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Power Cylinder Blow-By: Blow-By Mechanisms

RATIONALE

Not applicable.

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1. SCOPE

This document covers the mechanisms associated with the power cylinder which might affect blow-by. It will not discuss in detail the blow-by mechanisms from other engine subsystems.

1.1 Purpose

During the combustion event, the intent of the engine design is to contain the combustion gases in the combustion chamber to load the piston and drive the piston to turn the crankshaft. It is the intent of the power cylinder system to seal the gases and to control the oil film on the power cylinder parts. The gas that escapes around the rings and piston is referred to as blow-by gases or just blow-by. The power cylinder system and individual components are designed to seal the gases. The understanding associated with which features affect blow-by is important in the engine design and development process.

When diagnosing blow-by problems the engineer must be aware that other engine systems can affect blow-by. These systems are as follows:

- Power cylinder system
- Head gasket
- Cylinder head system (valve stem guides and seals)
- Turbocharger
- Supercharger
- Air compressors

To solve an excessive blow-by problem, these systems must be isolated so that the system causing the problem can be identified. If the power cylinder system is identified as the cause of the blow-by problem, this document will provide guidance as to which design feature has made the greatest contribution to the excessive blow-by. The guidance provided by this document will also help the development engineer to optimize the blow-by and oil consumption of the engine. In addition to the design, it must also be recognized that the quality and cleanliness of the power cylinder components as well as the assembly practices can have a major influence on the blow-by of an engine. There is not very much detail on the influence of quality of the components on blow-by. In addition, there is no mention of how blow-by is measured because it is typically engine specific and company specific. This document will provide guidance for solving and preventing blow-by problems from the design viewpoint.

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2. REFERENCES

2.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J1588 Internal Combustion Engines—Piston Rings—Vocabulary

SAE J2612 Internal Combustion Engines—Piston Vocabulary

3. DEFINITIONS

See SAE J2612, Piston Vocabulary for the piston nomenclature.

See SAE J1588, Piston Ring Vocabulary for the piston ring nomenclature

4. BASICS OF MECHANISMS OF BLOW-BY

Fundamentally, any combustion gas that flows past the piston into the oil pan is considered blow-by of an engine. The power cylinder design is established to seal combustion gases and to control the oil.

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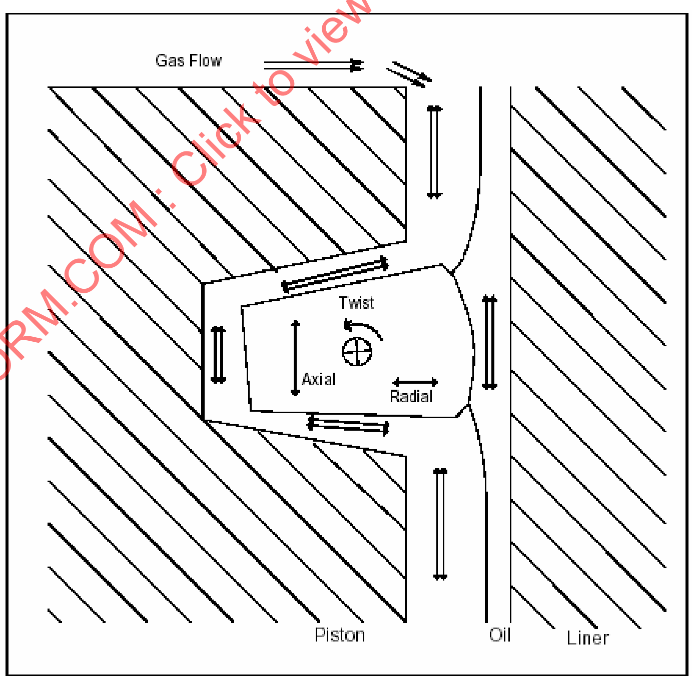

FIGURE 1 - FLOW OF OIL AND GASES PAST A RING

5. POWER CYLINDER COMPONENT - EFFECTS ON BLOW-BY

The following power cylinder components each can contribute to blow-by. These effects will be described in subsequent sections.

Components
- Piston
- Rings
    - Top Compression Ring
    - Second Compression Ring
    - Oil Control Ring
- Cylinder Bore
- Oils
- Oil Jets
    - Under-crown Spraying
    - Gallery Cooling Sprays
- Piston Pin
- Connecting Rod

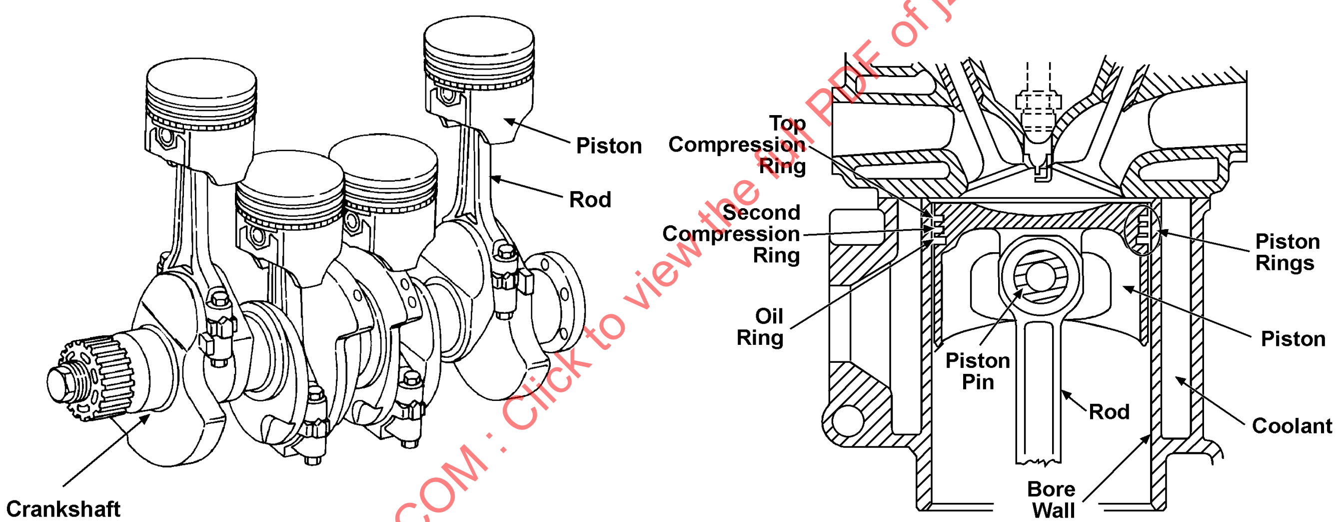

FIGURE 2 - POWER CYLINDER

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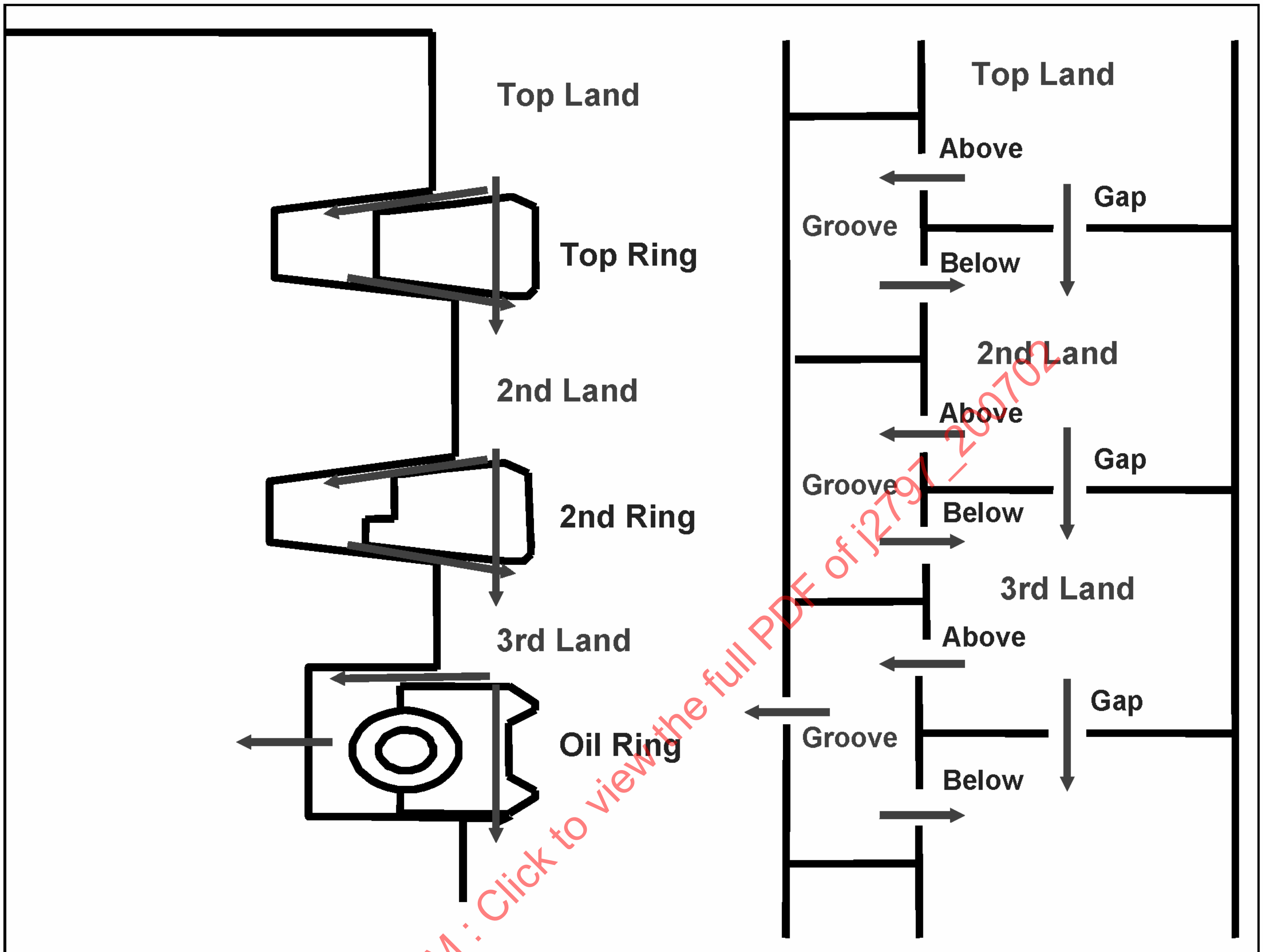

FIGURE 3 - RING PACK - ORIFICE/VOLUME MODEL

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5.1 Piston and Ring Pack

The piston and ring pack can be characterized as a series of volumes connected by orifices or flow channels through which the blow-by gases flow (See Figure 3). The gases from the combustion chamber are restricted by the rings. Gases accumulate between and behind the rings. The net flow out the bottom of the piston is the blow-by.

