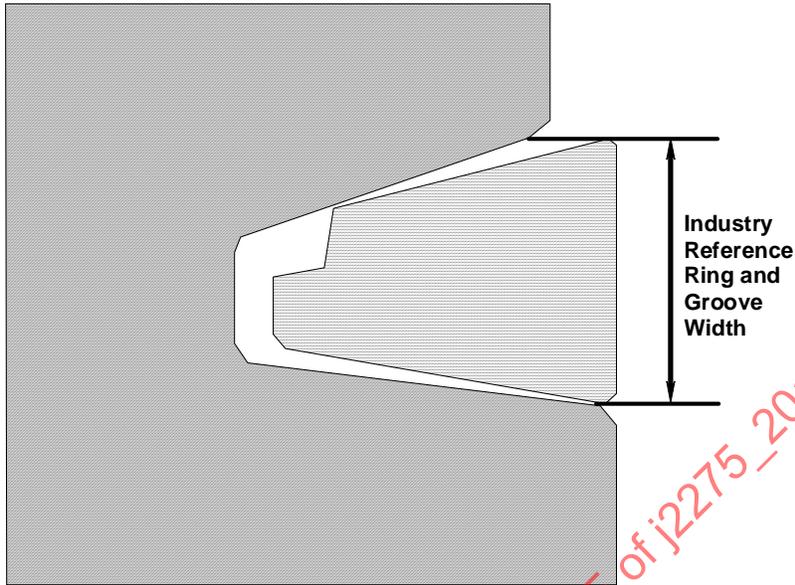**Industry Reference Ring and Groove Width**

FIGURE 18 - INDUSTRY REFERENCE RING AND GROOVE WIDTH

5.2.1   Keystone Ring Width Definition, Measurement Method

Measurement methods for keystone ring width should be in accordance with ISO 6624.

