FORM NO. SEBG4010

SHOP MANUAL

GUIDANCE FOR REUSABLE PARTS

ENGINE

CYLINDER LINERS, PISTONS AND PISTON RINGS

GUIDANCE FOR REUSABLE PARTS

KOMATSU

INDEX

INTRODUCTION

This publication contains colored photographs of typical failures encountered with cylinder liners, pistons, and piston rings at the time of engine, disassembling and inspection, and is intended to provide guidelines for deciding by visual inspection whether the parts are fit to be reused or not, prior to reassembly. This guide also contains basic information on the parts and explanations of the failures and their causes.

Because engine parts of construction equipment are usually exposed at high speeds under heavy loads, heat and exhaust gas, and the condition of the coolant, lubricating oil, and fuel have profound effects on the failures. Thus, failure symptoms of engine parts are quite different to those appearing in other components.

Moreover, engine parts failures in general are caused by a single cause, multiple causes or their combined effects and are varied in nature, this publication should be useful for anybody engaged in the diagnosis and repairs of construction equipment engines. The writers will be happy to hear that, "lowering in repair costs" through appropriate reusing of parts, as well as "prevention of reoccurrence of failures" through correct diagnosis of their causes, is achieved.

FAILURE SIGNS, THEIR CAUSES AND DIAGNOSIS FOR REUSAGE

When determining whether a part can be used again or not, it is important to consider daily maintenance and work conditions, and search for the real cause which caused the very failure. Combined with the distributor's acquired experience, the photographs of failures ranked by three should be used as guidelines to determine reusage of each part.

Moreover, the extent of the failure is an important factor in determining whether that part is reusable or not, however, full consideration should be paid to the risk against damage borne in the engine as a result of reusing a failed part.

Inspection Points for Parts Reusage Diagnosis

To inspect failed parts correctly, wash and clean the parts, and inspect them by referring to the following inspection points.

Part name	Inspection points
Cylinder liner	• Outside surface: Corrosion, pitting, and cracks • Inside surface: Scratches along the length, corrosion, and rust • Seal ring groove: Corrosion and damage • Cylinder liner protruding part: Damage and fatigue • Cylinder liner flange: Damage and cracks
Piston	• Piston top: Damage and cracks • Outside surface: Lengthwise scratches and damage • Pin bore area: Damage and cracks • Ring grooves: Wear and damage
Piston ring	• Outside surface: Wear and lengthwise scratches • Top and bottom faces: Wear

Standards for Failure Determination

Rank	Failure degree
Use again (As is)	• The failure does not affect engine performance, and will not cause secondary failures.
Use after reconditioning	• The failure does not immediately affect engine performance but is liable to cause secondary failures. • If part is reconditioned part can be reused.
Do not use again	• Performance of the machine is clearly affected by the failure, and further use of the part will surely cause severe damage.

Note: To determine the amount of wear, refer to the 'Repair limit and Maintenance standards' in the Shop Manual.

Cylinder Liners: Determination for Reusage

Location of failure	Rank	Failure degree
Top and middle part	**Use again (As is)**	• Depth of the pits are less than 30% of the cylinder liner wall thickness.
	Use after reconditioning	• Depth of the pits are less than 50% of the cylinder liner wall thickness.
	Do not use again	• Cracks are evident and pits are more than 50% of wall in depth.
Bottom part	**Use again (As is)**	• No pitting in the grooves.
	Use after reconditioning	• Location of pits is within 20% of groove width from top edge of seal groove. Depth of pit is less than 30% of cylinder liner wall thickness at the groove.
	Do not use again	• Location of pits is more than 20% of groove width from top edge of seal groove. Depth of pits is more than 30% of cylinder liner wall.

Pistons: Determination for Reusage

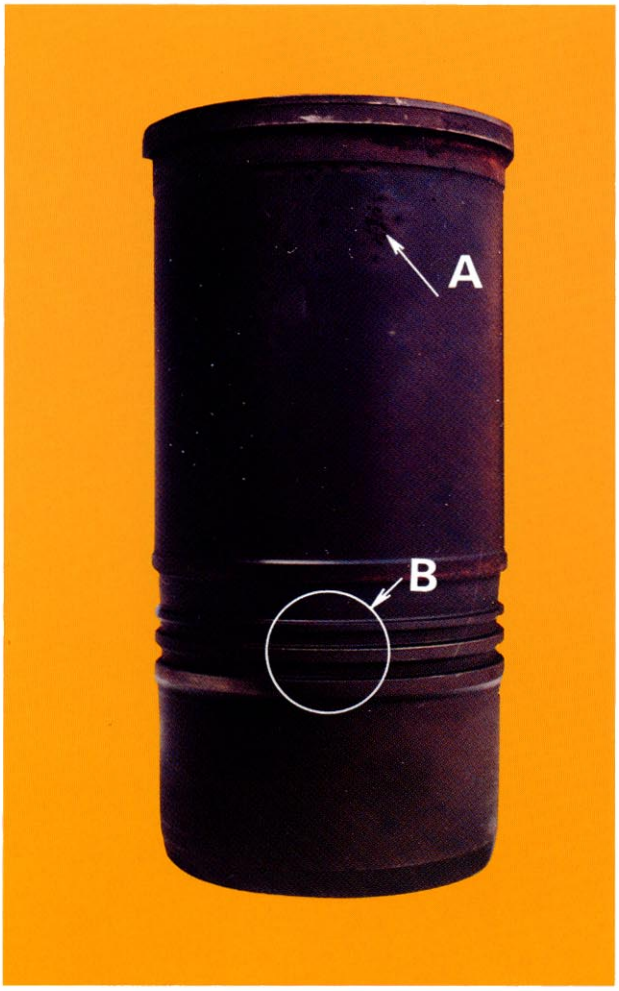
Location of failure	Rank	Failure degree
Combustion chamber	**Use again (As is)**	• No failure observed or width of cracks around toroidal combustion chambers of direct injection type pistons should be 0.15mm or less.
	Do not use again	• Cracks over those shown above.
Top ring land and piston skirt	**Use again (As is)**	• Scuffing and carbonizing is very slight.
	Use after reconditioning	• No signs of seizure or melting at base metal.
	Do not use again	• Signs of seizure or melting at base metal.
Ring groove	**Use again (As is)**	• No scratches or dents are evident.
	Use after reconditioning	• Scratches or dents are visible but piston ring rotates freely around its groove after reconditioning.
	Do not use again	• Scratches and dents are excessively large and many.
Pin boss	**Use again (As is)**	• No cracks and scratches are evident.
	Do not use again	• Cracks and scratches are large and many.

Piston Rings: Determination for Reusage

Rank	Failure degree
Use again (As is)	Piston Rings that conform with all of the below listed items can be reused. • Clearance and contact is normal. • Width of contact surface is less than 60%. (Excluding ring gap area) • No scuffing, scratches marks (large enough to be felt by one's finger-nail when run across), or oil-film destruction in parts and consequent discoloration. • At time of disassembly, no* sluggishness, pinching or sticking is evident.
Do not use again	Those that fail to conform with one out of all of the above listed items should not be used again.

*Sluggish: Ring will turn when pushed by the finger but is heavy.
Pinching: Ring will not turn when pushed by the finger, but ring surface is bright.
Sticking: Ring will not turn when pushed, and ring surface is dirty with carbon.

Cylinder Liners



USE AGAIN

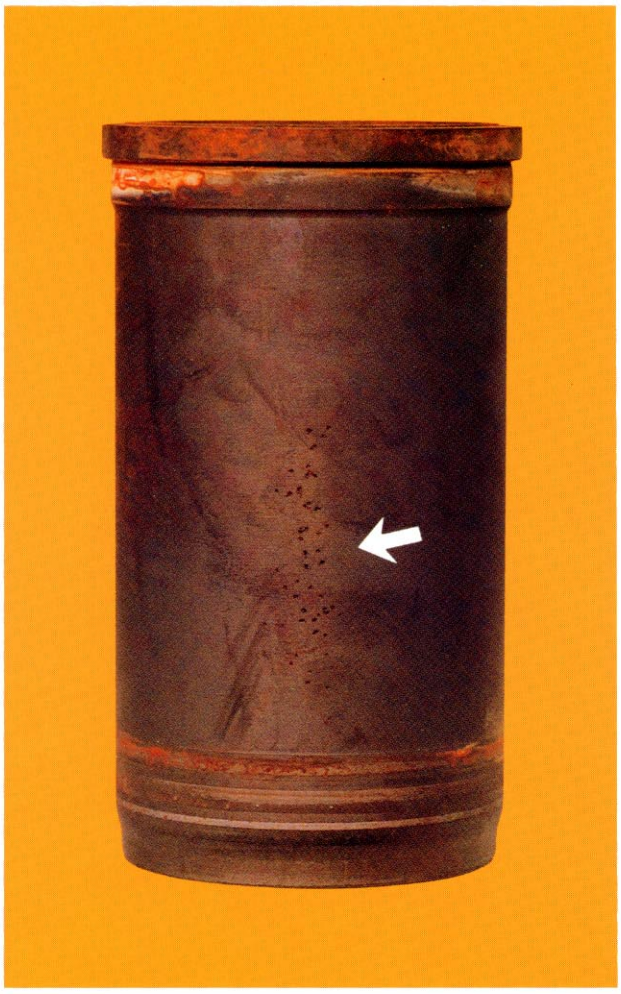
Failure Signs

- Top part of the cylinder liner (A) has a light pitting but no damage is evident in crevice seal and O-ring grooves (B).