5.2 Piston

The gases flowing past the piston cause the blow-by of the engine. The piston must provide a seal in combination with the piston rings to block the flow of gases. The grooves and lands form locations where gases can accumulate. This accumulation will affect how the gases flow past the ring.

5.3 Top Ring

The top ring is the primary seal for the combustion gases and as a result has the most significant effect on blow-by. However, the top ring is the final obstacle before the oil is transported into an area where it can be consumed. Thus the top ring is also important for oil control.

5.4 Second Ring

The primary function of the second ring is to scrape the excess oil off the bore surface that passes by the oil ring. As a result it is very important for good control of oil consumption. However, the second ring seals the gases that flow past the top ring. Therefore, the effect that it has on blow-by is significant.

5.5 Oil Ring

The oil ring is not typically considered to have a significant effect on blow-by. However, gases must flow past the oil ring to enter the crankcase and the ring can restrict the flow. Therefore it is possible for the oil ring to affect blow-by but not control blow-by.

5.6 Cylinder Bore

The interaction of the piston and rings with the bore surface affects the gas and oil sealing of the cylinder. The conditions of the bore (temperatures, distortion, surface finish, etc.) need to be optimized for proper blow-by control.

6. OTHER EFFECTS ON BLOW-BY

There are other components and factors that can also significantly affect blow-by which are listed below. These are not discussed in detail in this document, but it is important to understand their influence when diagnosing blow-by problems or optimizing the blow-by of an engine. These other systems must be isolated in order to optimize or determine the blow-by contribution by the power cylinder system.

- Turbocharger
- Supercharger
- Cylinder Head Gasket
- Cylinder Head System (valve stem seals, seats, and guides)
- Air compressors

7. PISTON EFFECTS ON BLOW-BY

7.1 Piston Ring Grooves

7.1.1 Groove Type (Medium Effect)

Conventional wisdom is that rectangular ring grooves are better for oil and blow-by control. However in some cases keystone ring grooves are needed to prevent ring sticking, especially in diesel engines. If rings stick, they will lose their sealing capability.

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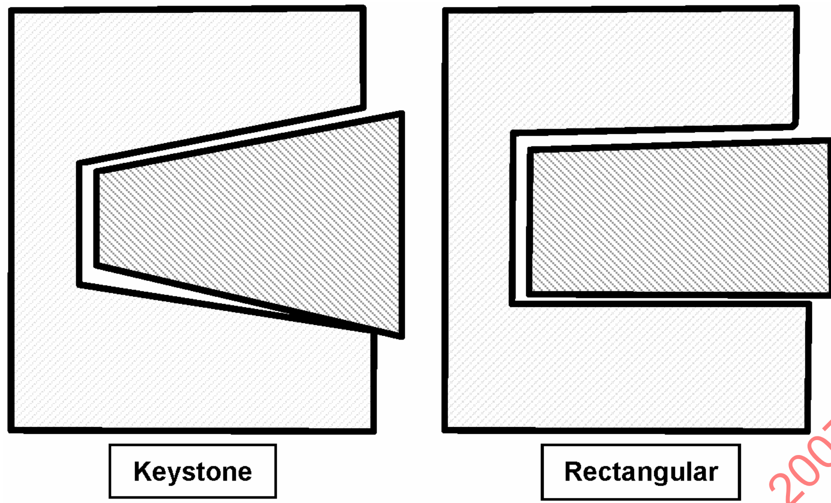

FIGURE 4 - TYPES OF RINGS AND GROOVES

7.1.2 Tilt (Minor Effect)

The uptilt of the ring groove is defined by the angle that a symmetrical ring groove will have relative to the horizontal.

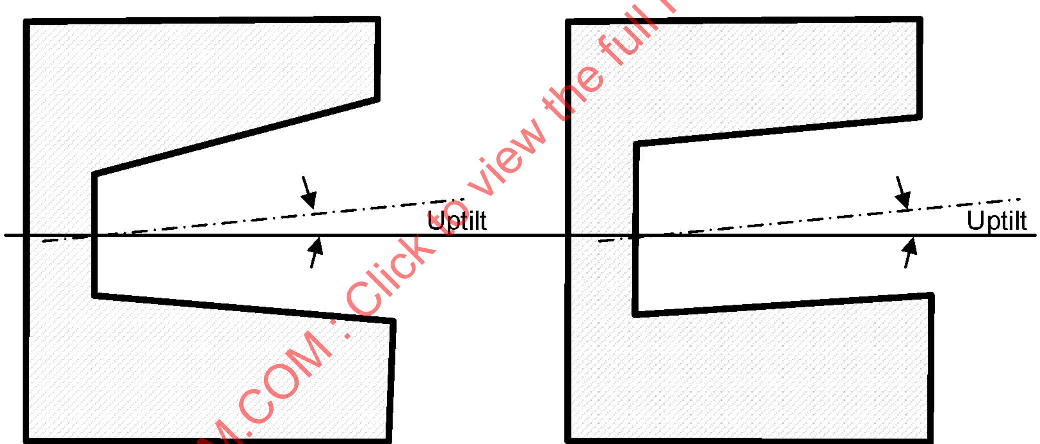

FIGURE 5 - GROOVE UPTILT

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Due to high temperature and pressures, it is possible that the ring groove will rotate downward. This arching effect will be more pronounced on the first ring groove. It is common to give the ring grooves a positive uptilt to compensate for this arching of the piston. Finite element models can be used to predict the extent of the piston arching so that the uptilt can be specified appropriately. To verify the prediction, the top ring face should have a wear track that is centered on the ring face after the engine has been run under high thermal conditions.

A negative tilting of the ring groove can cause ring to bore contact at the upper edge of the ring face. This contact can result in upward scraping of oil and increased blow-by.

Groove tilt and/or ring twist can be used to cause inner edge contact of the ring to groove to give better gas seal. Outer edge contact can allow gas under the lower side face of the ring and reduce the tendency to seal.

7.1.3 Waviness (Major Effect)

Circumferential waviness will affect how the ring will seal with the piston ring groove. Excessive waviness will create flow paths for oil and/or gases to pass by the ring. The circumferential length and the height of a wavy portion determine whether there is a leak path or not.

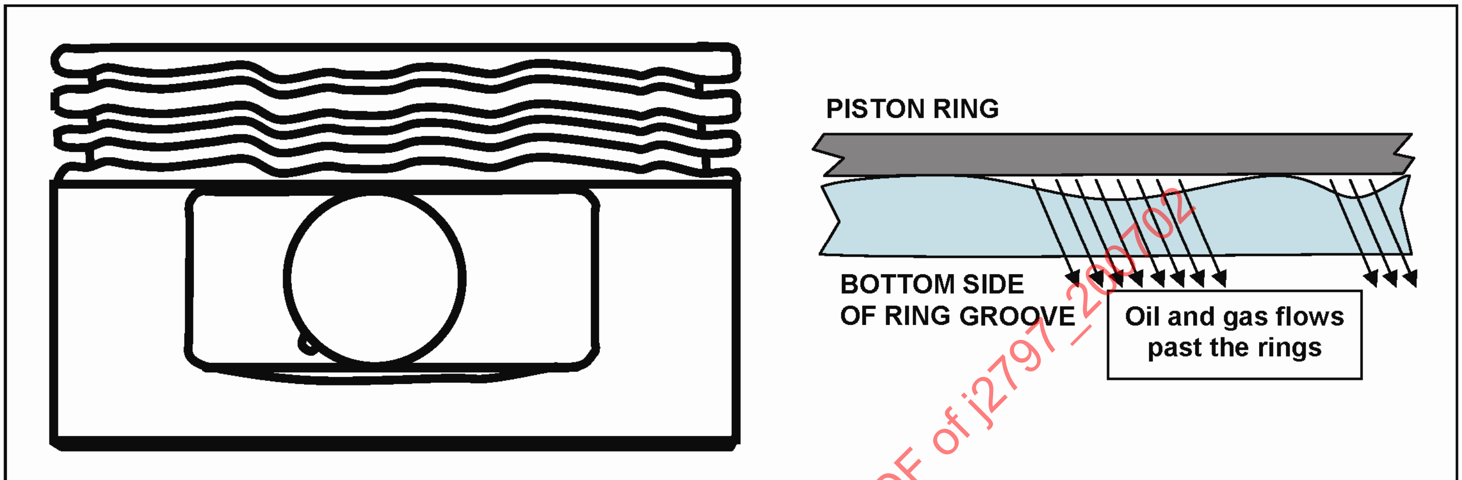

FIGURE 6 - GROOVE WAVINESS

7.1.4 Surface Conditions (Major Effect)

If the surface roughness or waviness is excessive, the ring will not seat properly with the groove. This will create passages through which oil or gases might flow.

The method in which a ring groove is machined can affect blow-by. It will affect how the gases may flow around the side of the ring.

Tool chatter produces peaks and valleys on the groove sides. Valleys interrupt the seal of the ring face to the groove face creating gas and fluid transport paths.

Coarse surface finish reduces ring/piston effective sealing area thereby reducing the transport pressure resistance of gases and fluids.

7.1.5 Chamfers (Medium Effect)

The outside diameter edge break on the bottom side of the ring groove can significantly affect blow-by and oil consumption (See Figure 7). If the edge break is too large, the gas flow area at the gap will be increased and affect the pressure balance of the ring-pack. Also the ring might twist down causing the ring to ride on the upper edge of the face.

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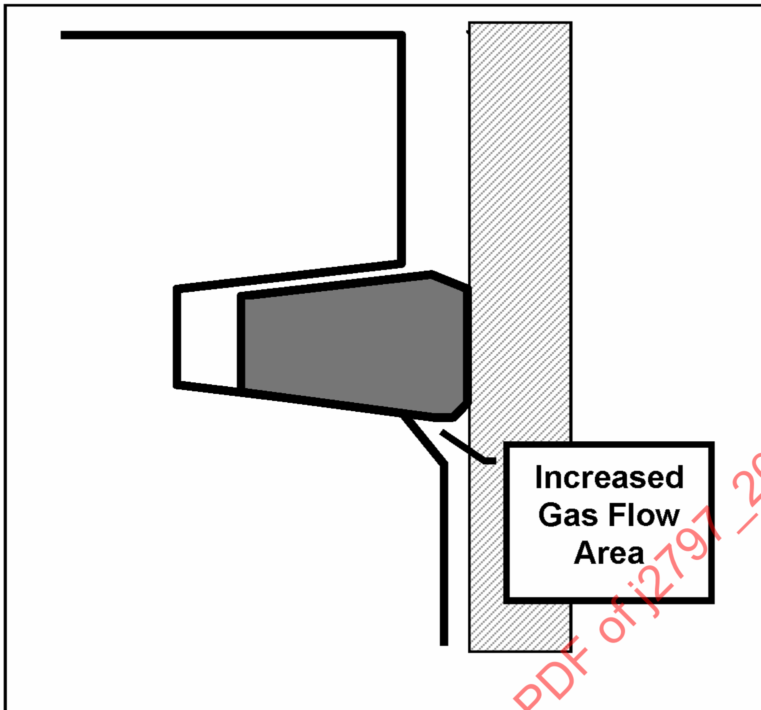

FIGURE 7 - EFFECT OF THE LARGE OUTSIDE DIAMETER EDGE BREAK

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7.1.6 Parallelism (Minor Effect)

For rectangular grooves, one side face must be symmetrical to the other and they must be parallel. Deviations from parallelism can contribute to sealing issues which provide gas and fluid transport paths.