5.2.2   Keystone Groove Width Definition, Measurement Method

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

diameter over pin

gage pin

gage pin diameter

groove width **W**
gage distance specified
from land diameter

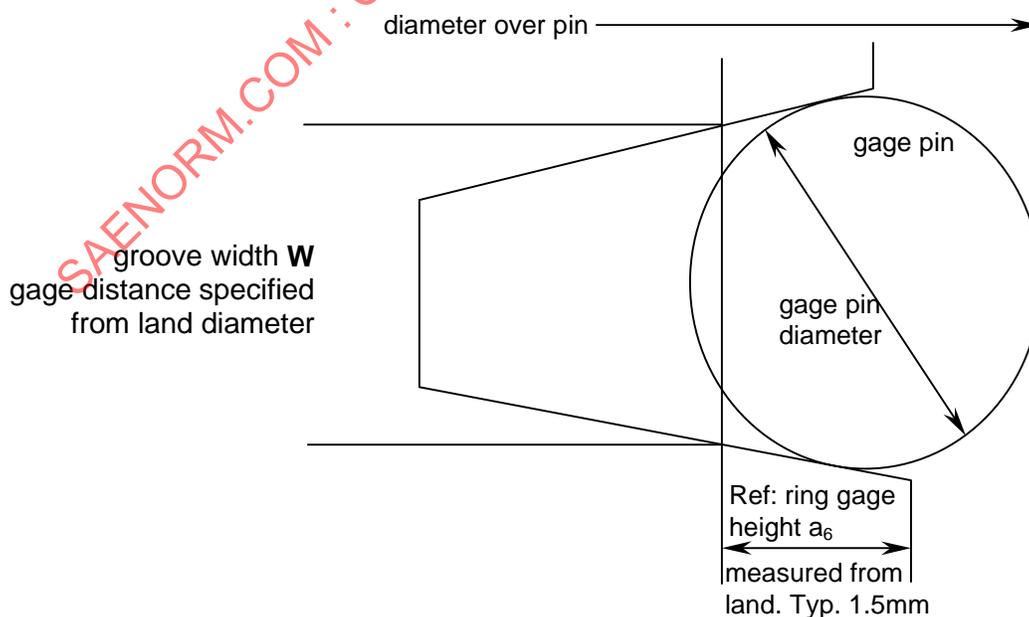Ref: ring gage height a_6

measured from land. Typ. 1.5mm

FIGURE 19 - 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 20.
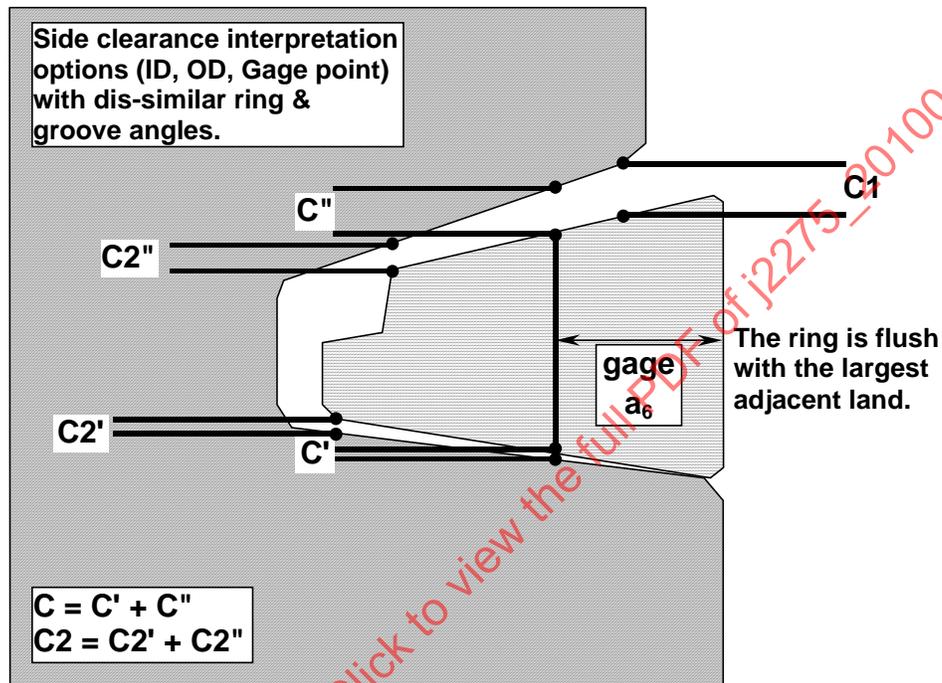
Side clearance interpretation options (ID, OD, Gage point) with dis-similar ring & groove angles.

C"

C2"

gage a6

The ring is flush with the largest adjacent land.

C1

C2'

C'

C = C' + C"
C2 = C2' + C2"

FIGURE 20 - 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 1. See Figure 20.

5.2.3.1   Keystone Ring Groove Clearance Calculation
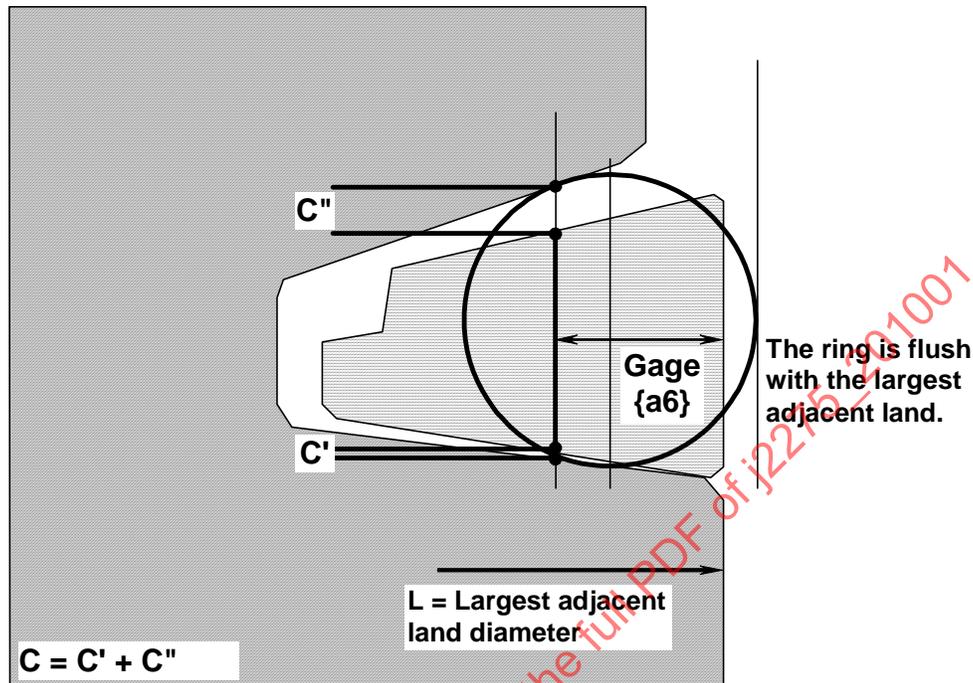
See Figure 21 for an example calculation.

