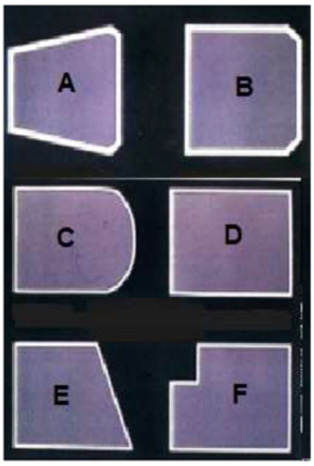
KMP BRAND TECHNICAL BULLETIN

Piston Ring Failures

KB-15005

The purpose of this bulletin is to illustrate the possible types of damage that could occur when piston rings are subjected to abnormal operating conditions.
So are the piston rings a critical component ?
Most definitely, they are not only there to control the escape of combustible gases from entering the crankcase, a ring group also stabilises the piston as it moves up and down the bore, minimising the chance of point contact on the piston top land and lower skirt.
In addition they also conduct approximately three quarters of the heat in the piston into the liner/cylinder bore besides controlling the engine lubricant which is travelling in the opposite direction; all this with the minimum amount of contact force.
Obviously a single piston ring would be unable to fulfil all these requirements by itself so over the years there have been a number of different individual ring designs, these were introduced in response to particular characteristics or problems in an engine or the piston design.



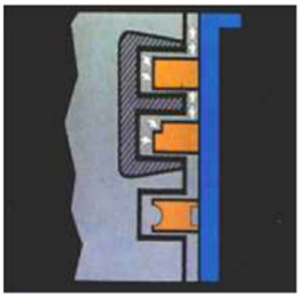
The compression rings are either of the keystone design (A) or rectangular (B) and are normally made from heat treated ductile (nodular) cast iron although in some applications steel could be used.

There are also various ring face finishes and combinations, the barrel face (C), flat face (D), taper face (E), and the torsional twist or stepped ring (F).

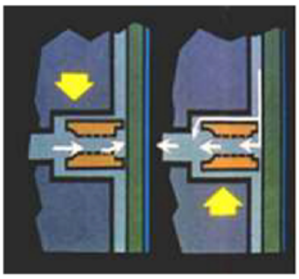
The barrel face is the favoured finish for the top compression ring because it beds in quickly and controls the oil flow more effectively and the keystone shape tends to prevent the ring from sticking in the groove.

The second compression ring serves a dual purpose because not only does it seal off any escaping combustion gases that bypass the top ring, it also assists the oil control ring by scraping off any excess oil that has not been removed by the faces of that ring.

The oil control ring can consist of one, two or even three components and as the name implies the purpose is to remove any excess oil from the bore and return it through the piston back into the crankcase.



In addition to the tangential force which is manufactured into the compression rings, the rings require the combustion gasses to force them downwards onto the ring grooves and outwards against the liner bore.



The oil rings are forced outwards against the liner bore by means of an expander spring, which is specifically designed to allow the correct amount of oil to remain on the liner surfaces.

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PISTON RING GAPS

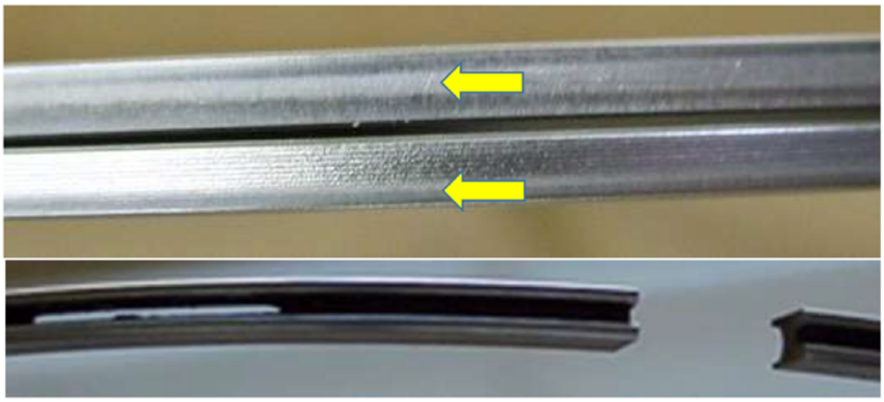
Some users express concern that the rings are not to engine manufacturer's specification with regard to the ring gaps.
The concern being that if the gap is too large the combustion gases and the oil will pass through the gap, therefore the gap must be as small as possible to prevent the blow-by and oil consumption.
The important point to remember is that the manufacturer makes the gap to suit the **fitted gap at operating temperature.**
There are a number of factors to consider when the ring manufacturer pre-gaps the ring, namely the material used, the thermal expansion of that material, the ring location on the piston and the nominal bore size.
There are possible instances where the gaps may vary from other manufacturers rings because of the selection of materials and surface treatments.
Research has indicated that as long as the bore is correctly sized and finished, the ring grooves are sized and finished correctly, then a new ring on a new piston in a new bore will not create blow-by or oil consumption, even if the ring gap is slightly larger than that specified by the original engine manufacturer.