7.1.7 System Effects (Major Effect)

The interaction of the groove with the ring is very important. How the ring seats with the groove and how it moves within the groove can have a large effect on the performance of the power cylinder system.

The clearances between the piston, rings, and bore can all significantly affect blow-by. These should be designed to provide the optimum dynamic control for the rings. But the system should be designed to allow reservoirs where oil and gases can collect in appropriate areas (e.g. the second land) to minimize blow-by and oil consumption. However there are inappropriate reservoir locations (e.g. volume behind the top ring) that should be minimized to prevent excessive blow-by or oil consumption. .

7.1.8 Ring Groove Material (Medium Effect)

The groove material or coatings on the groove can affect the wear of the groove. High groove side wear and ring side wear can increase blow-by.

7.2 Piston Lands

7.2.1 Diameters (Major Effect)

The regions between the rings determine volumes into which gases and oil flow in and out. The volumes in these regions will be affected by the diameters of the lands and the profiles on the land.

The interface between the land and the ring end gap will determine the gas flow path through the rings. Therefore, the diameter of the lands will affect the amount of gases flowing through the ring-pack.

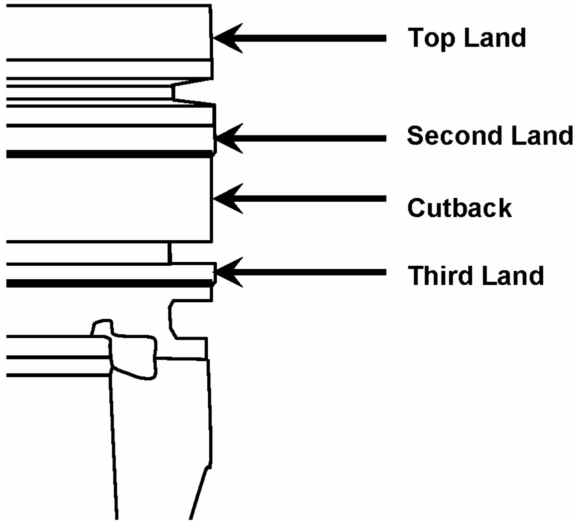

FIGURE 8 - LAND DIAMETERS

7.2.2 Piston Land Lengths (Medium Effect)

The length of the piston land will affect the volume between or below the rings for accumulating oil and gases. Therefore the length can affect oil consumption and blow-by.

7.2.3 Piston Land Profiles (Major Effect)

The profiles of the piston lands will affect how the blow-by gases flow and accumulate within the ring pack. Typically the top of the piston will have higher temperatures than the lower regions. Therefore the piston lands are typically profiled where the upper lands are cut back more than the lower lands to compensate for the higher temperatures.

Land profile can be cylindrical, tapered, balcony, or barrel shaped.

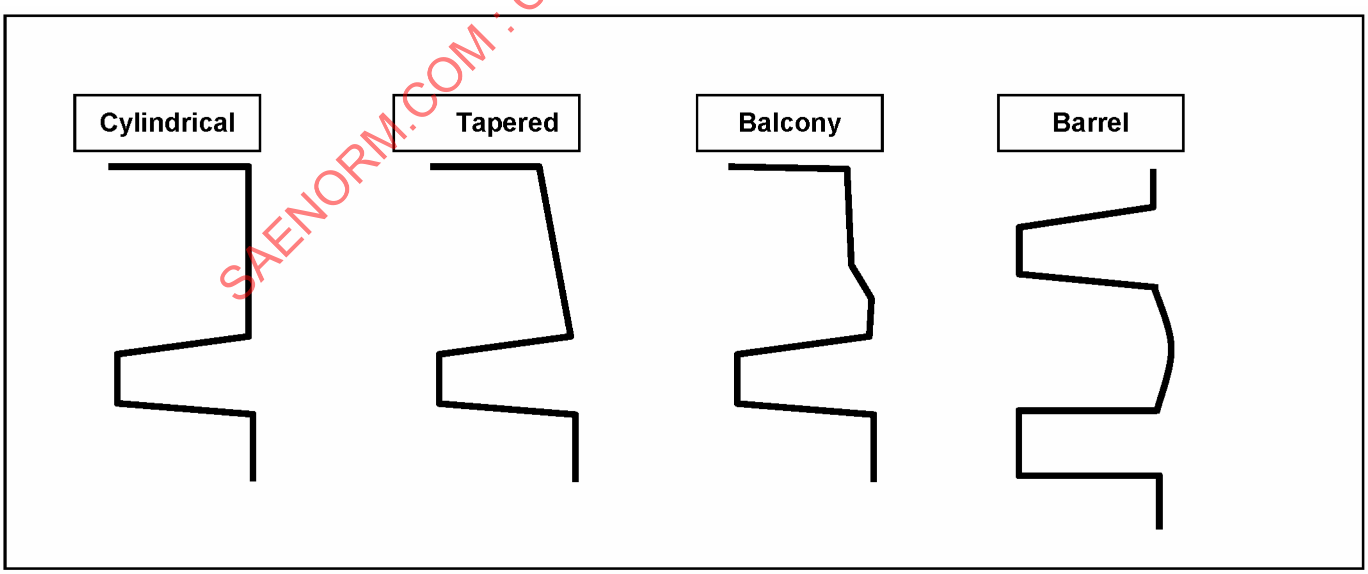

FIGURE 9 - LAND PROFILES

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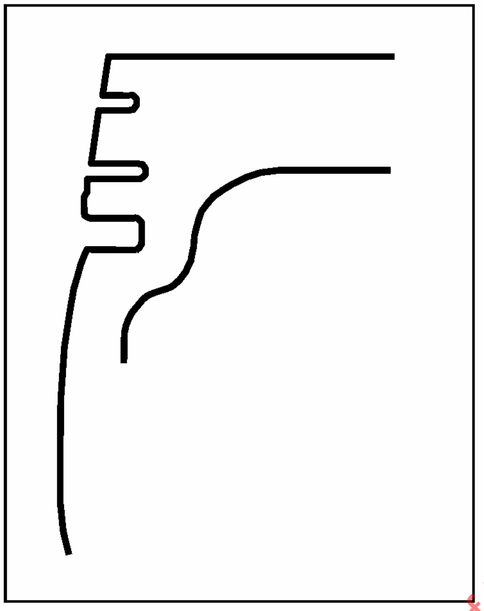

FIGURE 10 - LAND AND SKIRT PROFILE EXAMPLE

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7.2.4 Piston Land Circumferential Profiles (Minor Effect)

At times, ovality is necessary on the piston lands to compensate for the thermo-mechanical deformations of the piston and to enhance such things as scraped oil drainage and inter-ring gas pressure.

The bore will also deform into an oval shape during operation. The ovality of the piston should be chosen to help stabilize the piston in the oval bore. On an articulated piston, the second land is the guiding land and should have the appropriate ovality to stabilize the piston.

7.2.5 Piston Land Pressurization (Major Effect)

The top land will affect the pressure balance of the top ring. A tight clearance or a non-optimum profile might restrict the gas flow which seats the top ring. If the gas pressures cannot seat the top ring adequately, then the ring will flutter causing high blow-by and oil consumption.

Excessive pressure build up on the second land might force gases upward. If there is oil in the land region, this will cause high oil consumption and affect blow-by.

7.2.6 Piston Guidance by a Land (Minor Effect)

The piston may be guided by one of the lands depending on the piston design. An articulated piston will have one guiding land because of its design. The one piece piston is typically guided by the skirt but can at times have a contribution from a land. The profile of this land is important because it will interact with the oil film. Land profile can be cylindrical, tapered, balcony, or barrel shaped.

7.2.7 Accumulator Grooves (Medium Effect)

Some engines will have a large land diameter directly under the ring to restrict the gas flow. This is followed by cutback area or accumulator volume. Oil and gases can then accumulate in this region rather than migrate upward to the top ring. A large second land volume may decrease the second land pressure, enhancing the seating of the top ring. Typically, it will also reduce blow-by.

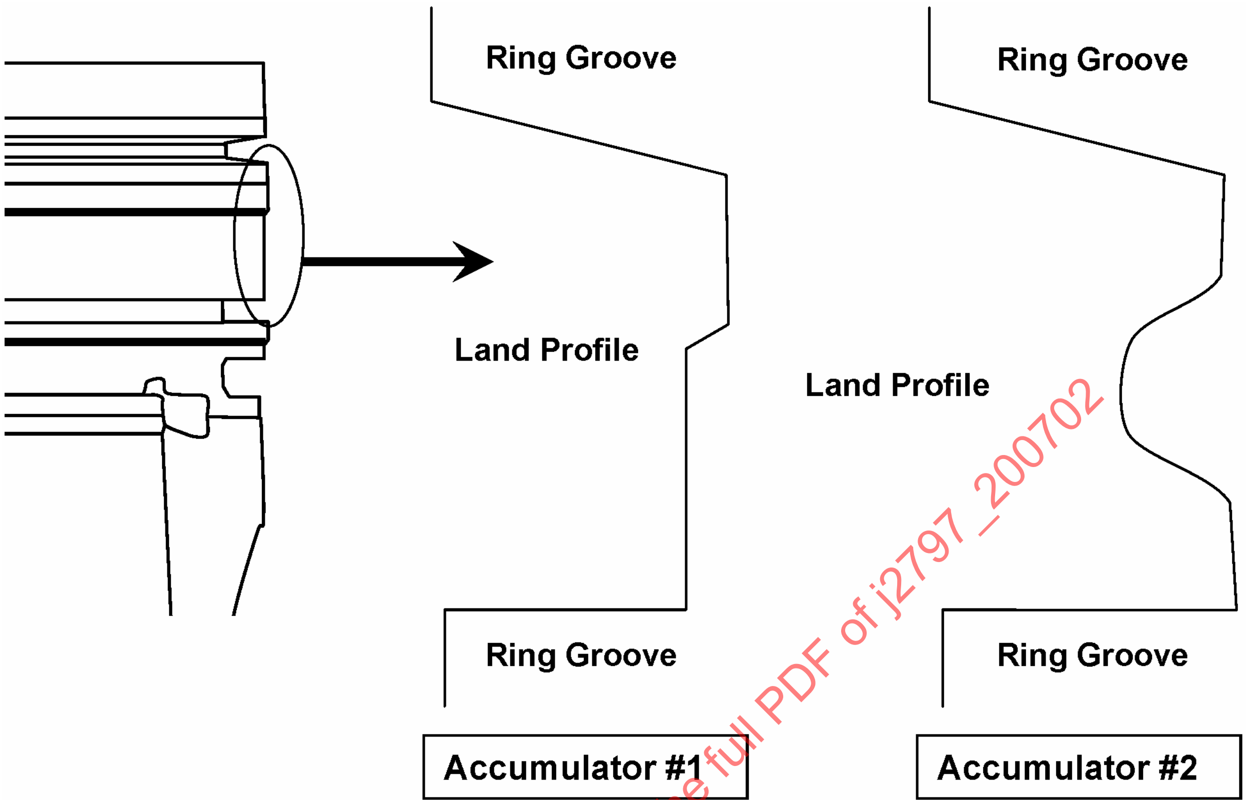

FIGURE 11 - LAND ACCUMULATOR GROOVES

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7.3 Oil Drain Features (Minor Effect)