FIGURE 21 - 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

Keystone compression ring tolerances - reference ISO 6624. Piston groove dimensions, typical tolerances, 15 degree included angle:

- Diameter over Pin: ±0.12
- Piston land diameter: ±0.10
- Land run-out 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 run-out 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 1.

TABLE 1 - 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 2.

TABLE 2 - 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 3.

TABLE 3 - 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 22.

piston vertical axis

groove included angle (c)

groove center line

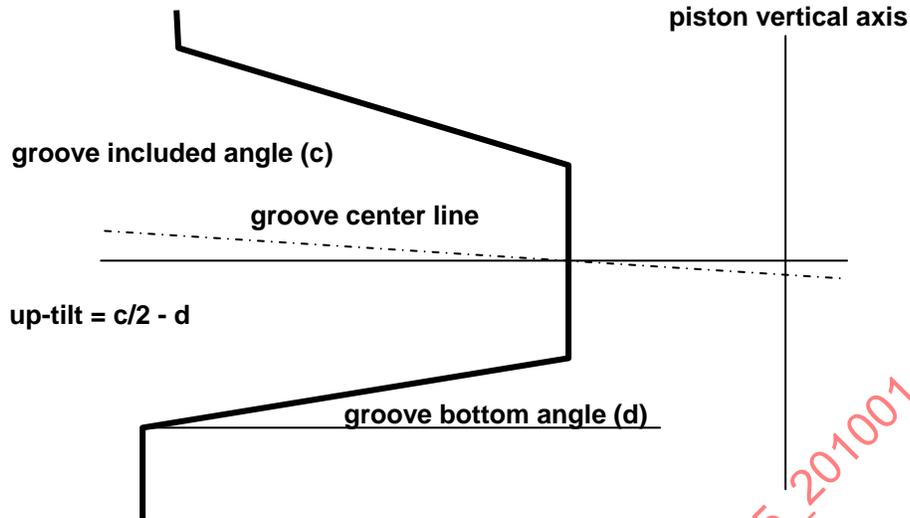**up-tilt = c/2 - d**

groove bottom angle (d)

FIGURE 22 - 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 23.

ring bottom face angle (b)

OD or 'front edge' contact
(positive)

ID or 'back edge' contact
(negative)

groove bottom angle (d)

contact bias, g = b - d
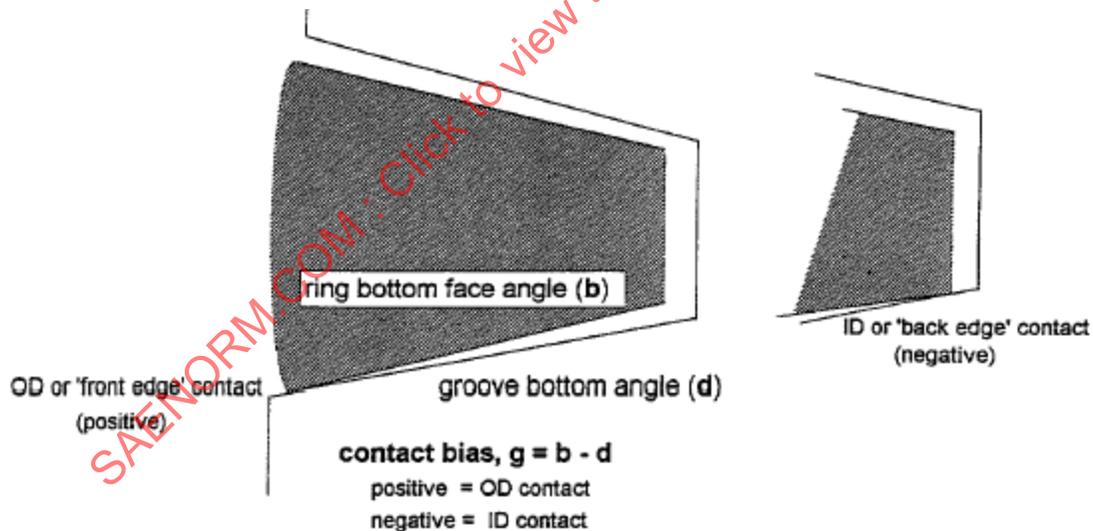positive = OD contact
negative = ID contact

