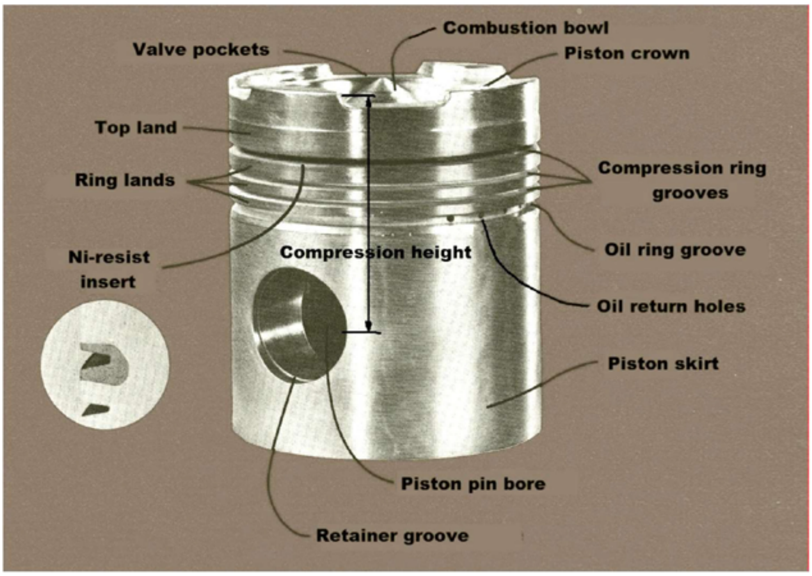
KMP BRAND TECHNICAL BULLETIN

Piston Failures

KB-15003



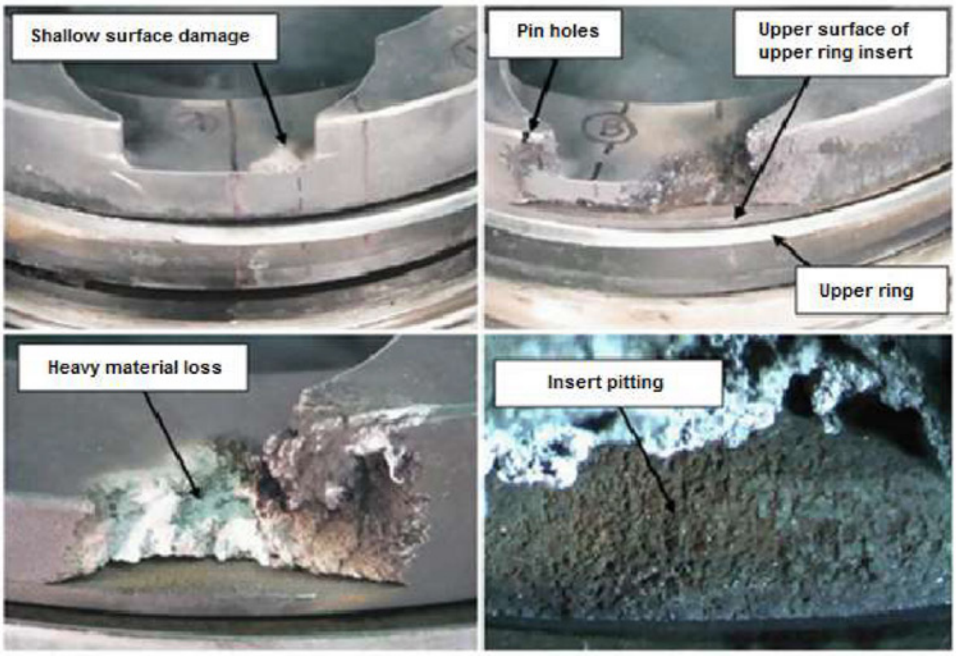
The purpose of this bulletin is to illustrate the possible types of damage that could occur when pistons are subjected to abnormal operating conditions.
The most important point to remember when diagnosing a failure is to establish the cause of the problem and this may not always be clear and obvious.
All too often repairs are carried out, and then when the engine is returned to service, the same failure occurs again, because the **actual cause** of the initial failure was not identified and rectified.
So it is inevitable that some "detective work" is needed, gather and organise the facts, observe the facts, think logically with the facts, and finally, identify the most logical cause.

An example where this logic was not applied is shown below.