USE AGAIN

Failure Signs

- Pitting caused by cavitation erosion is seen in the middle part of the cylinder liner, but damage is slight.



USE AGAIN

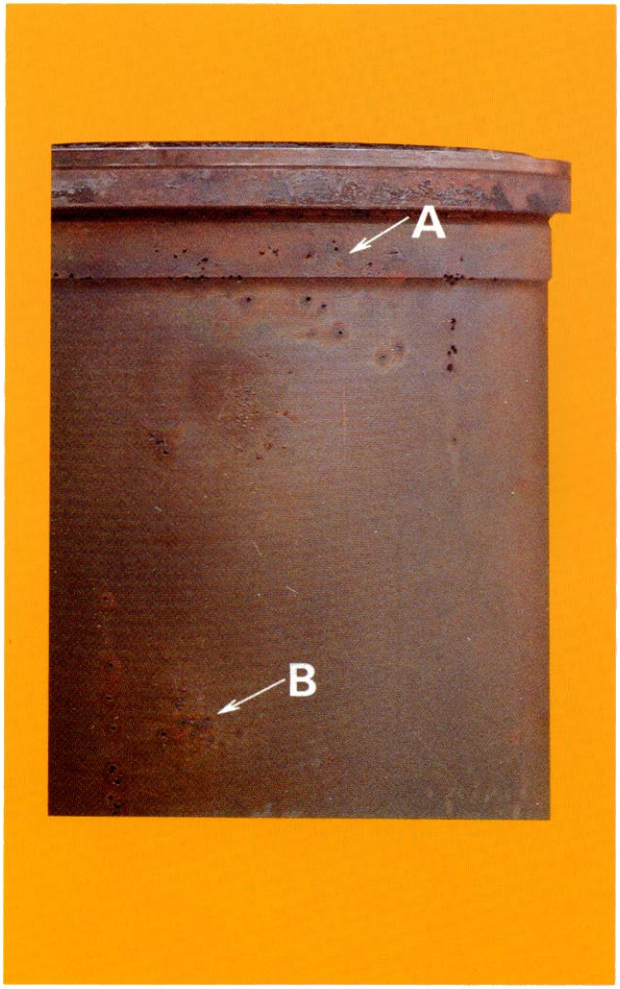
Failure Signs

- Pitting is observed on the middle part of the cylinder liner's outside surface, however the damage is light since the depth of the pits is less than 30% of the wall's thickness.

USE AGAIN

Failure Signs

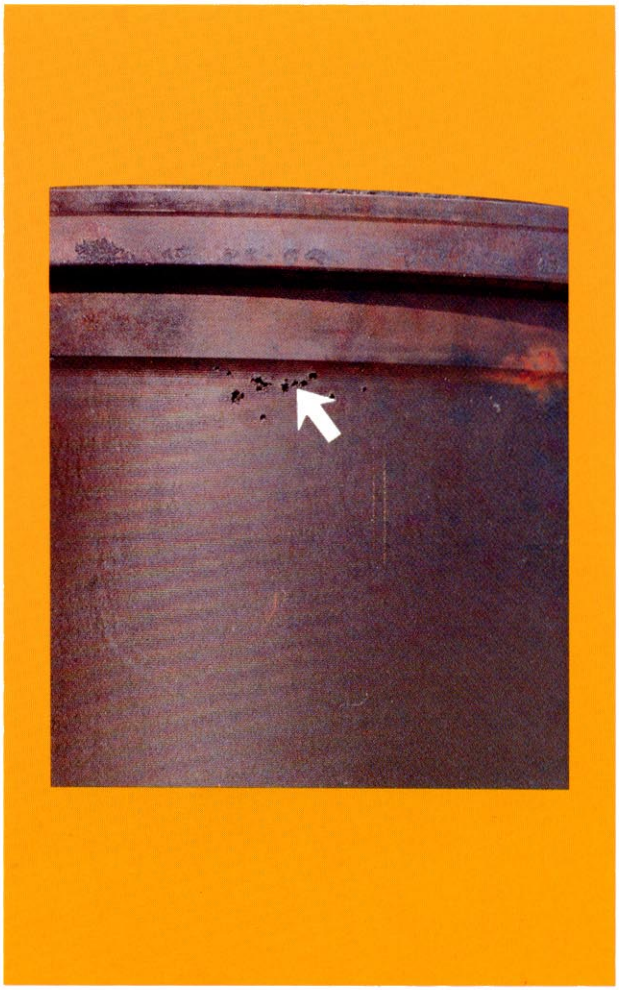
- Pitting is observed on the top (A) and middle (B) portion of the cylinder liner, however the pits are all only slight.



USE AGAIN

Failure Signs

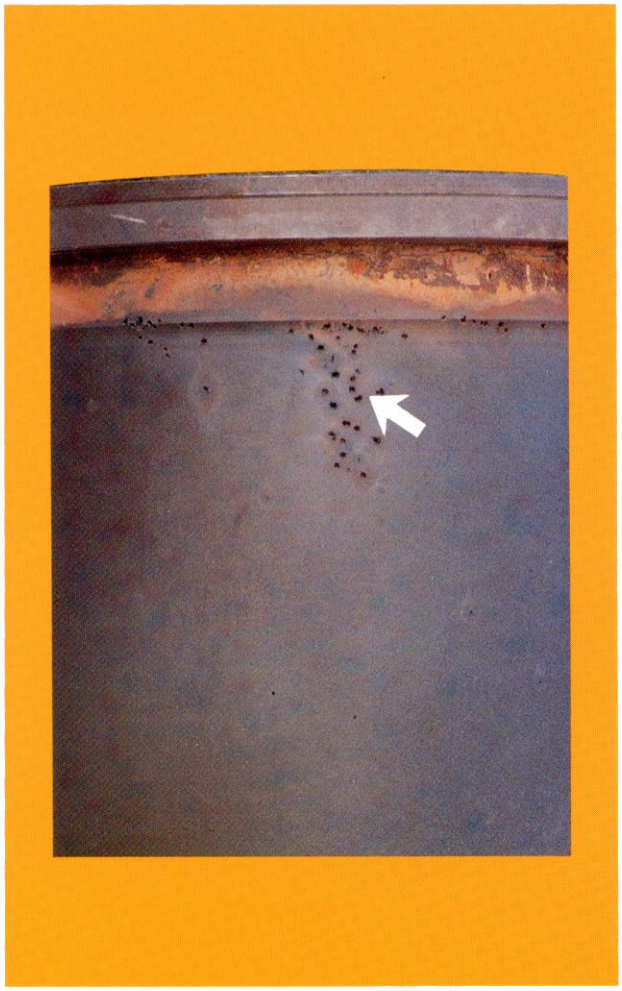
- Slight pitting is observed on the top (A) and middle (B) portion of the cylinder liner.



USE AGAIN

Failure Signs

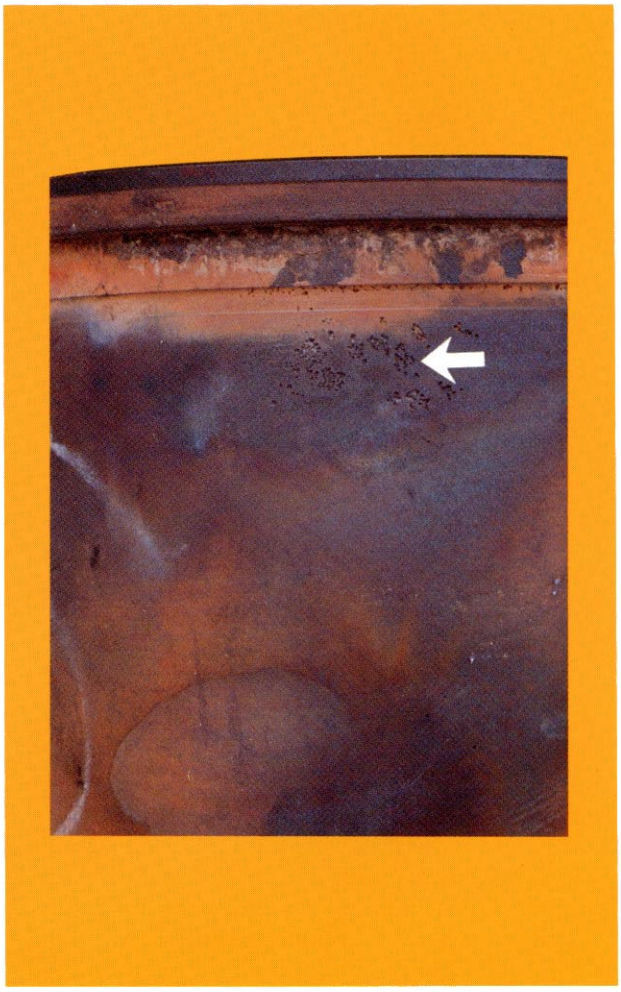
- Light corrosion damage is observed at the top part of the cylinder liner.