FIGURE 23 - 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

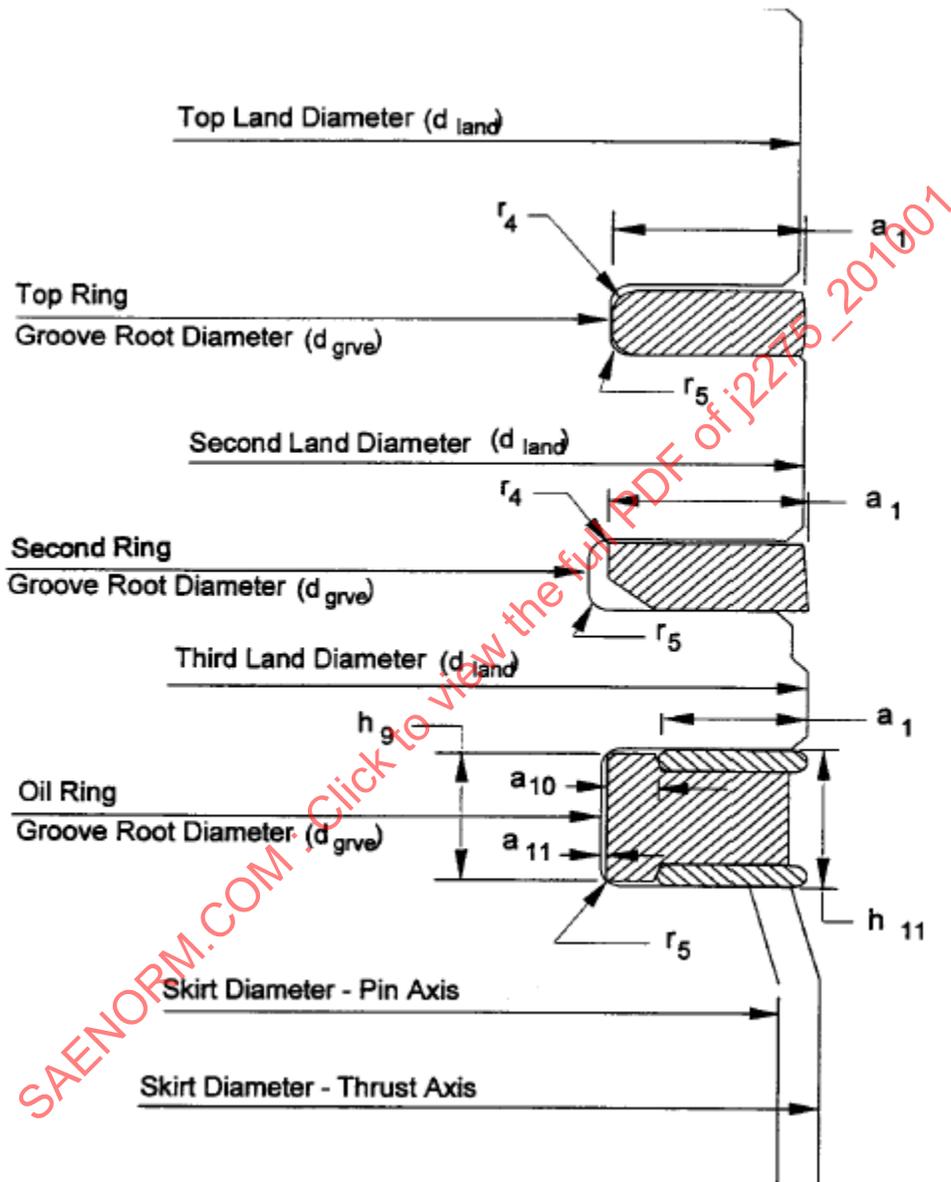(See Figure 24.)