Oil drain features on the piston may cause an increase in blow-by. Oil Drain features include oil drain holes, oil drain slots, and trans-slots.

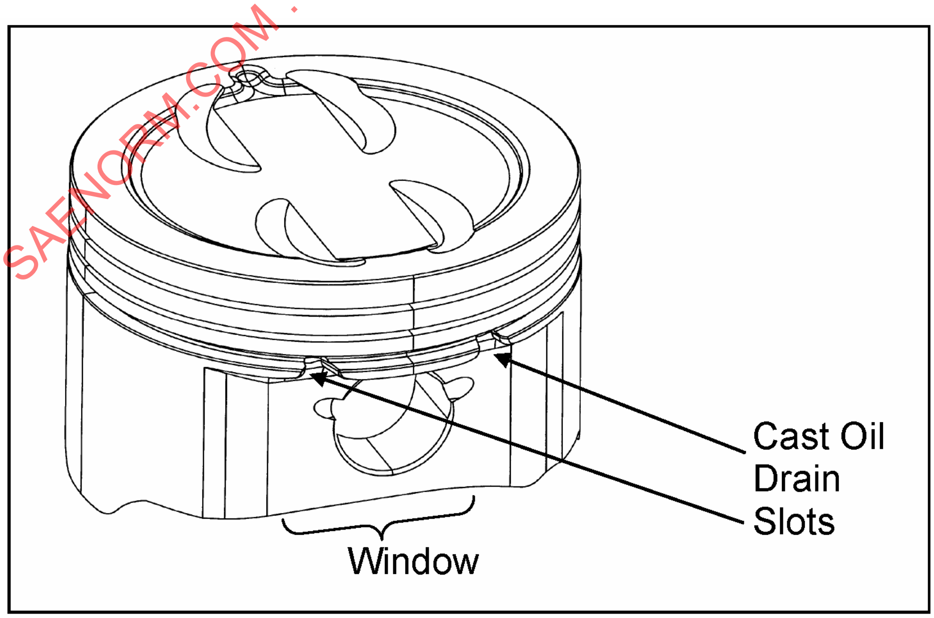

FIGURE 12 - OIL DRAIN SLOTS

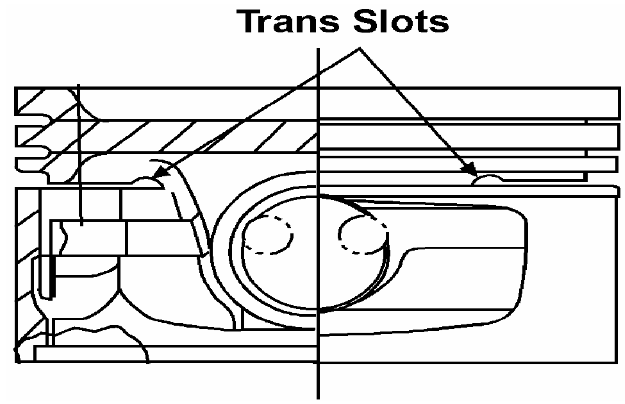

FIGURE 13 - OIL DRAIN TRANS SLOTS

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7.4 Piston Skirt

7.4.1 Piston Guidance or Piston Secondary Motion (Minor Effect)

The skirt will guide the piston in the bore. The stability of the piston and the resultant blow-by may be affected by how well the piston is guided by the skirt.

The stability of the piston is determined by the piston secondary motion or lateral/tilting motion in the cylinder bore. There are analytical models for this type of motion.

7.4.1.1 Pin Offsets (Minor Effect)

A piston pin offset can significantly affect how the piston moves within the cylinder bore.

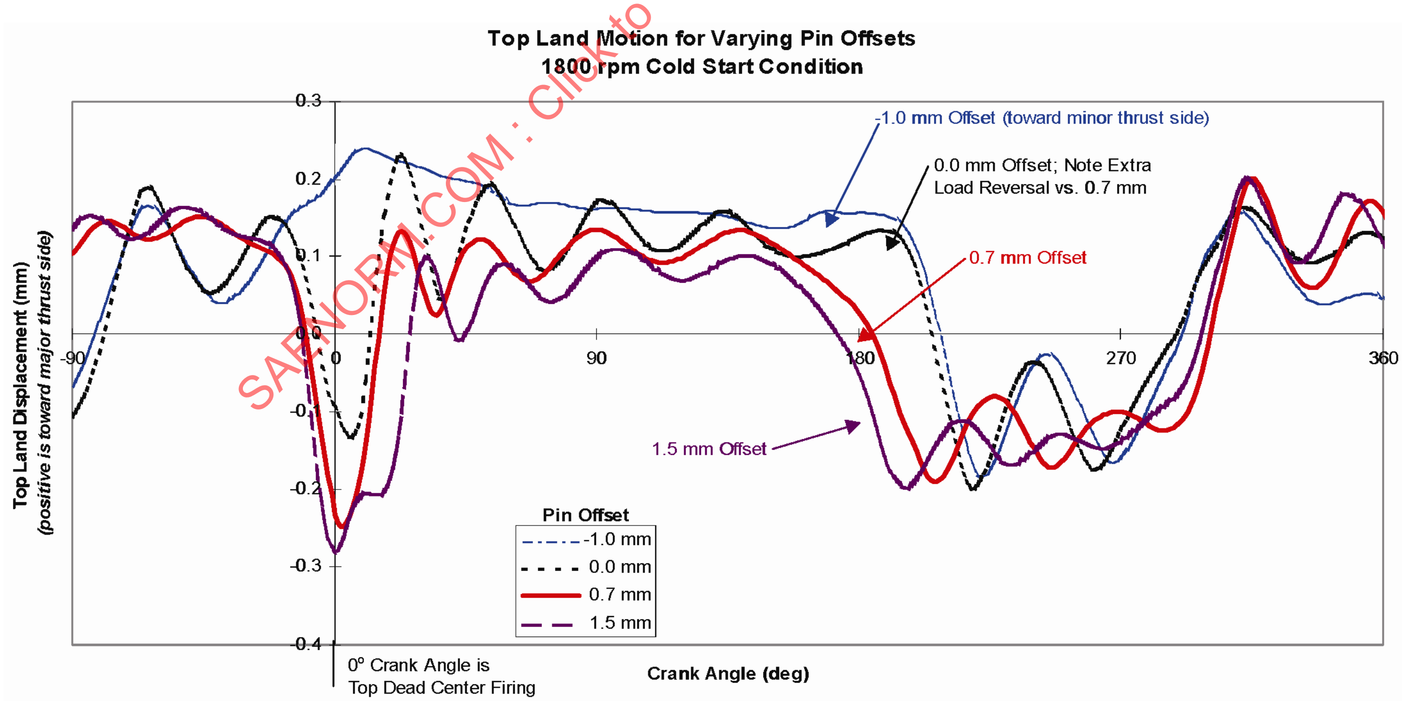

FIGURE 14 - EXAMPLE OF THE EFFECT OF PIN OFFSET ON PISTON MOTION

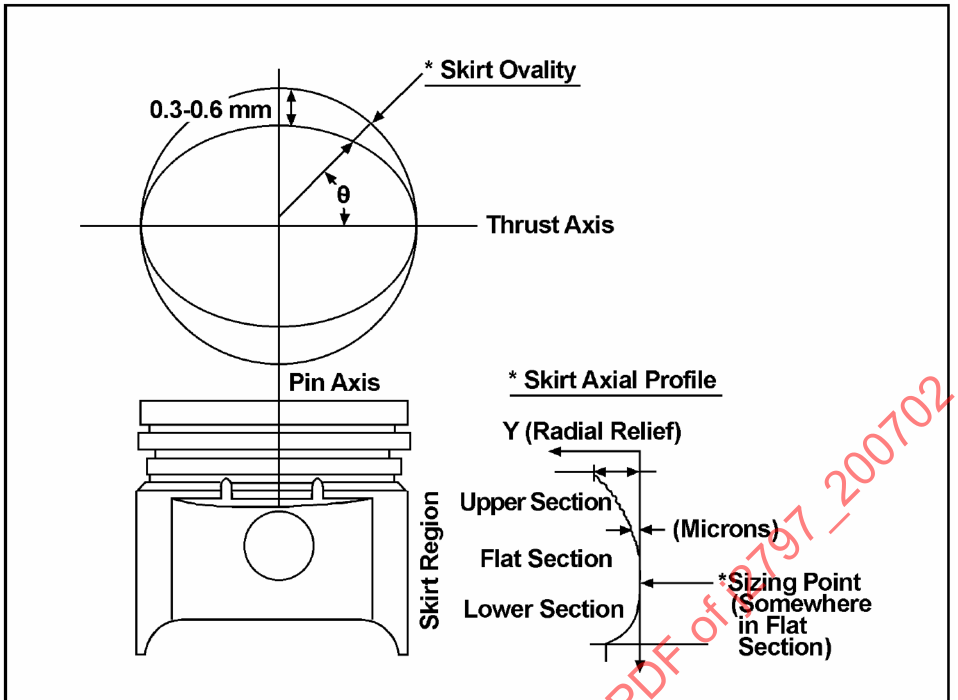

FIGURE 15 - PISTON PROFILES

7.4.1.2 Skirt Axial Profile (Barrel) (Minor Effect)

The axial profile of the skirt is designed to create good hydrodynamic lubrication with the bore to minimize contact wear while providing guidance for the piston to minimize secondary motion. Theoretically, if the skirt profile provides inadequate piston guidance, ring sealing can be adversely affected and increase blow-by.