USE AGAIN

Failure Signs

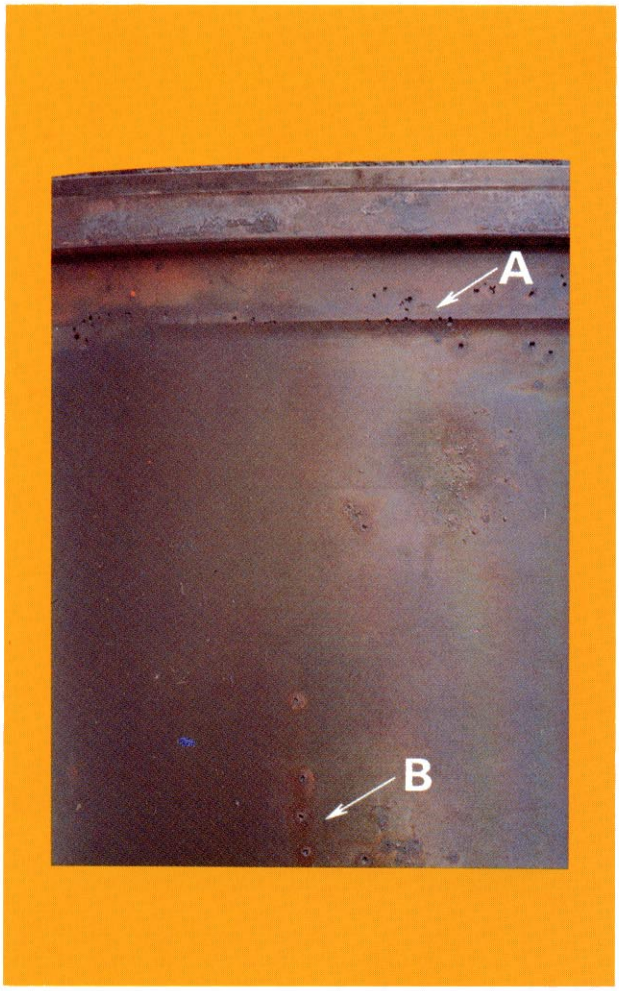
- Light corrosion damage is observed at the top part of the cylinder liner.



USE AGAIN

Failure Signs

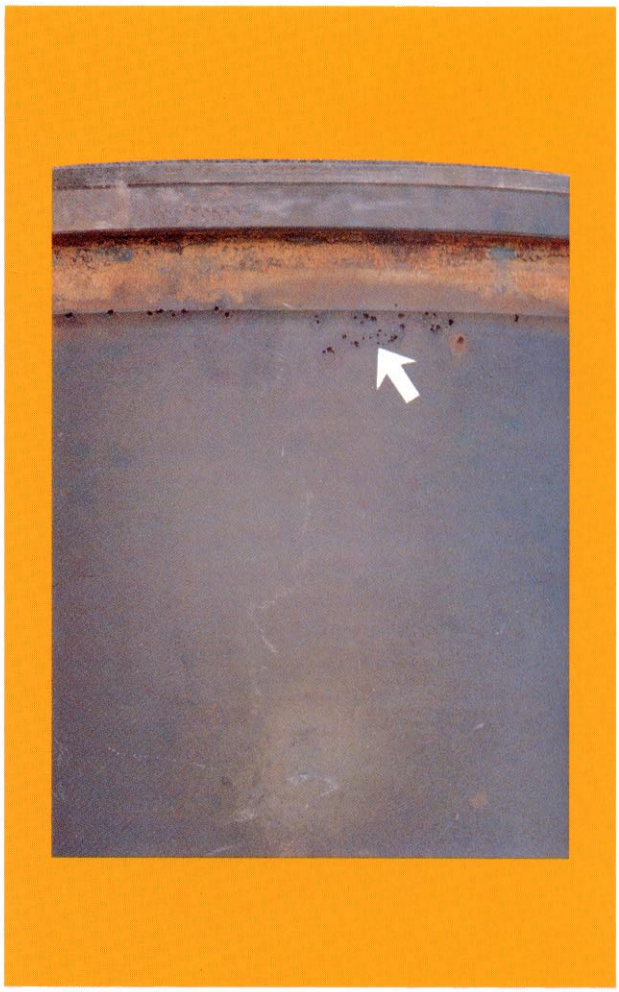
- Very slight pitting at top part of the cylinder liner.



USE AGAIN

Failure Signs

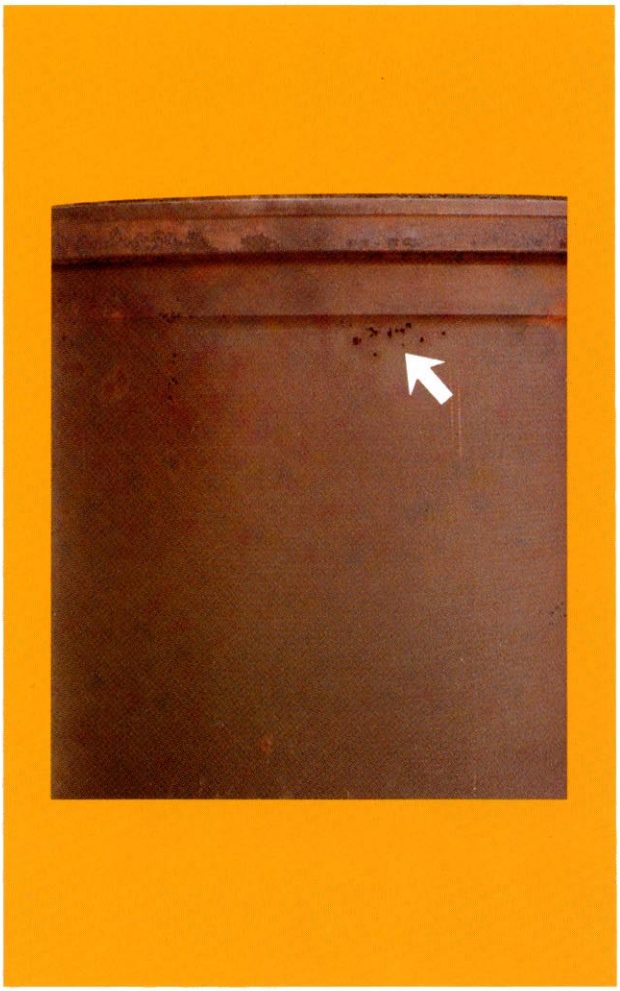
- Light pitting can be observed at the top (A) and middle (B) part of the cylinder liner.



USE AGAIN

Failure Signs

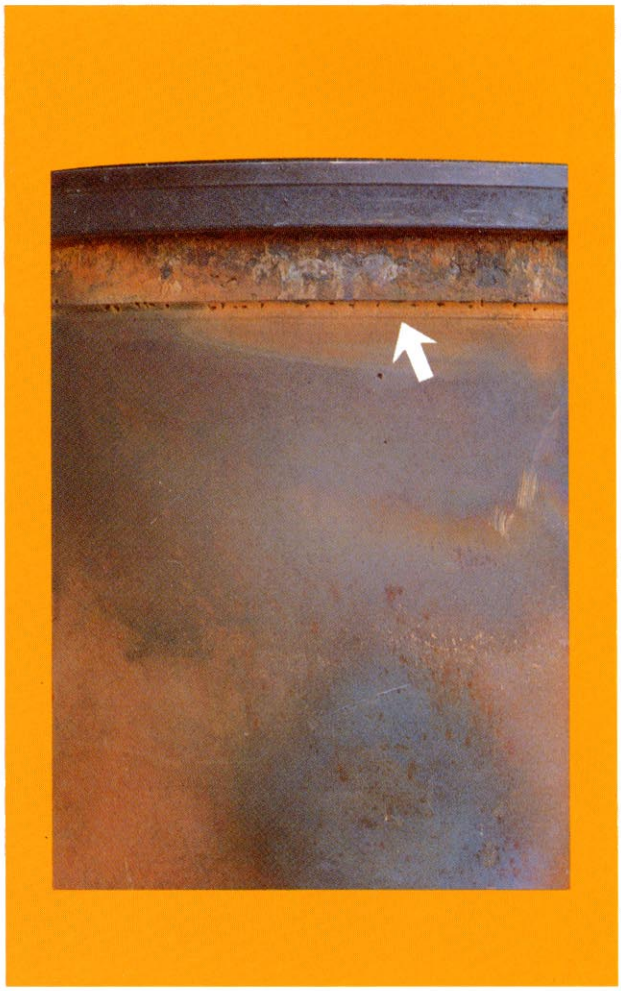
- Light pitting can be observed at the top part of cylinder liner.



USE AGAIN

Failure Signs

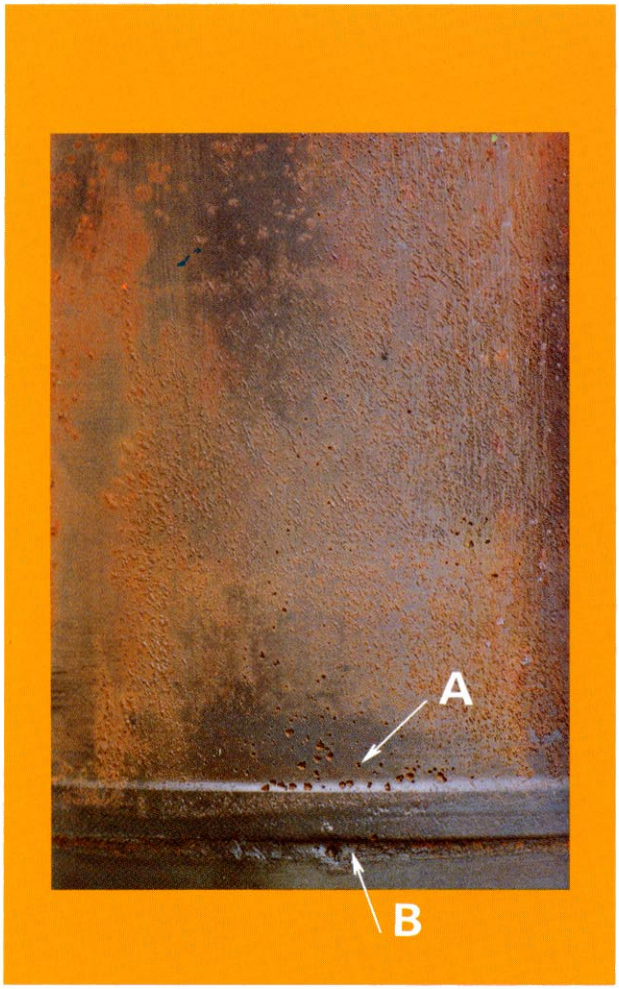
- No rust is found to be adhering.
- Pitting at the top part is also slight.