The failures were initially attributed to excessive operating time at low speed/power on the basis of past experience, and the damaged pistons were simply replaced. Additional failures in March however, in some cases after only 48 hours of operation, prompted the metallurgical examination discussed herein. The findings of uncombusted fuel droplets was then provided in April to engine system personnel who identified contamination from fuel biological growth as the most likely cause. The fuel tanks were cleaned and the engines returned to service in late June. Catastrophic piston failures continued and two engines had major failures/damage due to piston seizures. The continuation of piston damage along with the more severe piston seizures, prompted an intensive two week, onboard "detective" type effort in late July to determine the true root cause, which in turned out to be incorrect fuel injection timing. The timing was corrected and the engines have been operating with no piston failures since the correct remedial action was taken. To reiterate, the entire sequence starting with failures in January and ending with identification and correction of the root cause in late July covered a full seven months.

Metallurgical Evaluation

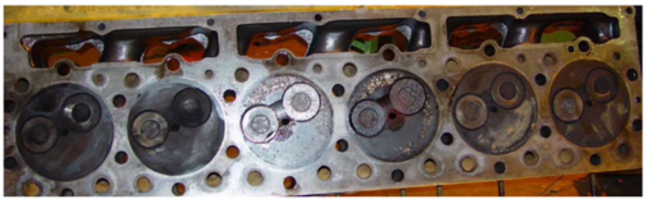
Metallurgical evaluation was performed on two pistons that failed after only 48 hours. The evaluation consisted of visual inspection, metallography, scanning electron microscopy (SEM), and hardness testing.

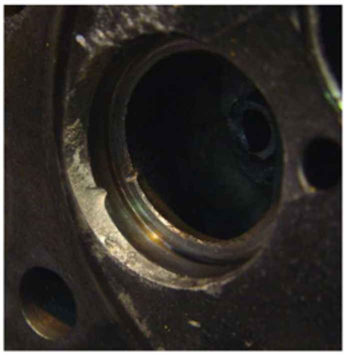


Piston OD visual damage. Note the heavy material loss working in from the OD, but no ring damage.

Interpretation of the damage caused by the failure is vitally important and often the signs can be misleading, below is another example of this.
Initially it was thought that a dislodged valve seat had created the damage to the crowns and the displaced material is what caused the damage to the skirts.

Closer inspection of the two pistons and other related components, namely the liners, cylinder head and the valves, revealed that there had definitely been a combustion irregularity based on the observations.


The primary cause of the failure was a combustion irregularity which caused the channelling which was evident on the two exhaust valves; it had resulted in deposits of molten piston material onto the valve seating faces as it was exiting the cylinders, this prevented them from seating properly – as a consequence the channelling occurred.

Valve seats are a shrink fit into the cylinder head, and therefore once the integrity of the seat is affected (in this case by the channelling) the retention is lost and the seat will be dislodged.

Satisfactory combustion ensures that the fuel injected ignites with the shortest ignition delay and burns completely with the desired pressure cycle, and the time lag between the commencement of fuel injection and actual ignition becomes extended if the fuel is not fully atomised or is injected at the incorrect time.

The excess fuel then burns and generates so much heat that the melting point of the piston material is exceeded, this combined with the inertia forces and erosive effects of the combustion gases causes particles of the piston material to be torn out, as evidenced in this failure.

Unburnt or incompletely burnt fuel also tends to destroy the lubrication film on the cylinder walls, resulting in damage to the piston skirt and liner bore, and as the failure progresses this reduced lubrication deteriorates even more because of the presence of the molten aluminium which further interferes with the oil film and then severe scoring occurs.

To prevent unnecessary costs it is important that the true cause of the failure is identified before repairs are carried out.

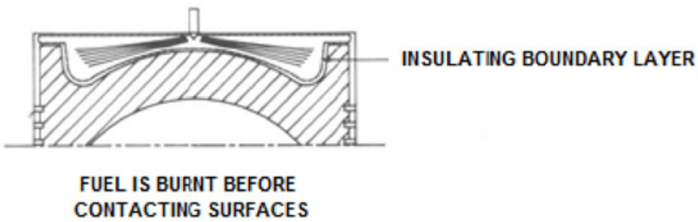
EXAMPLES OF CROWN EROSION

If crown erosion is evident in a diesel engine it is imperative that a thorough check of the entire fuel injection system is carried out.

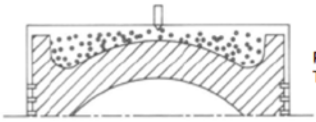
It would be wrong to blame the crown erosion on the piston's metallurgy as there is not a piston alloy that would resist fuel burning on its surface.