The piston will typically be designed with an axial profile so that the diameter is larger in the lower regions of the skirt than at the top. This is done primarily to allow thermal expansion.

Piston profiles can also affect noise (croaking). Therefore, the profile needs to be designed for good piston stability, oil lubrication, and noise.

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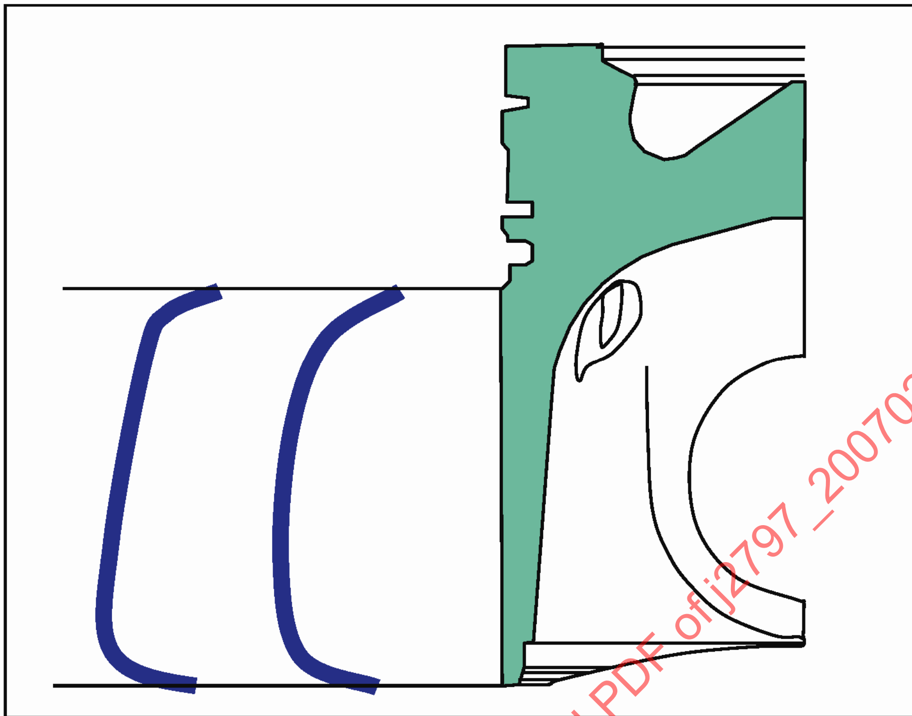

FIGURE 16 - SKIRT AXIAL PROFILES

7.5 Piston Cooling (Minor Effect)

7.5.1 Connecting Rod Spray

The piston may have a cooling spray under the crown of the piston or from the connecting rod. It also may have a cooling gallery. The way a piston is cooled will have a significant effect on the piston temperatures and as a result may have an effect on blow-by.

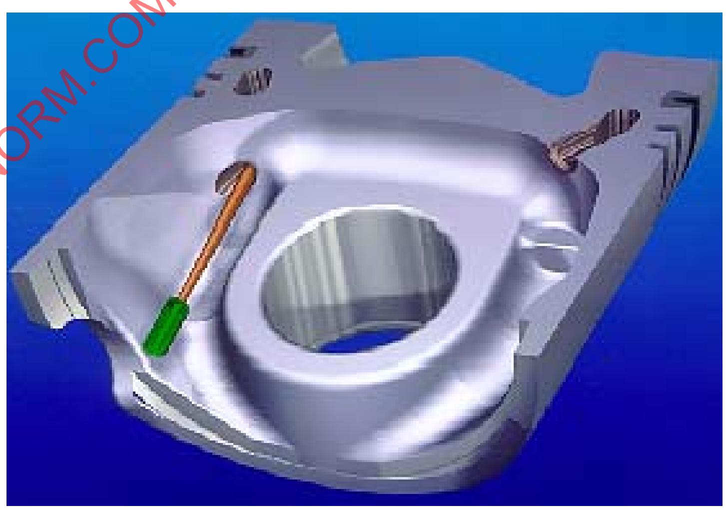

FIGURE 17 - GALLERY COOLED PISTON

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7.5.2 Piston Temperatures (Minor Effect)

Blow-by can be affected by piston temperatures in the following ways.

7.5.3 Piston Thermal Distribution

The piston thermal distribution should be addressed as a system to reduce incidences and effects of incorrect clearances, excessive wear or friction, carbon build up, and ring performance.

7.5.4 Carbon Build Up

Carbon can build up on the piston lands. This can cause polishing of the bore surface if the carbon bridges between the piston and bore. Excessive polishing will affect the ring face sealing and possibly blow-by.

7.5.5 Piston Temperature

Ring end gap and piston to bore clearance are temperature dependent. Better control of piston temperature permits the use of smaller clearances, resulting in lower blow-by.

8. RING EFFECTS ON BLOW-BY

8.1 General Piston Rings

8.1.1 Conformability (Major Effect)

The conformability of a piston ring (compression ring or oil ring) can have a significant effect on both oil consumption and blow-by. The ring must create a seal with both the cylinder wall and the piston ring groove. In the engine the cylinder walls will not be perfectly cylindrical because of machining imperfections, thermal distortion, and mechanical distortion. The piston grooves and also the ring itself will not be perfectly flat. The sealing ability of the ring will depend on its ability to conform to the distortions in itself and the mating surface.

8.1.1.1 Elastic Circumferential Conformability (Major Effect)

Conformability of the piston ring to the cylinder wall will be strongly influenced by the radial wall thickness of the ring and its circumferential shape. The circumferential conformability due to the elastic tension of the ring may be estimated by determining the elastic conformability factor of the ring:

$$k = \frac{F_t d_1^2}{EI} \qquad \text{(Eq. 1)}$$

Where:

k = Elastic Conformability Factor
F_t = Tangential Tension
d_1 = Bore Diameter
E = Young's Modulus
I = Moment of Inertia of the Cross-section

The higher the Elastic Conformability Factor (k), the greater ability of the ring to conform to the distortions of the cylinder wall. The oil ring is typically designed with the most conformability so that it can effectively scrape oil off the cylinder walls. Compression rings need to seal the combustion gases primarily and also provide oil sealing.

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8.1.1.2 Conformability to the Groove (Major Effect)

The conformability of the piston ring to the piston ring groove will be strongly affected by the axial width of the ring. A thinner ring will be able to conform better to the circumferential distortions of a ring groove when pressure is acting axially on the ring.

8.1.1.3 Conformability to Axial Distortion in the Cylinder Wall (Minor Effect)

The piston rings must also conform to the axial distortions of the cylinder wall. If there is an axial “bump” in the cylinder, the ring must travel over the “bump” and maintain contact at all times. If the ring is moving too fast and the tension of the ring is not sufficient then the ring might not be able to react and it could create a “jumping” effect of the ring. This may cause a temporary loss of sealing to the ring face.

8.1.2 Surface Conditions (Major Effect)

The surface conditions of both the side and face of the piston ring can significantly affect how well the piston ring will seal. Surface finishes that are too rough may result in high oil consumption especially on the sides of the rings. Sometimes a rough ring face is chosen for oil retention to improve scuff resistance. Unusual waviness or bumps may also cause the ring to lose its sealing ability.

8.2 Compression Rings

8.2.1 Ring Twist (Major Effect)

The twist of the ring affects the seating of the ring to the groove (Figure 18). A positive twist ring will promote back edge contact on the bottom side and is very effective at sealing gases. A negative twist ring will promote a front edge contact on the bottom side. This enhances the flow around the back of the ring and will generally increase blow-by. The axial force due to gas pressure that holds the ring down is also reduced.

The seating of the ring caused by the twist will have a major effect on blow-by. The negative twist second ring will have a tendency to flutter since the gas pressure force is reduced. This flutter will cause high blow-by, but conversely can lower oil consumption. Oil consumption is reduced since the downward flow is enhanced with the increased blow-by.

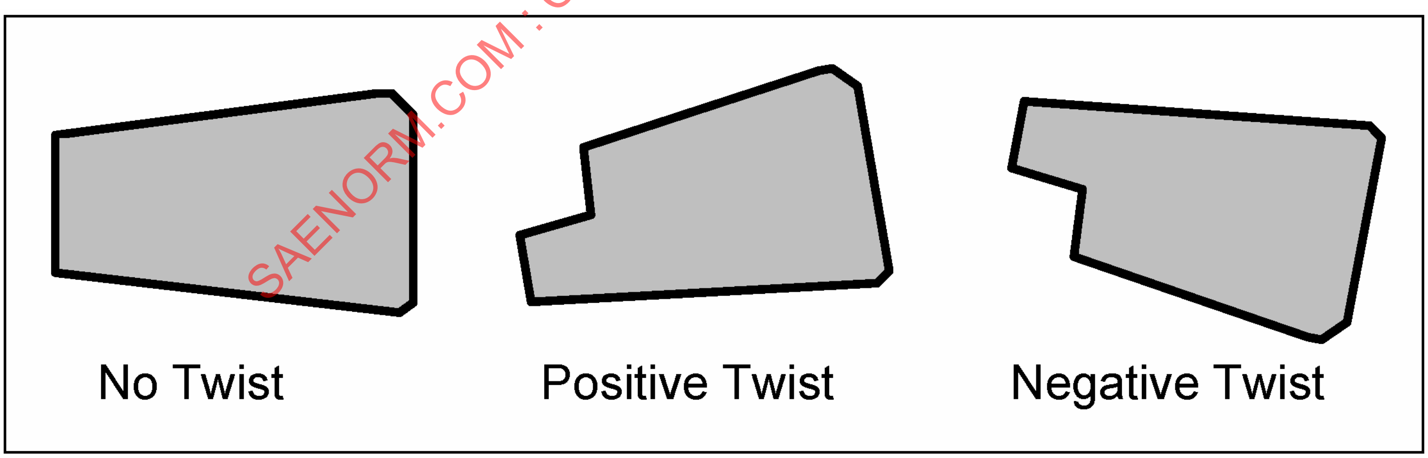

FIGURE 18 - RING TWIST TERMINOLOGY

8.2.2 Angles (Minor Effect)

Conventional wisdom is that rectangular rings are better for oil and blow-by control. However in some cases keystone rings are needed to prevent ring sticking, especially in diesel engines. Stuck rings will not conform to the bore and will allow leak paths for oil and blow-by.