USE AGAIN

Failure Signs

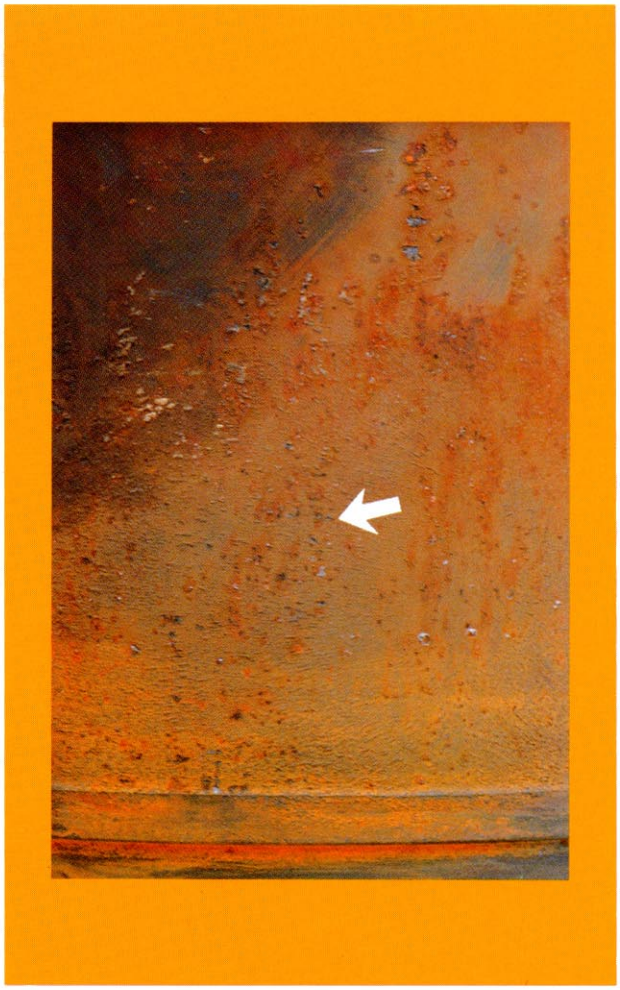
- Slight pitting is seen at the top part of the cylinder liner.



USE AGAIN

Failure Signs

- Corrosion can be seen at the bottom part (A) of cylinder liner and in the crevice seal groove (B), however they are both slight.



USE AGAIN

Failure Signs

- A thin film of rust can be seen adhering over the whole surface, however traces of machining can be observed.

USE AFTER RECONDITIONING

Failure Signs

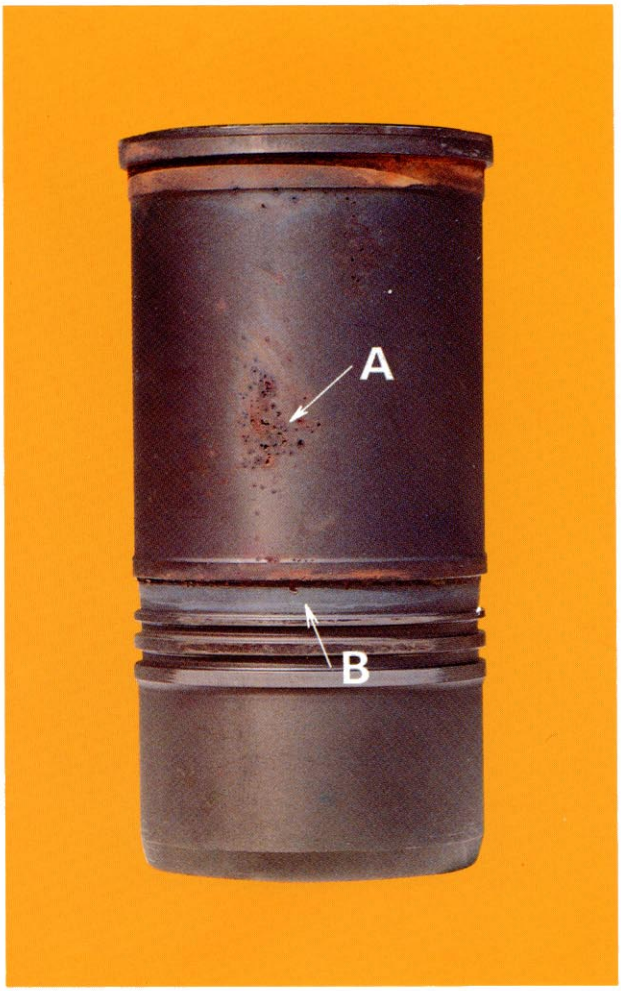
- Pitting in the middle part of the cylinder liner is over 30% of the wall's thickness.

Causes

- Quantity of cooling water is insufficient.
- Maintenance of corrosion resistor is improper.

Reconditioning Method

- Refill pits with chemical agent.
- Rotate cylinder liner by 90° and install it again.



USE AFTER RECONDITIONING

Failure Signs

- Light pitting in middle part (A) of cylinder liner.
- Crevice seal groove (B) is corroded, depth of corrosion is less than 30% of wall thickness.

Causes

- Quality of cooling water is not suitable.
- Quantity of cooling water is insufficient.
- Maintenance of corrosion resister is improper.

Reconditioning Method

- Refill pits with chemical agent.
- Rotate cylinder liner by 90° and install it again.

USE AFTER RECONDITIONING

Failure Signs

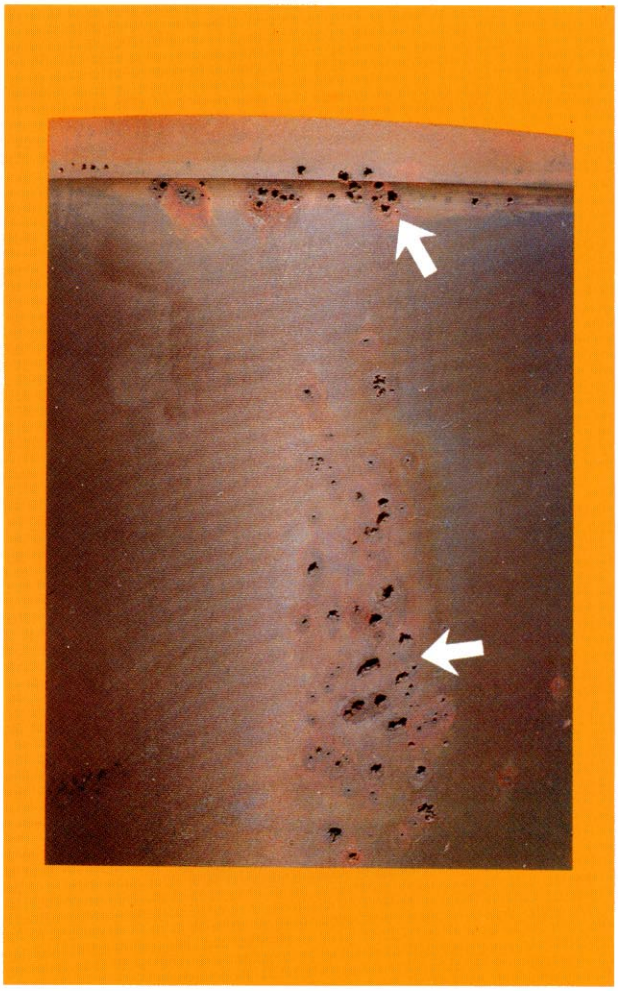
- Pitting in middle part caused mainly by cavitation erosion.
- Depth of the pits reach 30% of the wall thickness.

Causes

- Quantity of cooling water is insufficient.
- Maintenance of corrosion resister is improper.

Reconditioning Method

- Refill pits with chemical agent.
- Rotate cylinder liner by 90° and install it again.



USE AFTER RECONDITIONING

Failure Signs

- Corrosion in the upper (A) and middle part (B) of the cylinder liner.
- Depth of the corrosion is less than 50% of the wall's thickness.

Causes

- Quantity of cooling water is insufficient.
- Maintenance of corrosion resistor is improper.

Reconditioning Method

- Refill pits with chemical agent.
- Rotate cylinder liner by 90° and install it again.