RUNNING-IN

As previously mentioned it is the combustion pressure which assists the compression rings in forming a satisfactory seal/seating against the liner bore and this can only be achieved by loading the engine once all the preliminary checks have been carried out.
Obviously a dynamometer test is the most effective way of achieving this because everything can be controlled and monitored, but this is not always feasible; so as long as the engine is loaded with about 75% of the full load for at least four hours, this should be sufficient to obtain satisfactory ring seating.

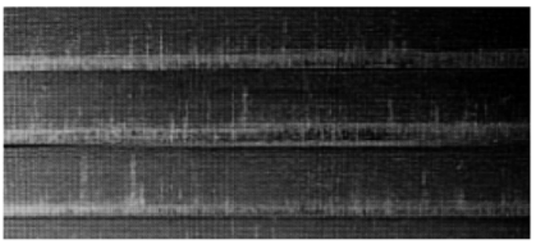
FAILURES AND THEIR POSSIBLE CAUSES

The photographs below show the appearance of three new rings, a barrel faced top compression ring, a scraper second compression ring and the oil ring; the arrows indicate the lapping marks on the ring faces which assist with a more rapid seating of the rings.



As it is with many other engine components the biggest contributor to failures is **abrasive contamination**.

The appearance of three oil rings which have been considerably worn by abrasive contamination.



Three second compression rings worn by abrasive contamination.

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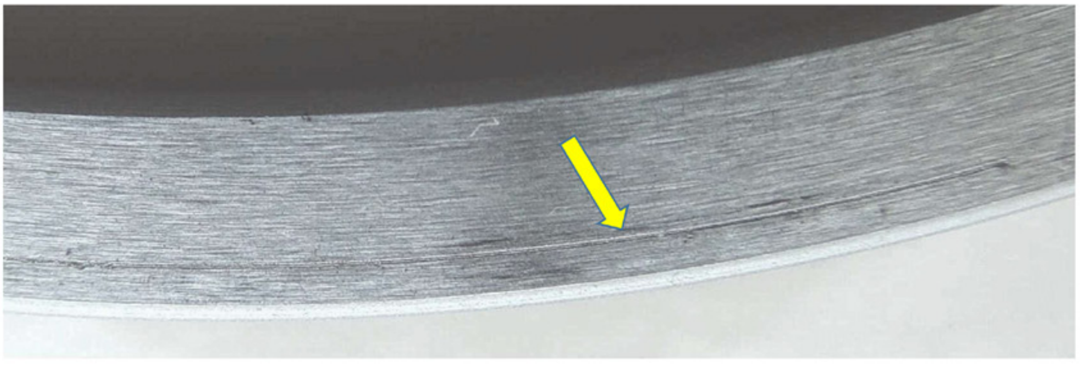
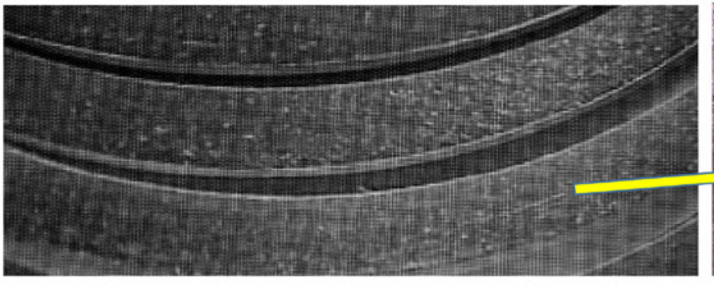
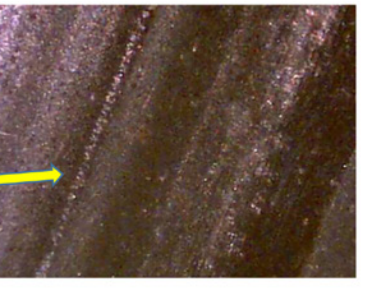
In addition to the wear exhibitted on the outer ring faces there will also be evidence that abrasive particles were also trapped between the lateral ring face and the face of the piston groove.