An assumption that the material was faulty would merely delay identification of the true cause – fuel injection malfunction.

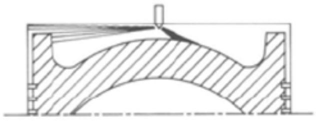
The diesel injection system must meter the correct amount of fuel in an atomised form in the correct spray pattern and at the right time; when all these criteria are met combustion takes place without any fuel being deposited on any of the surfaces. Correct combustion maintains a thin boundary layer of gas which protects any of the surfaces from burning, this is because it provides the thermal protection which is necessary to limit the heat transfer to other components – whilst this boundary layer is very thin (only microns in thickness) its presence is of the utmost importance, see below.



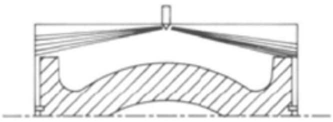
FUEL INJECTION MALFUNCTIONS



POOR FUEL ATOMISATION RESULTS IN FUEL CONTACTING THE PISTON



AN INCORRECT SPRAY PATTERN RESULTS IN FUEL CONTACTING THE PISTON CROWN AND THE BORE WALL



INCORRECT TIMING RESULTS IN THE FUEL CONTACTING THE WALL OF THE BORE

When these irregularities occur, and without the presence of the protective boundary layer, the fuel wets the surfaces and burns at extremely high temperatures, these exceed the melting point of the piston alloy, and as a consequence crown erosion is inevitable.

PISTON SCUFFING AND SCORING

This type of damage can result in different types of failure patterns, however, all of them would have resulted in the elimination of running clearance because of excessive heat which caused thermal expansion; this results in an area or areas of the piston making contact with the bore in which it is operating.
What starts as scuffing can rapidly progress to severe scoring because of the additional frictional heat that is created.

Quarter point scuffing, refer to illustration no.1

Full skirt seizure, refer to illustration no.2

Top land seizure, refer to illustration no.3

Centre scuffing, refer to illustration no.4

Quarter point scuffing

- Lack of crown cooling by the lube oil - check for misaligned, damaged, blocked or missing piston cooling nozzles.
- Low oil pressure – maintain correct oil levels, faulty oil pump or oil relief valve, oil gallery restriction.
- Overheating of coolant system - low coolant level, faulty thermostat, faulty water pump, damaged or slipping belts.
- Lack of heat transfer in cylinder – aeration of coolant.

Illustration no.1

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PISTON FAILURES

Illustration no.2

Full skirt seizure

If all pistons exhibit the same seizure pattern then overheating of the engine is usually the main contributing factor for this type of failure; the possible causes are low coolant level, defective thermostat, defective water pump, damaged or slipping belts, plugged radiator. Alternatively a lack of lubrication could have been the contributing factor because thermal expansion of the piston could have eliminated the film of lubrication, in such cases other engine components should be checked for evidence of insufficient lubrication.

Illustration no.3

Top land seizure

Over-fuelling of specific cylinder – faulty injector or injector timing.

Lack of fresh air to that cylinder – replace filters at recommended intervals and avoid lugging of the engine which reduces the air intake.

Exhaust restriction – check for leaking or damaged pipes or faulty exhaust muffler.

Engine or injection timing – avoid deviations from the manufacturer's specifications.

Lack of piston crown cooling – check for misaligned, damaged, blocked or missing piston cooling nozzles.

Illustration no.4

Centre scuffing

High loading on a cold engine – because pistons are not round until the engine reaches operating temperature it is important not to load the engine prematurely.

Cooling system malfunction – low coolant level, faulty thermostat, faulty water pump, damaged or slipping belts.

Oil dilution or incorrect grade of oil – faulty injector or injector timing, only use manufacturer's approved lubricants.

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ABRASIVE DAMAGE

If it is considered that approximately 45% of piston failures can be attributed to damage caused by abrasive contamination, then a considerable amount of time could be saved by first looking for evidence of abrasive wear.
The piston skirts will have fine dull grey vertical scratches, the cylinder bores will also evidence vertical scratches and there may also be a distinct ridge at the top of the liner were the ring travel ends.
The presence of abrasive contamination can be confirmed by inspecting the faces and sides of the piston rings, there will be fine vertical scratches on the ring face and they will have a dull grey appearance, see the example below.

To be continued