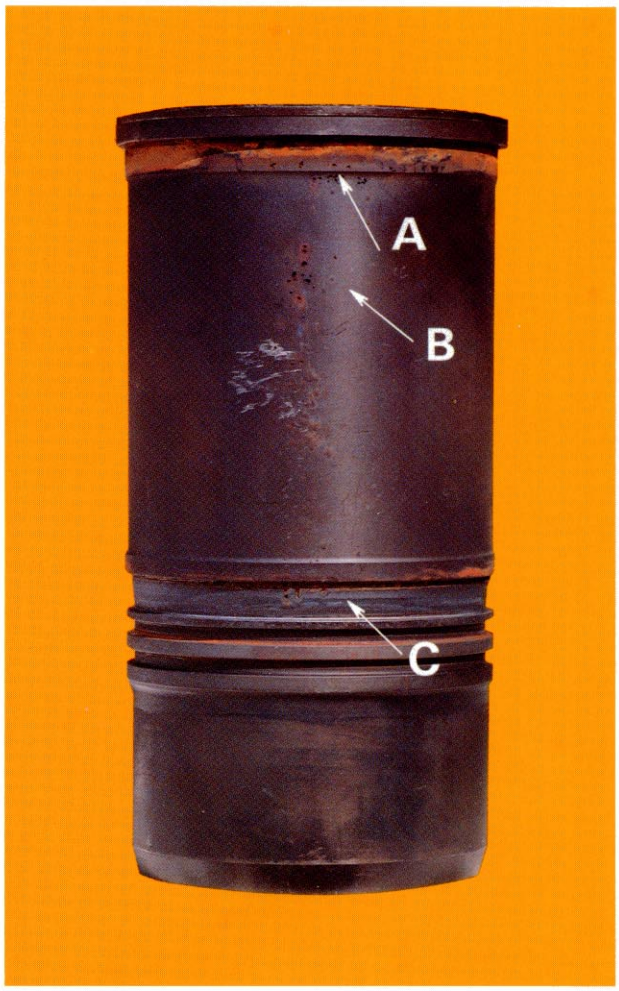
DO NOT USE AGAIN

Failure Signs

- Corrosion in the upper (A) and lower part (B) of cylinder liner.
- Cavitation erosion of the middle part (C) is the main cause, and fairly large pits can be seen.
- Corrosion at the seal groove exceeds 20% of the groove width.

Causes

- Quality of the cooling water is not suitable.
- Quantity of cooling water is insufficient.
- Maintenance of corrosion resistor is improper.



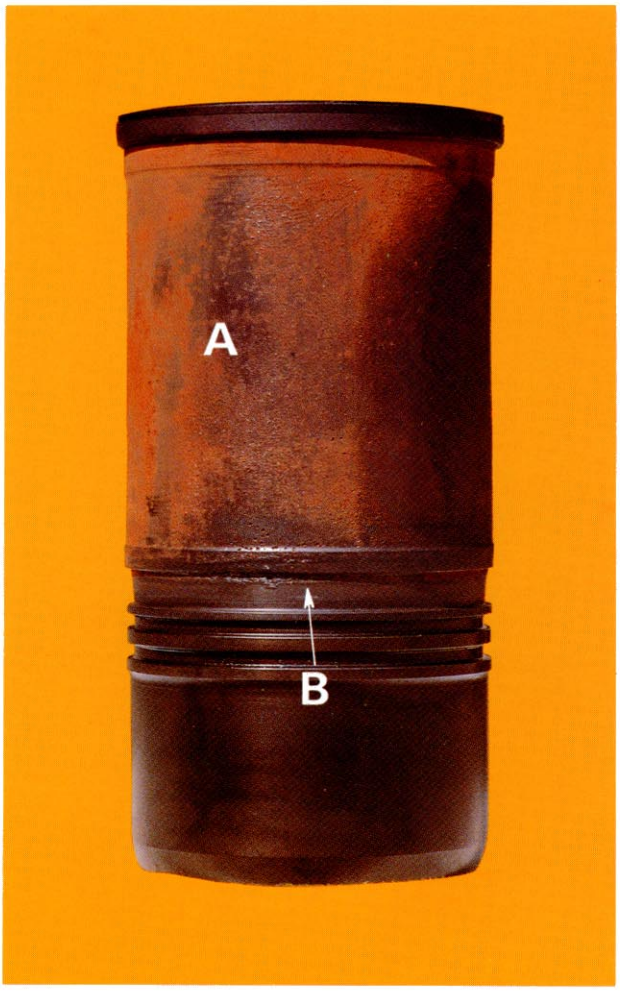
DO NOT USE AGAIN

Failure Signs

- Corrosion can be seen in the upper (A), and middle part (B) of the cylinder liner and in the crevice seal groove (C).
- Deep pits can be seen, in particular, in the crevice seal groove.

Causes

- Quality of the cooling water is not suitable.
- Maintenance of corrosion resistor is improper.
- Maintenance of anti-freeze is improper.



DO NOT USE AGAIN

Failure Signs

- Rust can be seen covering the entire surface (A), however, the markings from the finishing machining are still remaining.
- Deep corrosion can be seen in the crevice seal groove (B).

Causes

- Quality of cooling water is not suitable.
- Maintenance of corrosion resistor is improper.
- Maintenance of anti-freeze is improper.

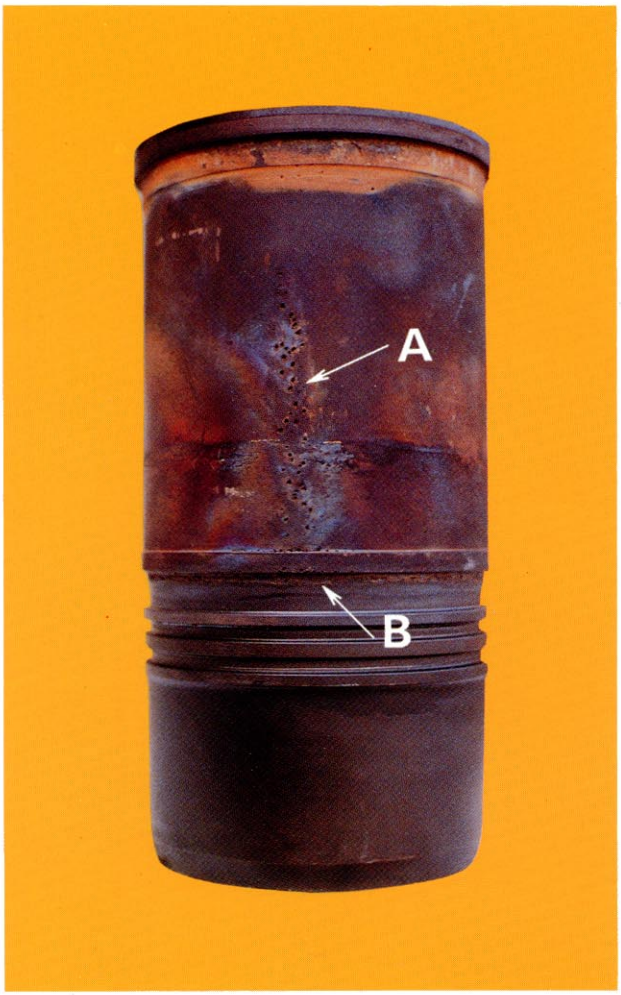
DO NOT USE AGAIN

Failure Signs

- Pitting in the top part (A) and middle part (B) of cylinder liner is slight, but pitting in the seal groove (C) at the cylinder liner's bottom part has spread considerably.

Causes

- Quality of cooling water is not suitable.
- Quantity of cooling water is insufficient.
- Maintenance of corrosion resistor is improper.



DO NOT USE AGAIN

Failure Signs

- Cavitation erosion can be seen in the cylinder liner's middle part (A).
- Color of the cylinder liner's surface shows sign of overheat.
- Pitting has spread, in particular, in the crevice seal groove (B).

Causes

- Quality of cooling water is not suitable.
- Quantity of cooling water is insufficient.
- Overheating.
- Maintenance of anti-freeze is improper.

DO NOT USE AGAIN

Failure Signs

- Numerous, relatively small pits can be seen, and because rust development is considerable, the cause can be attributed to the combined effect of both corrosion and erosion.
- Corrosion can be seen, and deep corrosion in particular in the grooved part (A).

Causes

- Quality of cooling water is not suitable.
- Quantity of cooling water is insufficient.
- Maintenance of corrosion resistor is improper.
- Maintenance of anti-freeze is improper.

DO NOT USE AGAIN

Failure Signs

- Corrosion in the cylinder liner's crevice seal groove has reached the stage where depth of the pits exceeds 30% of the wall thickness.

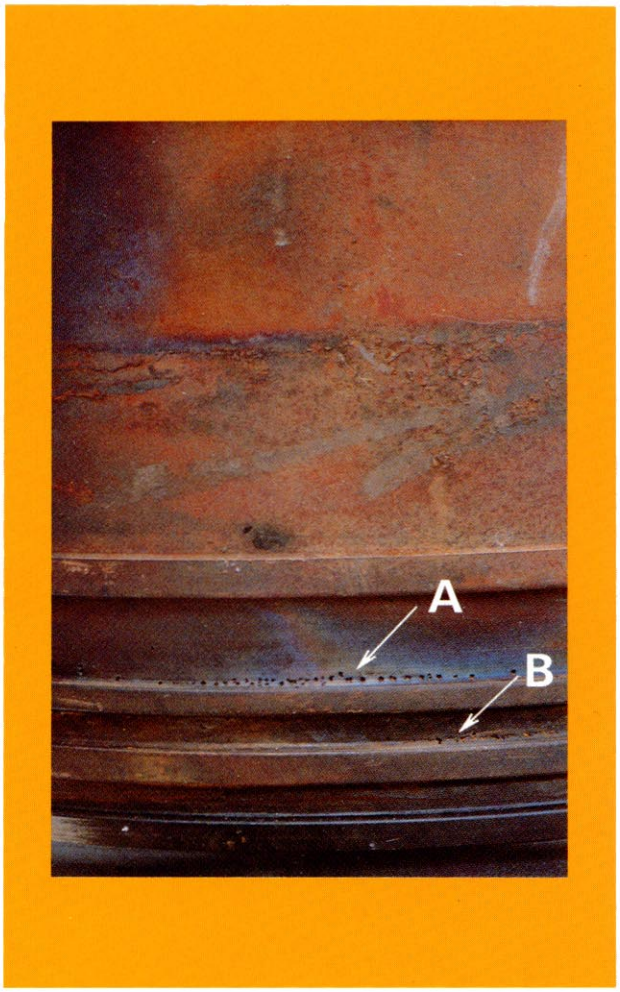
Causes

- Quality of cooling water is not suitable.
- Maintenance of corrosion resistor is improper.