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8.2.3 Closed Gap (Major Effect)

The closed gap of the ring form the main orifices through which the gases flow through the ring pack. This flow can be both up and down depending on the relative pressures above and below the ring. As a result this will significantly affect the blow-by and oil consumption.

8.2.4 Gap Ratios (Major Effect)

The ratio of the second ring end gap to the top ring end gap can significantly affect the performance and stability of the ring pack. As a result both blow-by and oil consumption will be affected. A proper balance between the two gaps needs to be determined to balance the effects on both blow-by and oil consumption. In general, the ratio of the second ring end gap to the top ring end gap is often two (2).

8.2.5 Ring Axial Width (Major Effect)

The width of the ring affects the top ring weight. In high speed engines this becomes a critical factor for top ring stability. At high speed operation, inertial forces may cause the top ring to lift early in the cycle. This will cause the top ring to flutter which will result in very high blow-by. Automotive engines which have high speeds and low cylinder pressures are more susceptible to this problem than diesel engines.

8.2.6 Ring Mass (Major Effect)

The mass of the rings is significant for the inertial forces acting on the rings. The mass of the rings will determine if the rings lift and flutter which can significantly affect blow-by and oil consumption. This effect is more significant with high speed engines.

8.2.7 Ring Circumferential Shape (Minor Effect)

Piston rings in the free shape are not round. The circumferential shape is designed to give specific contact pressures around the ring. This pressure pattern will affect how a ring will seal the oil and gases that might pass by the ring.

In some cases at room temperature, rings are designed with very low contact pressure near the end gaps. This is done so that at operating temperatures, there is uniform contact during operation.

Very simply, it is thought that the pressure exerted by ring on the cylinder should be constant around the ring periphery during operation. However, some suppliers will design the rings with a region of higher pressure in the region of 30° on either side of the end gap to promote "ring stability" and better blow-by control.

An example of the calculated circumferential ring pressure pattern can be seen in Figure 19.

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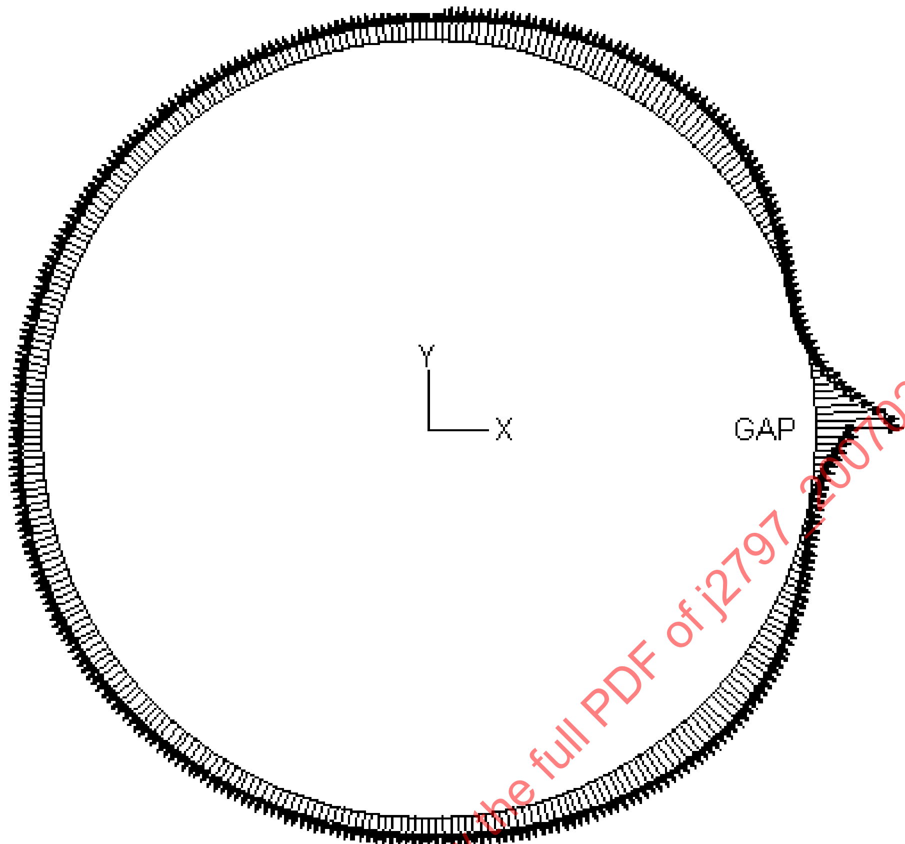

FIGURE 19 - EXAMPLE OF CALCULATED RING PRESSURE PATTERN

8.2.8 Ring Tension (Minor Effect)

The tension of the ring is the force required to close a ring down to the bore diameter or gage diameter for the engine (See Figure 20). This represents the force exerted on the cylinder bore. The ring tension affects the friction on the ring face and as a result can affect ring motion. The friction forces caused by tension of a compression ring are fairly small. However anything that can affect ring motion may affect blow-by and oil consumption.

In some engine configurations, if the tension of the ring is not high enough the ring might radially collapse inward. This will result in a loss of sealing on the face of the ring.

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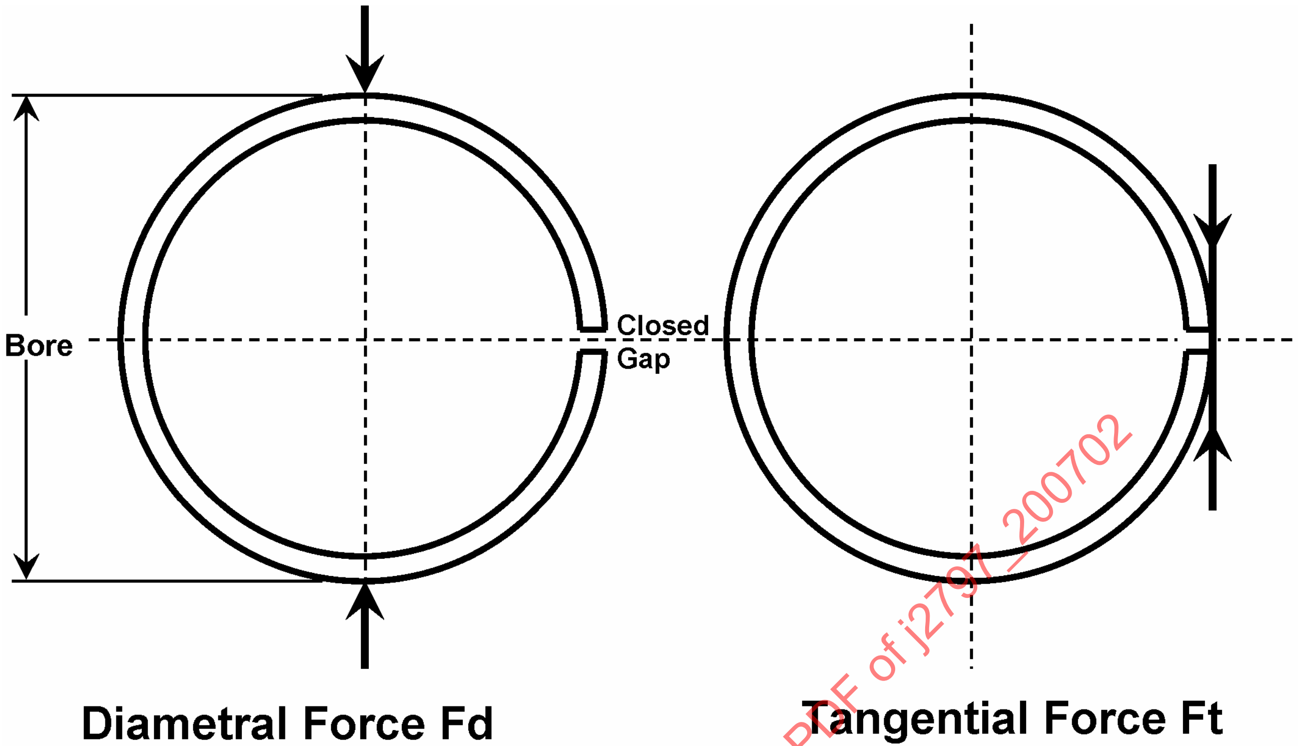

FIGURE 20 - ILLUSTRATION OF RING TENSION MEASUREMENTS

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8.2.9 Face Profile (Minor Effect)

The profile of the ring face will determine the oil film that is built up between the ring and the liner. Each ring will have different profiles for different purposes.

8.2.9.1 Top Ring Face Profile (Medium Effect)

The top ring face will typically be barrel shaped. The top ring bears the high cylinder pressure and must be designed to develop an adequate oil film to not have excessive wear. A ring with a large barrel drop will tend to build larger oil films at mid-stroke but these films will break down easier at the ends of the stroke. Conversely a ring with small barrel drop will not develop as thick oil films at the mid-stroke but will result in thicker oil films at the ends of the stroke because of the squeeze film effect.

An offset barrel towards the bottom side of the ring face is sometimes used to promote oil scraping downward. Also, the higher barrel drop on the top side will allow high pressures to act on the face of the ring and counteract some of the net pressure acting on the ring. Therefore the wear will be reduced while benefiting blow-by.