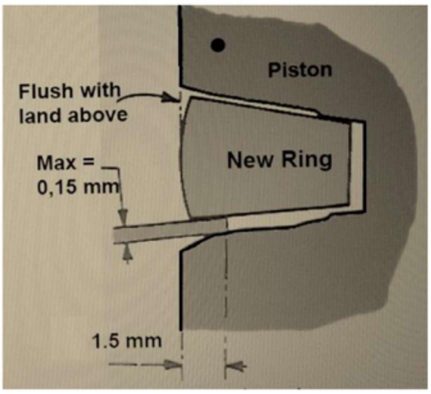


The bore of the liner as well as the piston skirt will also exhibit evidence that abrasive contamination was present whilst the engine was operating, refer to the photographs above.

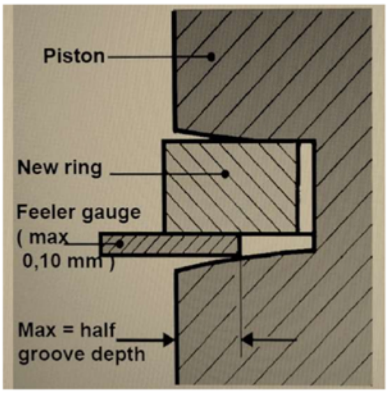
The contamination could have originated from a number of sources, either from the air intake system as a result of damaged or poorly fitted pipes, air filters not serviced at the correct intervals or not correctly seated when installed, lack of cleanliness during the assembly process, extended oil/filter servicing or careless practice when conducting the oil servicing.

Wear above the oil ring tends to indicate that the contamination entered from the air intake, whereas wear below the oil ring is an indicator that contamination was probably from the oil.

If abrasive wear has been diagnosed as the cause of the failure then it is imperative that the ring grooves are checked for wear to establish that they are still within specification prior to installing the new rings.



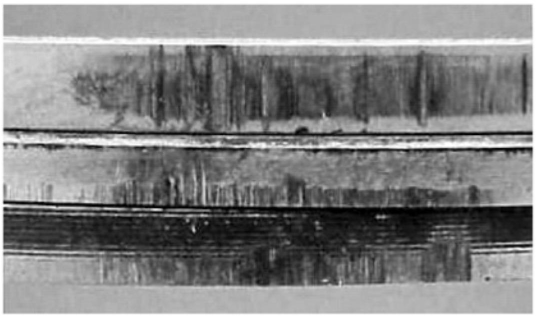
KEYSTONE RING AND GROOVE



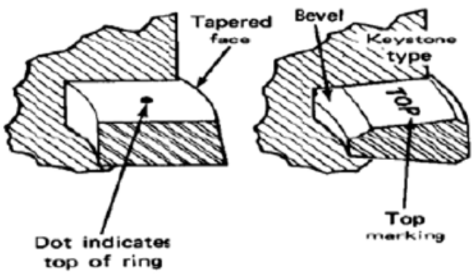
RECTANGULAR RING AND GROOVE

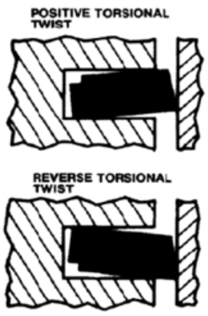
Ring scuffing is something that occurs when the oil film between the ring face and the liner bore is insufficient and as a consequence there is metal transfer/adhesion between the two surfaces.
There are a number of possible causes for this phenomenon – lubrication system, cooling system or fuelling system, any irregularity in any of the systems could have resulted in the scuffing/scoring of the ring faces.

- Lubrication – worn or defective oil pump, faulty/defective oil relief valve, blocked screen or oil gallery, bearing clearances incorrect, low oil level, incorrect grade of oil or a blocked/misaligned piston cooling nozzle.
- Cooling – low coolant level, faulty thermostat, defective water pump (worn impeller), faulty radiator cap, air flow restriction through radiator core, internal flow restrictions in radiator, worn or loose fan belt(s) or a defective oil cooler.
- Fuelling – fuel timing incorrect, leaking injector nozzle or insufficient combustion pressure to facilitate complete combustion of the injected fuel (broken or incorrectly installed piston rings).



Installation errors can and do occur, the most common is the installation of compression rings upside down.