DO NOT USE AGAIN

Failure Signs

- Corrosion at the crevice seal groove has exceeded 20% of the groove width.



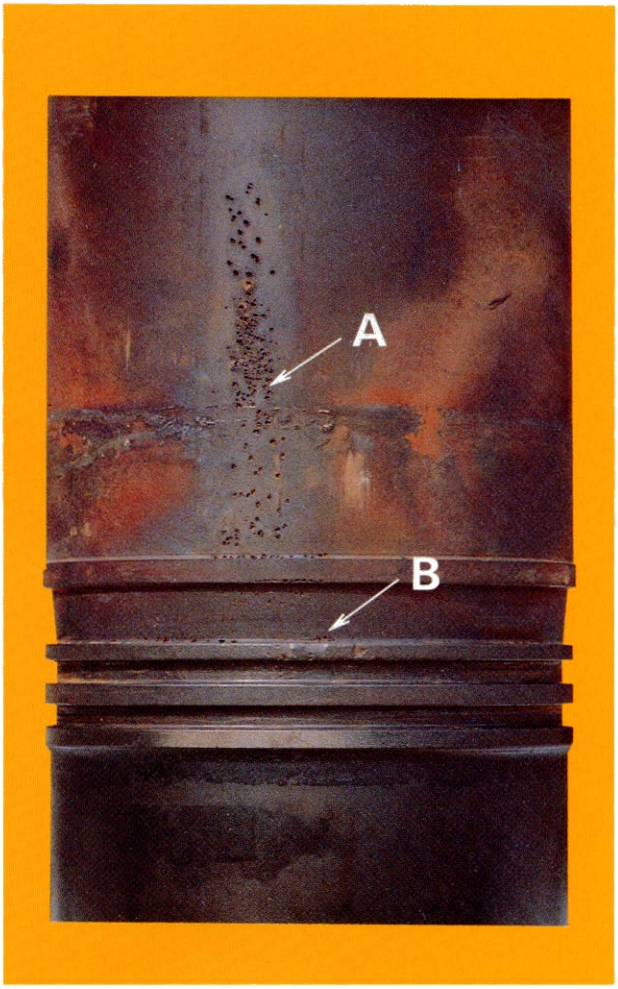
DO NOT USE AGAIN

Failure Signs

- Corrosion caused by water leakage through the crevice seal can be seen in the seal groove (A), and the lower part of the O-ring groove (B).

Causes

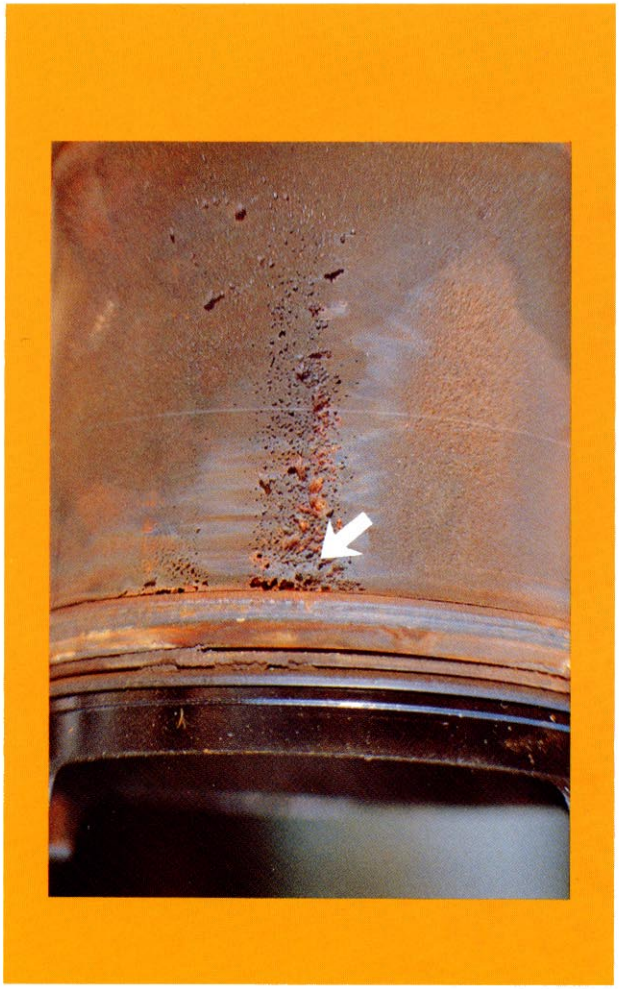
- Sealing effect of the crevice seal and O-ring has deteriorated; due to their hardening, because of engine overheating.



DO NOT USE AGAIN

Failure Signs

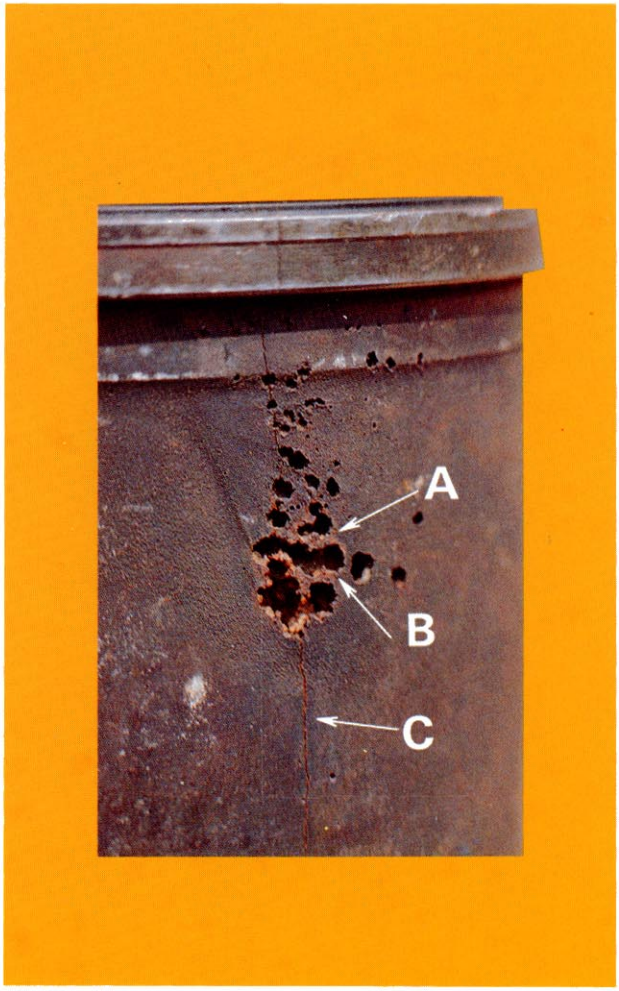
- Pitting has developed in the middle part (A) of the cylinder liner and in the crevice seal groove (B), the latter has spread to the top and bottom part of the groove.



DO NOT USE AGAIN

Failure Signs

- Corrosion can be seen spread from the middle part to the bottom part of the cylinder liner.
- Depth of the pits in the bottom part of cylinder liner exceed 30% of the wall thickness.



DO NOT USE AGAIN

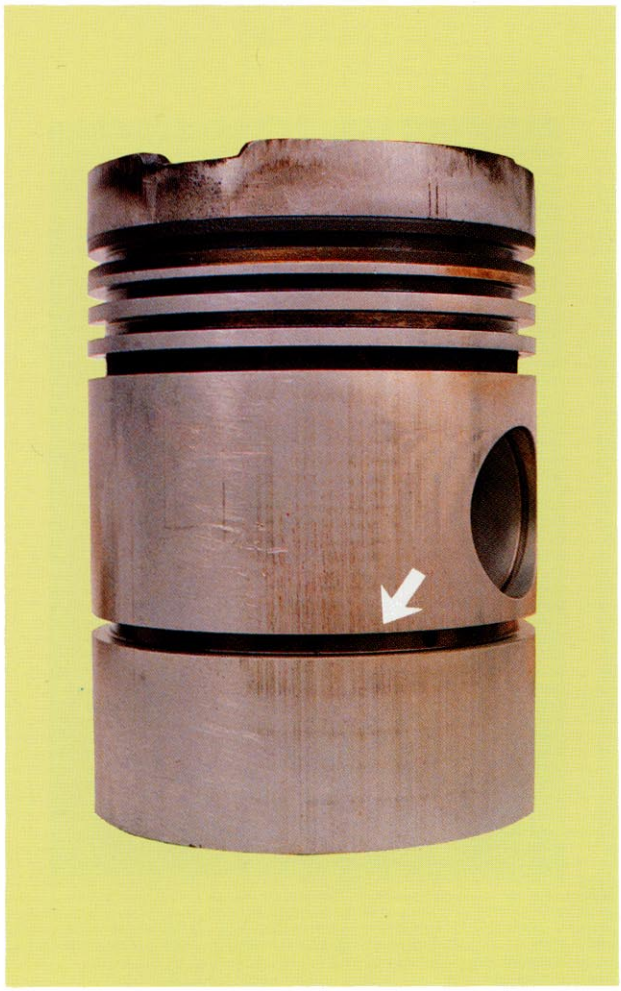
Failure Signs

- The pits are relatively large (A) and are caused mainly by cavitation erosion.
- The red coloring (B) around the pits' walls is caused by copper precipitated from the copper ions dissolved in the cooling water, this phenomenon speeds up eroding of the cylinder liner material.
- Cracks (C) have developed because of the deep pitting.