FIGURE 24 - PISTON AND RING ASSEMBLY

6.1.1   Coil Spring Loaded Oil Ring
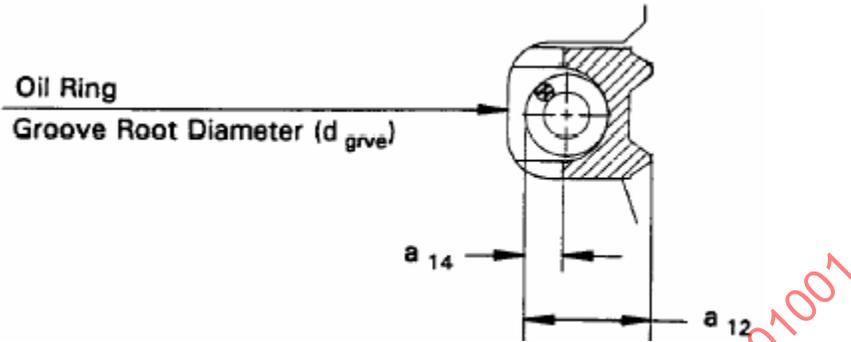
(See Figure 25.)

FIGURE 25 - COIL SPRING LOADED OIL RING

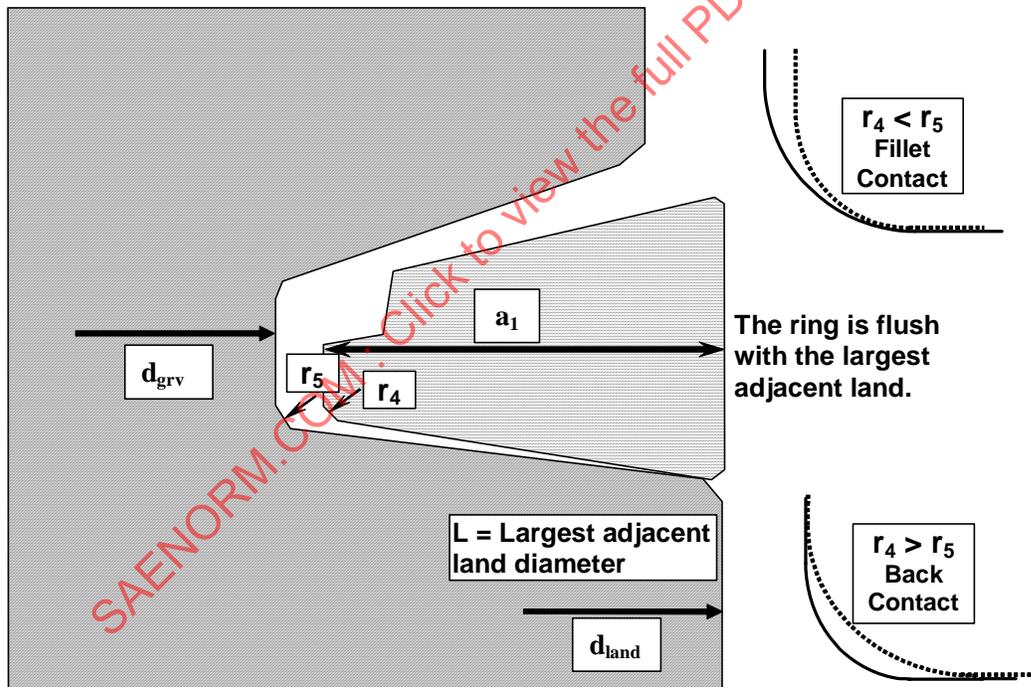6.2   Compression Ring Groove

(See Figure 26.)

FIGURE 26 - COMPRESSION RING BACK CLEARANCE

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

$$d_{grve}max_1 = (d_{land}min)_2 - (a_{ro}max) - 2(a_1max)$$
(Eq. 2A)

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

$$d_{grve}max_1 = (d_{land}min)_2 - (a_{ro}max) - 2(a_1max) - 2(r_5max) + 2(r_4min)$$
(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.