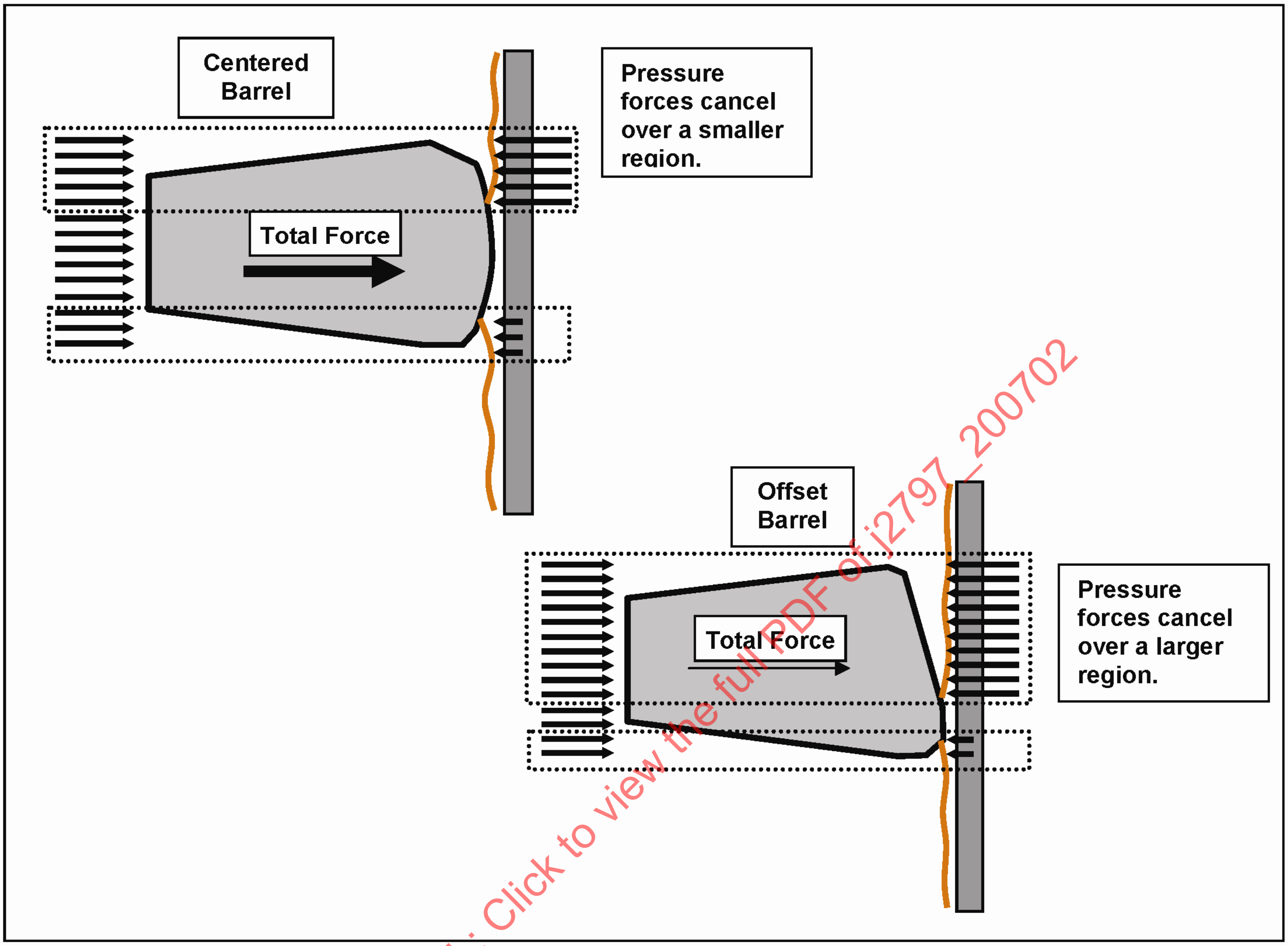

FIGURE 21 - EFFECT OF FACE PROFILE ON NET FORCE ACTING ON THE RING

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8.2.9.2 Second Ring Face Profile (Major Effect)

The second ring is not exposed to the high cylinder pressure so a ring with a more aggressive oil scraping role can be used. The taper is designed to scrape oil as the ring moves down in the stroke and ride over the oil films on the way up. The purpose for this design is the net effect of scraping oil down away from the top ring.

A stepped or napier face ring will have higher blow-by because of the increased gas flow area between the piston ring and piston ring groove at the ring gap. It is possible to use an "interrupted" cut design so that there is no cut-out at the gap. This will maintain low blow-by with the enhanced scraping ability of the ring face.

Another alternative in the stepped or napier face design is to make a very small cut out region. This "micro napier" design will minimize the increase in gas flow area caused by the cut out.

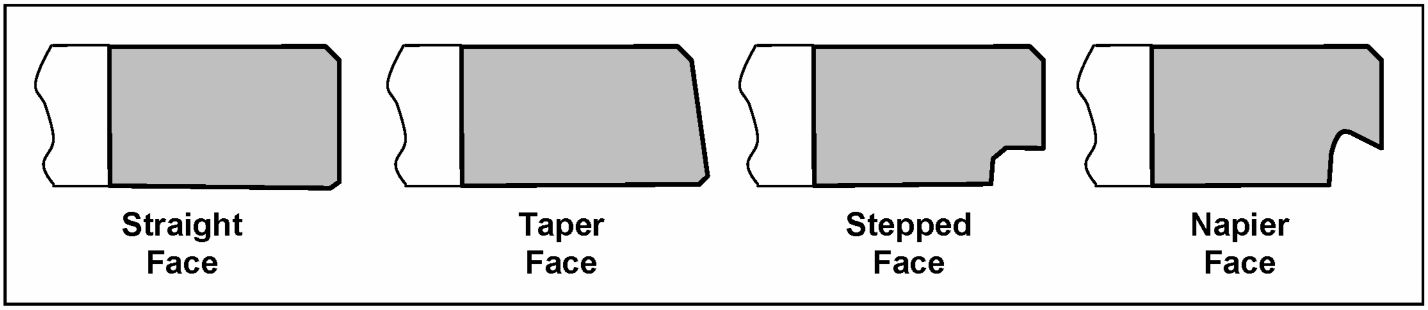

FIGURE 22 - SECOND RING FACE PROFILES

8.2.10 End Gap Chamfer (Major Effect)

The end gap chamfers of the rings help to form the orifice through which gases flow. Therefore this can affect the build-up of pressures between the rings and thus blow-by and oil consumption.

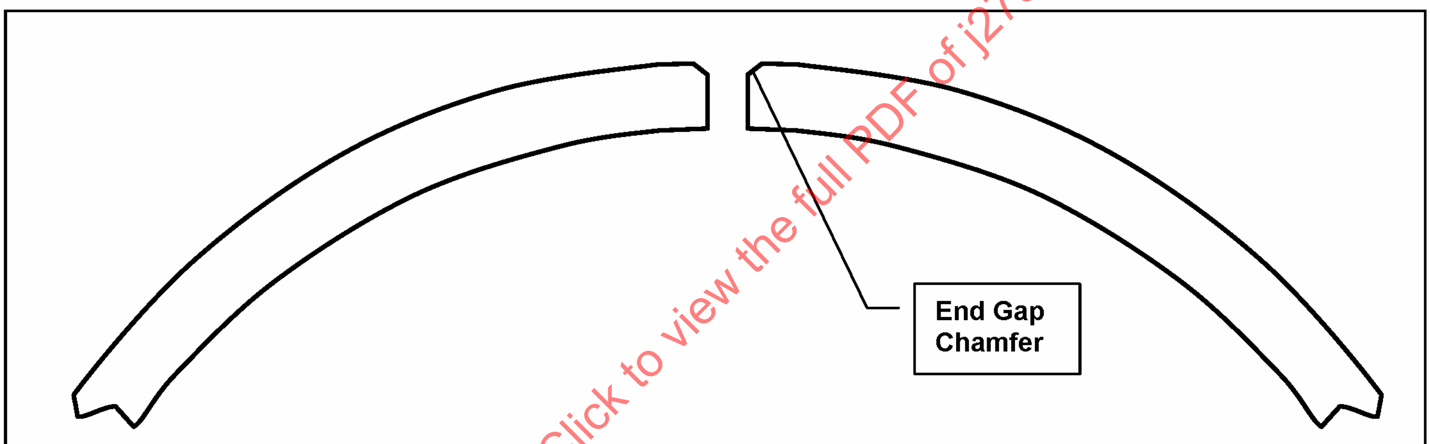

FIGURE 23 - END GAP CHAMFER

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8.2.11 OD Chamfers (Minor Effect)

The bottom outside diameter chamfer on the ring face also affects blow-by and oil consumption. It is important that the chamfer be kept as small as possible.

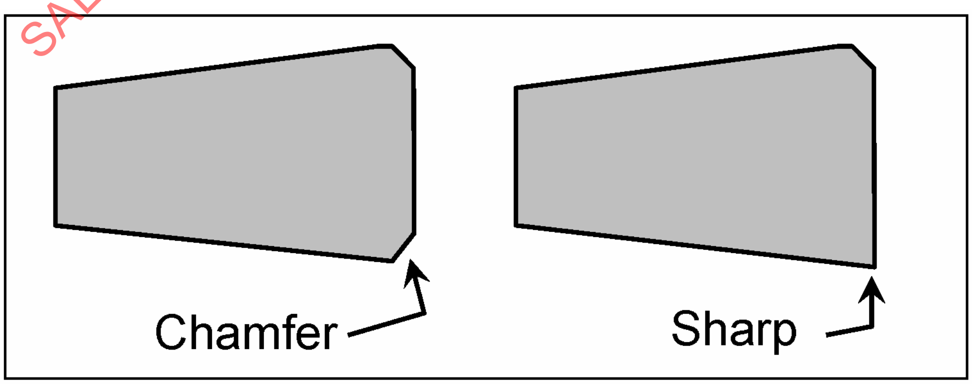

FIGURE 24 - SCHEMATICS OF BOTTOM SIDE OD CHAMFERS

Figure 25 shows different types of ring coatings. Typically, it is possible to get a sharper bottom outside diameter chamfer on rings with the semi-inlaid or inlaid coatings. The "inlaid" processing easily accommodates the sharp bottom corner because the bottom edge is the base iron material. If a coating is on the lower edge a larger chamfer is typically required.