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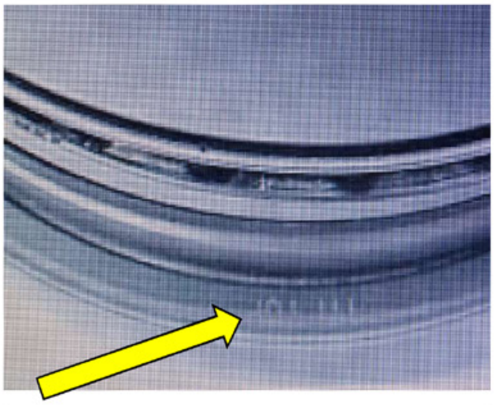
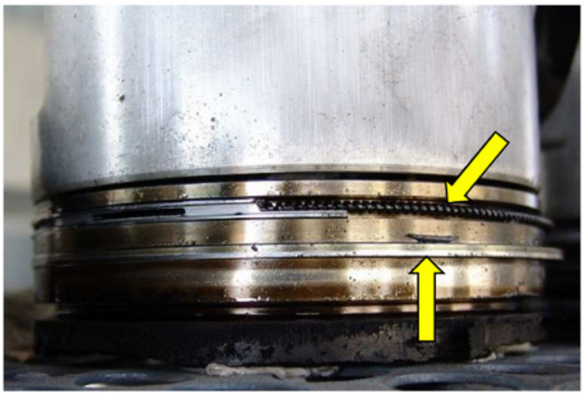
The tapered ring face (normally the second compression ring) should always face towards the bottom of the piston, irrespective of the design, either a positive torsional twist or a reverse torsional twist – there are always some indication on the ring which is the top side.
If the ring has been removed from the piston it will still be possible to establish if it was incorrectly fitted because of the polishing on the side face of the ring.
During engine operation the ring face contacts the bottom land of the piston groove and as a result it becomes more polished; therefore, if the ring has been installed upside down the the more polished face will appear on the top side of the ring.



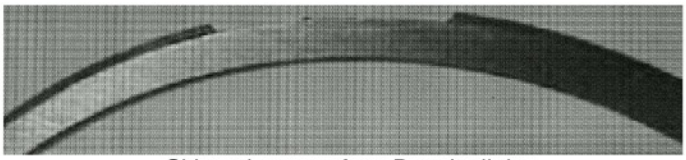
An example of an incorrectly fitted compression ring.



The customer complained that the rings were inferior because there was excessive oil consumption shortly after the engine had been overhauled.
Besides the oil ring being broken it was also noted that the second compression ring had been installed upside down.

Another area where problems can occur is during the actual installation of the rings onto the piston.
If the rings are not properly compressed into the piston grooves prior to installation into the liner bore, then the type of damage shown in the photographs below can occur

Damaged oil ring



Chipped contact face Detroit oil ring

Chipped hardfacing

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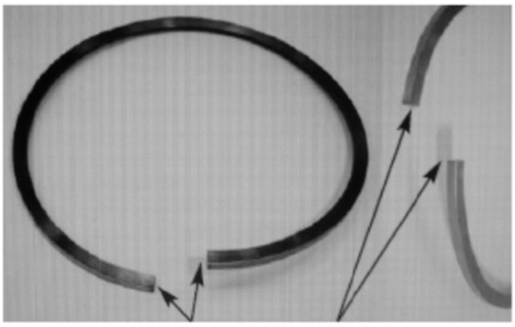
PISTON RING FAILURES

Other incorrect methods of installation can result in breakage, abnormal wear patterns on the ring and deformation.

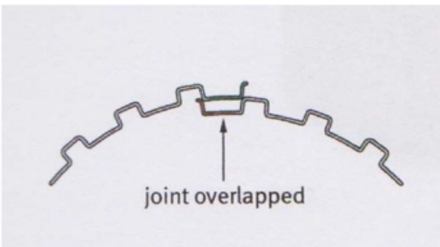


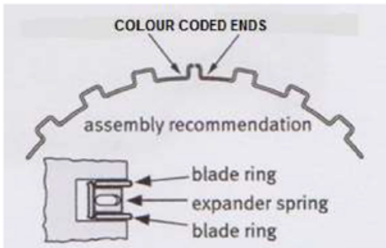
Because the correct tooling was not used to install the rings, they have been twisted and tensioned resulting in a spiral type of deformation.
As a consequence, abnormal wear will occur in the ring groove, the lateral sealing of the ring will be affected and because the ring is unable to rotate freely in the groove, it will create abnormal wear patterns on the ring face, which will eventually result in blow-by and oil consumption.

Ring was twisted during installation

Too much expansion during installation

Another area where extreme care must be taken is in the installation of the oil ring, especially if it utilises an expander type of design, because if the ends of the expander overlap then the oil control will be drastically reduced because there will be less radial pressure; similarly if the expander or tensioner spring is shortened to facilitate easier installation, the same would apply – insufficient oil control.





As a precautionary measure the colour coded ends should always be checked to establish that they are both clearly visible prior to installing the piston into the cylinder.

Lastly, were the rings that were installed the correct diameter for the specific cylinder bore, maybe they should have been oversize rings; another possible reason for excessive oil consumption could be that the wrong thickness of oil ring was used – there are different thicknesses of oil rings on the Caterpillar 3300 series engines.
Always check and double check before drawing the wrong conclusion.

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