Causes

- Quality of cooling water is not suitable.
- Maintenance of corrosion resistor is improper.
- Maintenance of anti-freeze is improper.

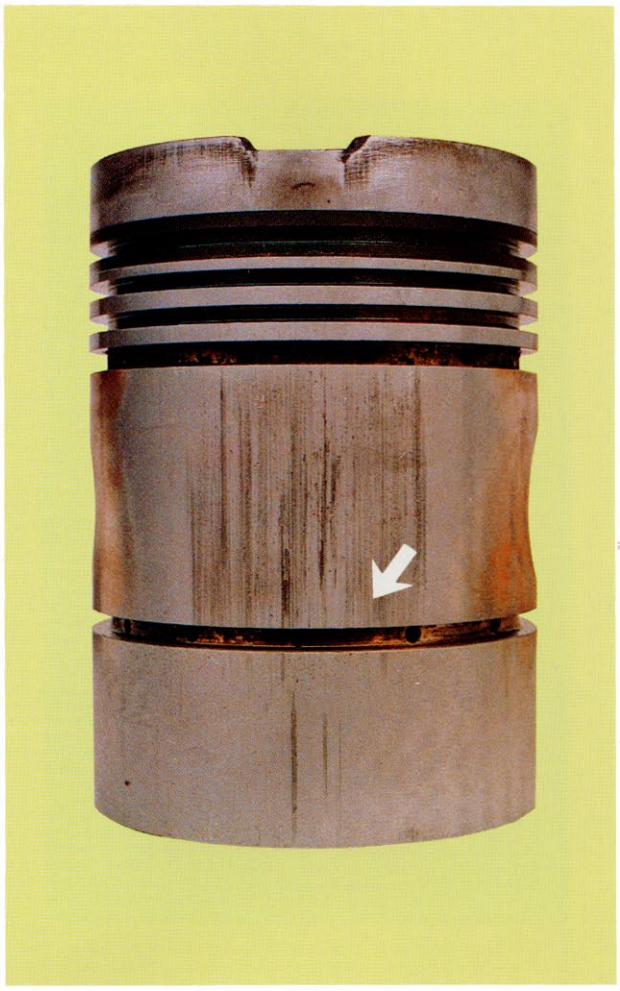
Pistons and Cylinder Liners



USE AGAIN

Failure Signs

- Slight scratching along the length of the piston skirt can be seen.



USE AFTER RECONDITIONING

Failure Signs

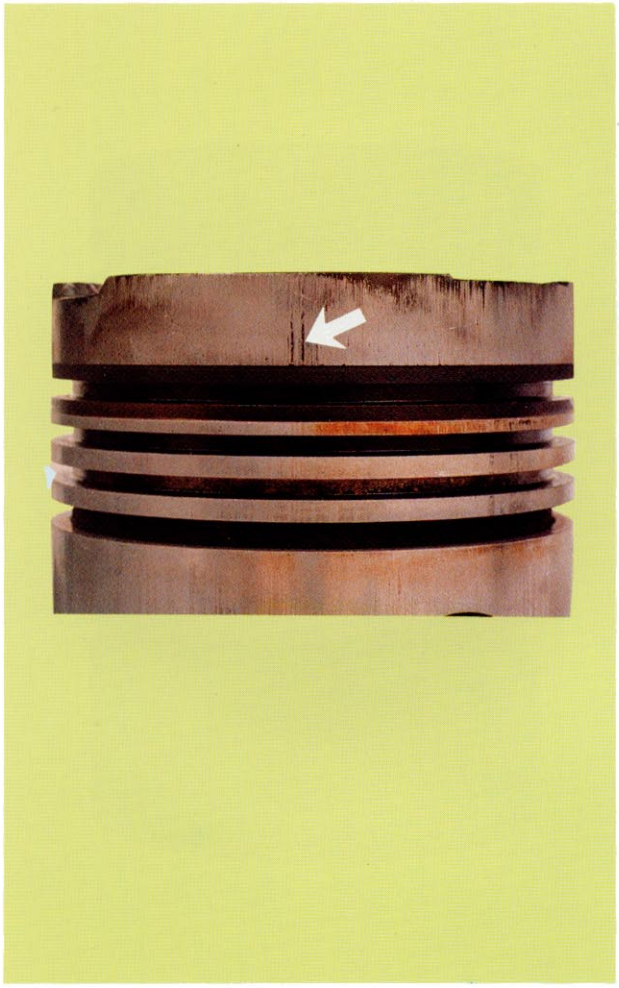
- Relatively numerous lengthwise scratches can be seen on the skirt area however, these scratches are slight and no signs of seizure are observed.

Causes

- Fuel dilution into engine oil.
- Use of engine oil with too low viscosity.

Reconditioning Method

- Remove the scratches by a fine oil-stone, and reuse the piston.



USE AFTER RECONDITIONING

Failure Signs

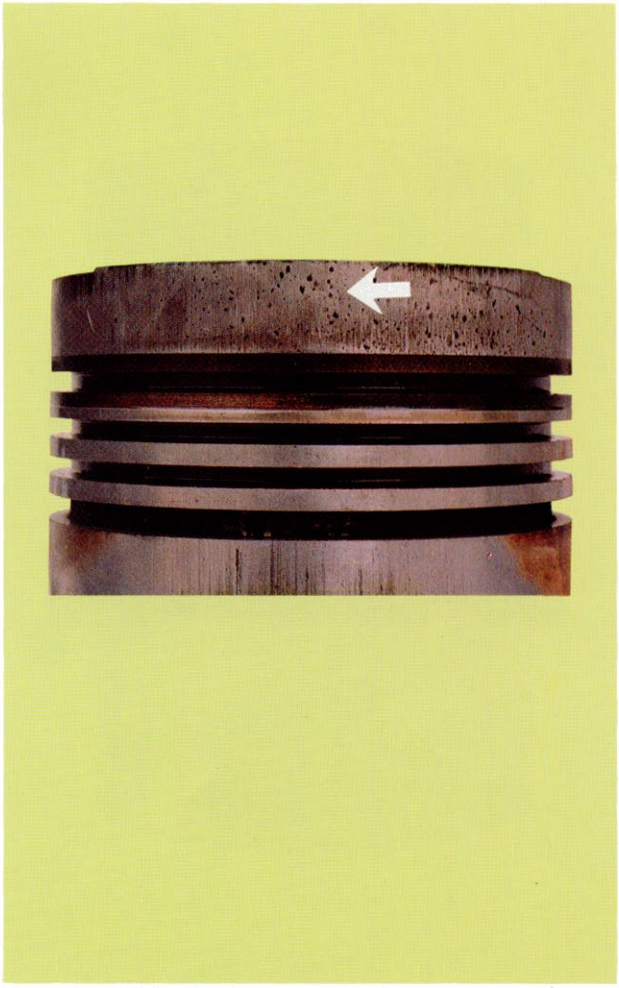
- Lengthwise scratches in the top ring land area probably caused by carbon deposits.

Causes

- Use of poor quality fuel.

Reconditioning Method

- Refinish the piston with a fine oil-stone and reassemble.



USE AFTER RECONDITIONING

Failure Signs

- Carbon lodged in the top ring land of the piston is excessive.

Causes

- Presumably due to long hours of running under high-load condition.

Reconditioning Method

- Clean the piston with a carbon-cleaning agent.

USE AFTER RECONDITIONING

Failure Signs

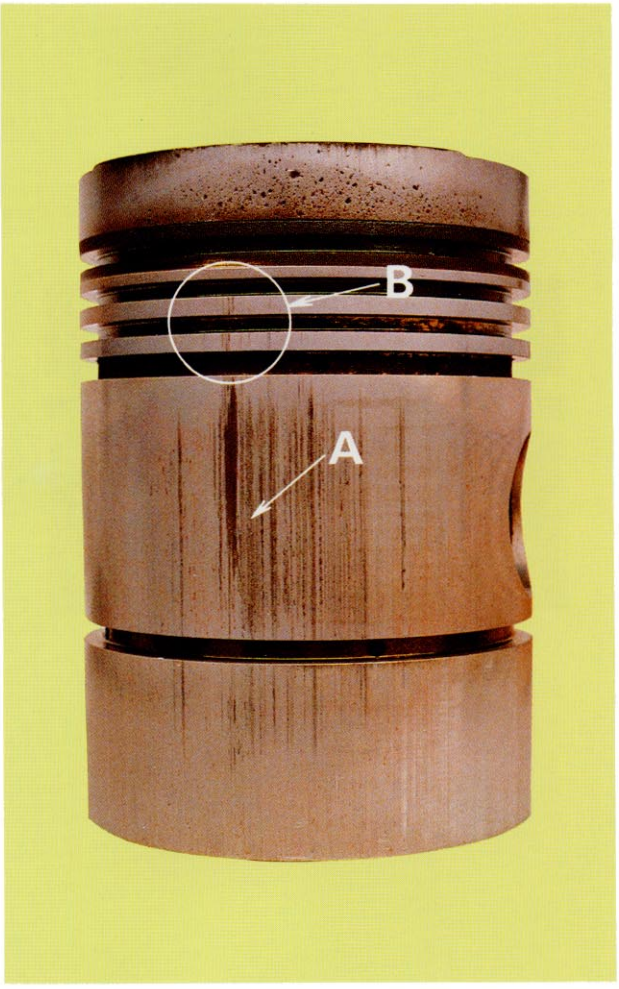
- Scratches on the piston top ring land area caused by carbon sticking to the top part of the cylinder liner.