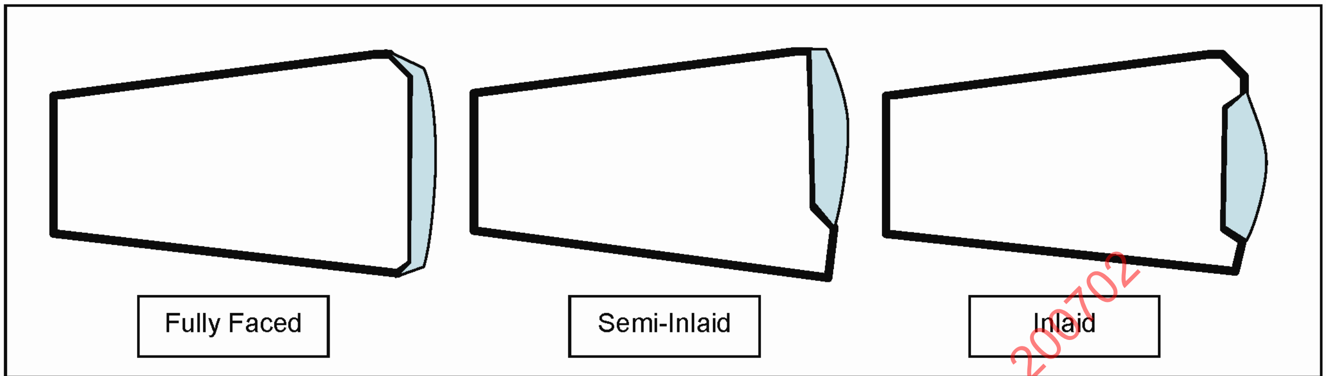

FIGURE 25 - RING COATING APPLICATION EXAMPLES

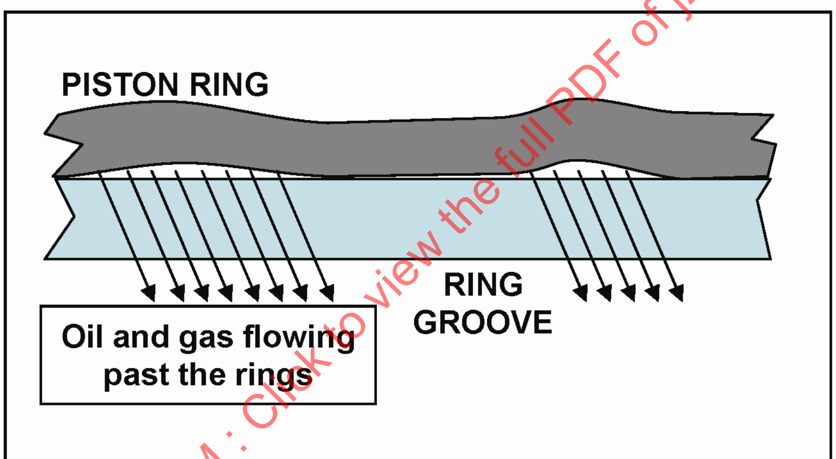

FIGURE 26 - WAVY RING EXAMPLE

8.2.12 Waviness (Chatter) (Major Effect)

Circumferential side face waviness affects how the ring seals with the piston ring groove. Excessive waviness will create flow paths for oil and/or gases to pass by the ring. The circumferential length and the height of a wavy portion determine whether there is a leak path or not. Waviness may be caused by chatter distortion of the piston during the machining operation of the grooves. Chatter is caused by vibration or stick-slip during machining

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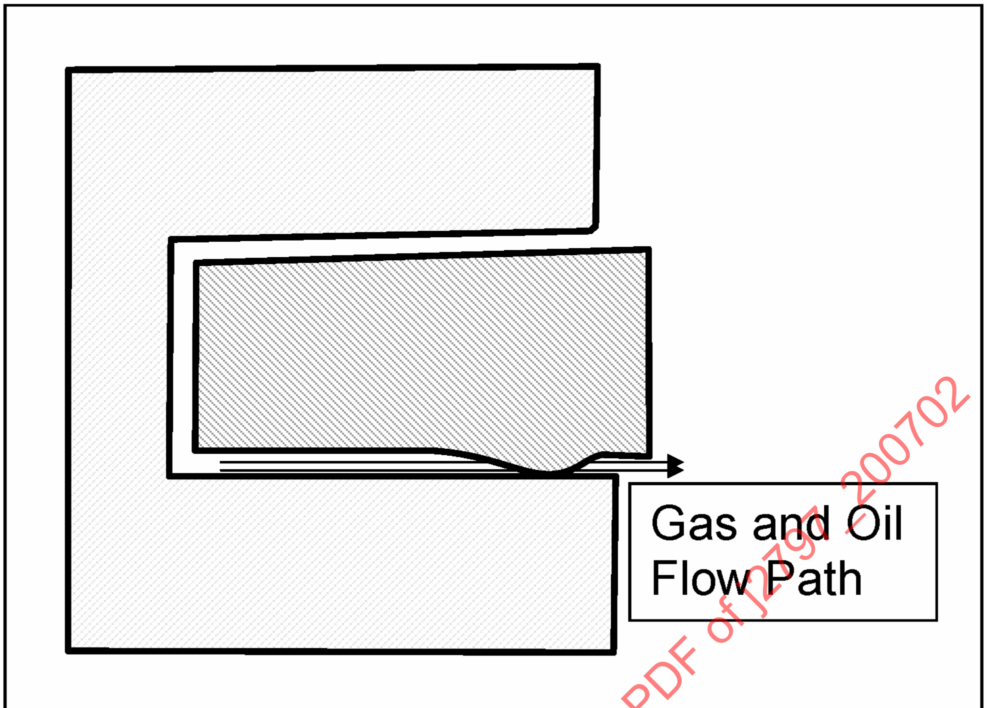

FIGURE 27 - RING STRAIGHTNESS EXAMPLE

8.2.13 Straightness (Medium Effect)

If the bottom side is not straight, oil and gas leakage flow paths may be formed.

8.2.14 Roughness (Medium Effect)

If the surface roughness or waviness is excessive, the ring will not seat properly with the groove. This will create passages through which blow-by gases might flow.

8.2.15 System Effects

The interaction of the groove with the ring is very important. How the ring seats with the groove and how it moves within the groove can have a large effect on the performance of the system.

8.3 Ring Materials (Medium Effect)

8.3.1 Base Material (Minor Effect)

The ring base material will affect side wear. Excessive side wear of the ring or groove can result in high blow-by. Excessive wear can also result in ring breakage.

8.3.2 Face Coating Material (Medium Effect)

The ring face material and its compatibility with the cylinder bore material will affect wear of the face of the ring and the cylinder bore. This could have a significant effect on how the rings operate and affect blow-by. A good wear couple needs to be chosen to prevent excessive wear and a corresponding increase in blow-by.

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8.4 Oil Control Ring

8.4.1 General Oil Ring (Minor Effect)

The oil ring typically does not have a major effect on blow-by. However, there are characteristics that can affect blow-by.

8.4.1.1 End Gap Width (Minor Effect)

The end gap of the oil ring might affect blow-by. This effect might be more significant with three piece oil rings that have positive side sealing than two piece oil rings. This is because the a ring with positive side sealing may be blocking gas flow around the ring, therefore the flow of gases is controlled through the end gap..

8.4.1.2 Interactions with the Ring Groove (Minor Effect)

The interface between the ring groove and the oil ring can affect how the blow-by gases flow around the ring. A wavy groove or wavy ring side will not seal gases effectively allowing oil to flow around the sides of the ring and increase blow-by. This effect is more pronounced with a three piece oil ring that has positive side sealing.

8.4.2 Two Piece Oil Ring

A two piece oil control ring is typically used by diesel engines and in some gasoline engines. The two pieces are the body of the oil ring and the spring expander. Friction and inertia will tend to drive the two piece oil control ring to the top side of the ring groove around top dead center firing. Gas pressures will force the ring downward. This results in a fluttering type of motion in which there is very little gas sealing. Therefore the effect of the two piece oil ring is very small on blow-by.

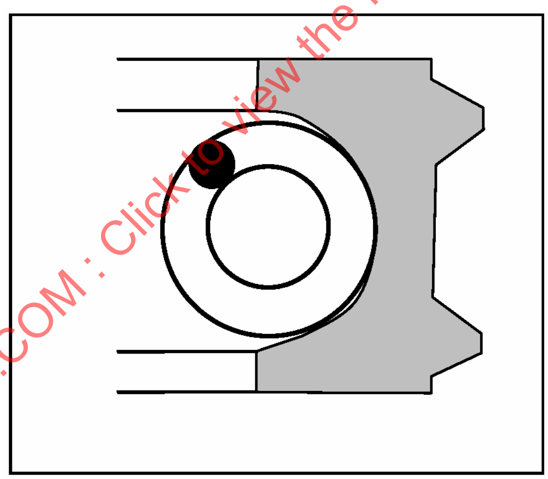

FIGURE 28 - TWO PIECE OIL RING

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8.4.3 Three Piece Oil Ring

The three pieces of this type of ring are two rails and an expander spring. The expander spring has the effect of not only pushing the two rails radially against the cylinder wall but may also push axially against the ring groove depending on the lug design. This has the advantage of sealing both sides of the ring actively to the groove as well as the cylinder wall. When a three piece oil ring has active or positive side sealing, the ring has a larger effect on blow-by than the two piece oil ring. The amount of positive contact between the sides of ring and the groove are dependant on the lug angle.

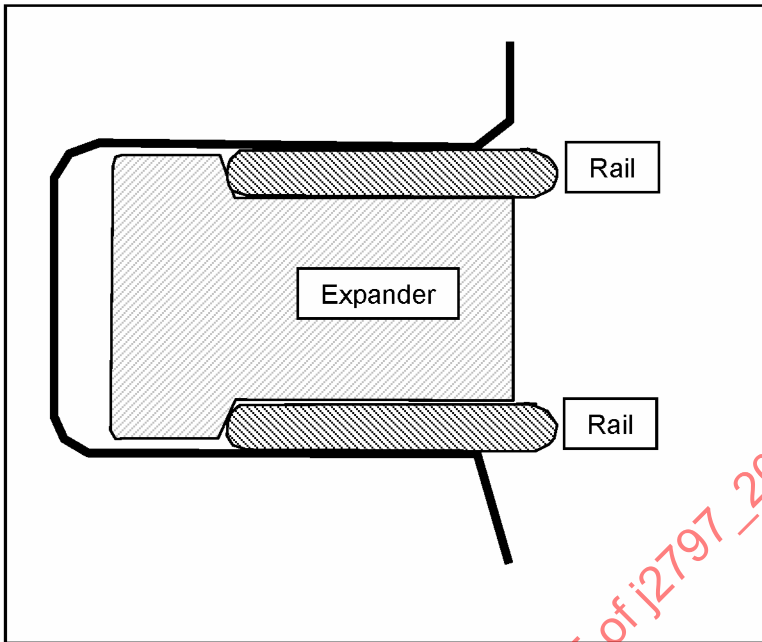

FIGURE 29 - THREE PIECE OIL RING

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8.4.3.1 Gap Alignment of the Rails (Minor Effect)

If the gaps of the two rails on a three piece oil ring are aligned, it will create a direct flow path for gases and result in high blow-by. Therefore when assembled the gaps should not be aligned with each other. Typically they are installed 180 deg apart (or greater than 30 degrees apart).

8.4.3.2 Rail and the Oil Drain Slot (Major Effect)

It is possible for the oil ring rails to get caught in the oil drain slot of the ring groove. This may result in high blow-by and should be avoided in the design.

8.4.3.3 Spacer Design - Lug Angle (Major Effect)

The rails of the three piece oil ring may be made to push directly on the sides of the ring groove and seal oil. The groove must be designed to be compatible with this design. The lug angle determines the amount of force that the rails apply to the sides of the oil groove. The force will affect how the ring seals the flow of gases and oil around the sides of the ring and will thus affect blow-by.

8.4.3.4 Engine Speed

The three piece oil ring may perform better than a two piece oil ring under high speed operation or high vacuum conditions. The high inertial forces might induce instabilities in the two piece design. Because of the positive side forces on the three piece oil ring, the ring will be more stable.

9. CYLINDER BORE EFFECT ON BLOW-BY

9.1 Cylinder Bore Surface Finish (Minor Effect)

The surface finish of the cylinder bore and honing patterns affect the sealing ability of the ring face to cylinder wall.