Causes

- Presumably due to long hours of running under high-load condition.

Reconditioning Method

- Refinish the piston with a fine oil-stone and reassemble.



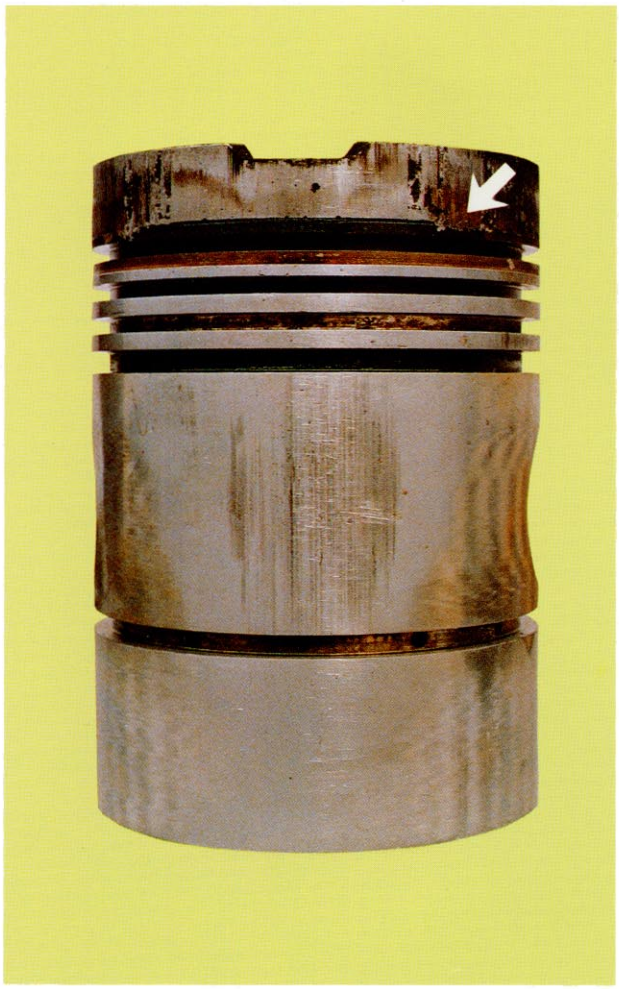
DO NOT USE AGAIN

Failure Signs

- Numerous lengthwise and fairly deep scratches (A) caused by lodging of foreign matter.
- Scuffing can be seen reaching to the ring land area (B).

Causes

- Presumably by, the entry of dust particles through the airintake system.



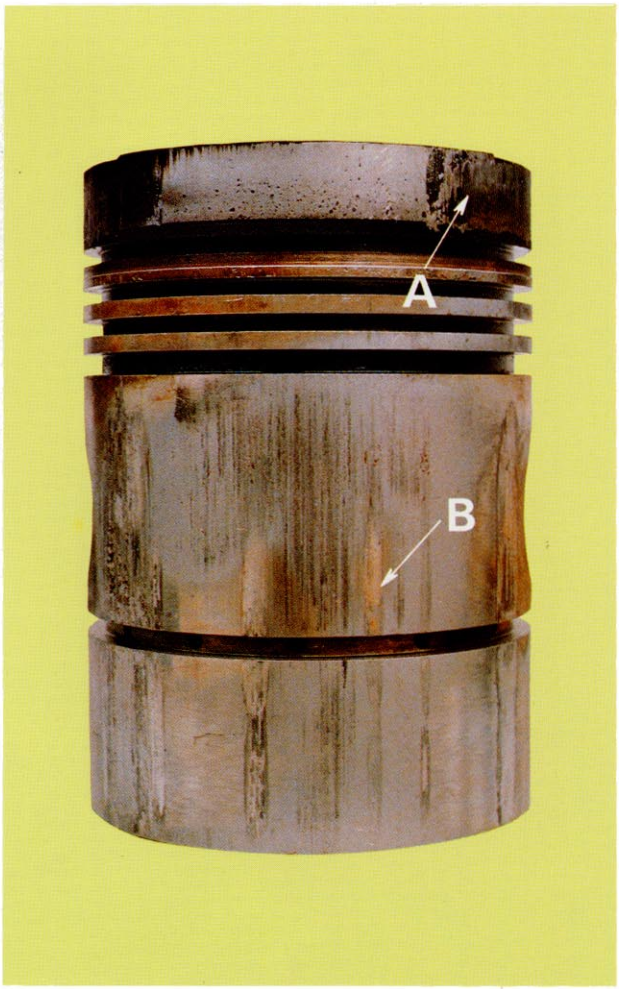
DO NOT USE AGAIN

Failure Signs

- Seizure of the piston top ring land area can be seen, with a part of the metal scratched-off.

Causes

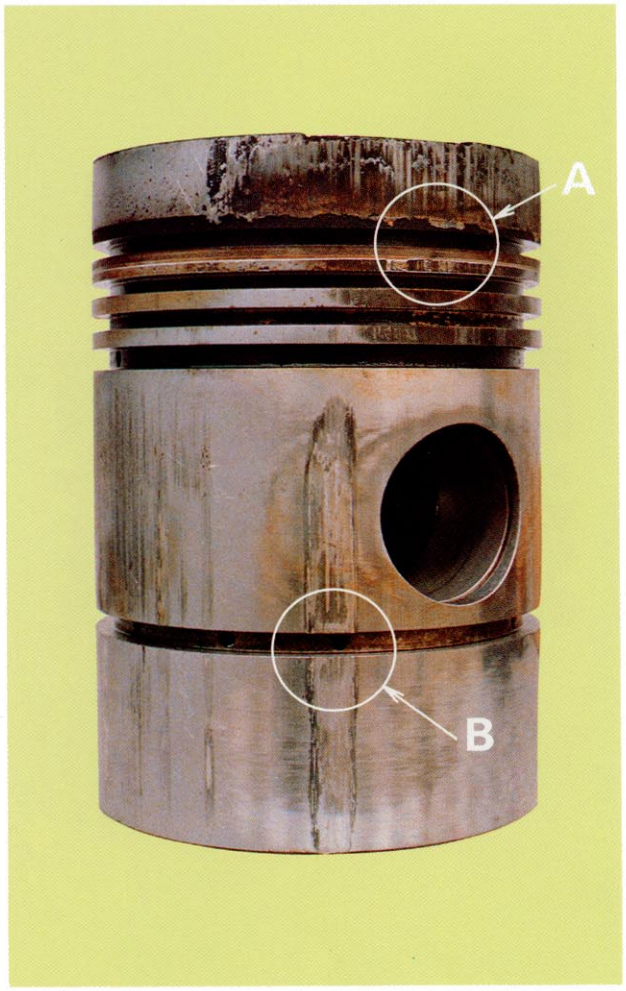
- Overfueling has caused overheating of the piston which in turn caused lack of clearance between top ring land area and cylinder liner.



DO NOT USE AGAIN

Failure Signs

- Seizure can be seen in the top ring land area and the piston skirt area.



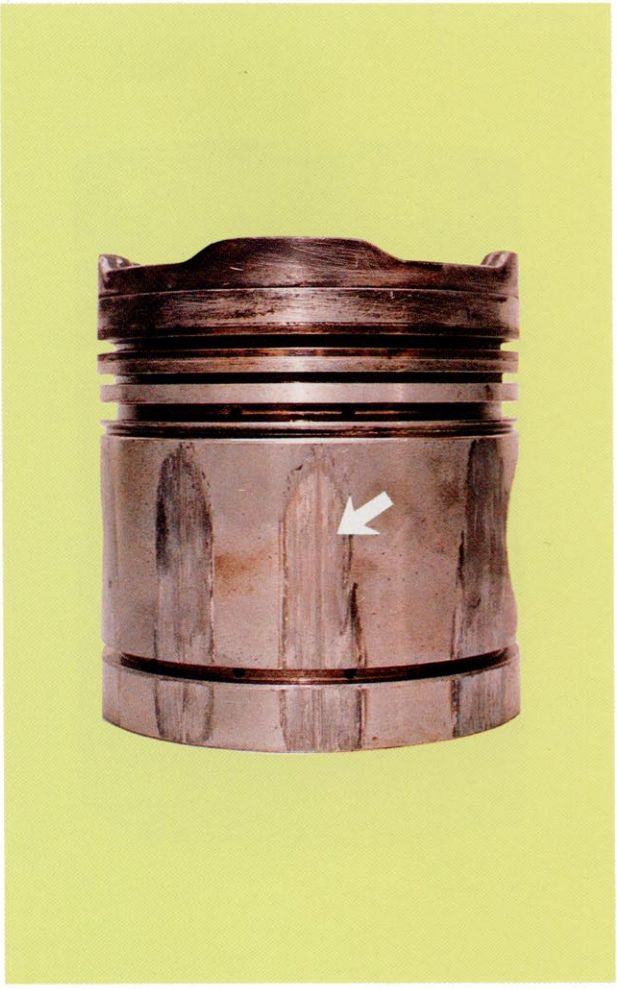
DO NOT USE AGAIN

Failure Signs

- Scurring at both the top ring land area (A) and skirt area (B) of the piston has caused seizure of the base metal.

Causes

- Damage to the top ring land area, above the pin boss is severe, presumably caused by overheating through overfueling.



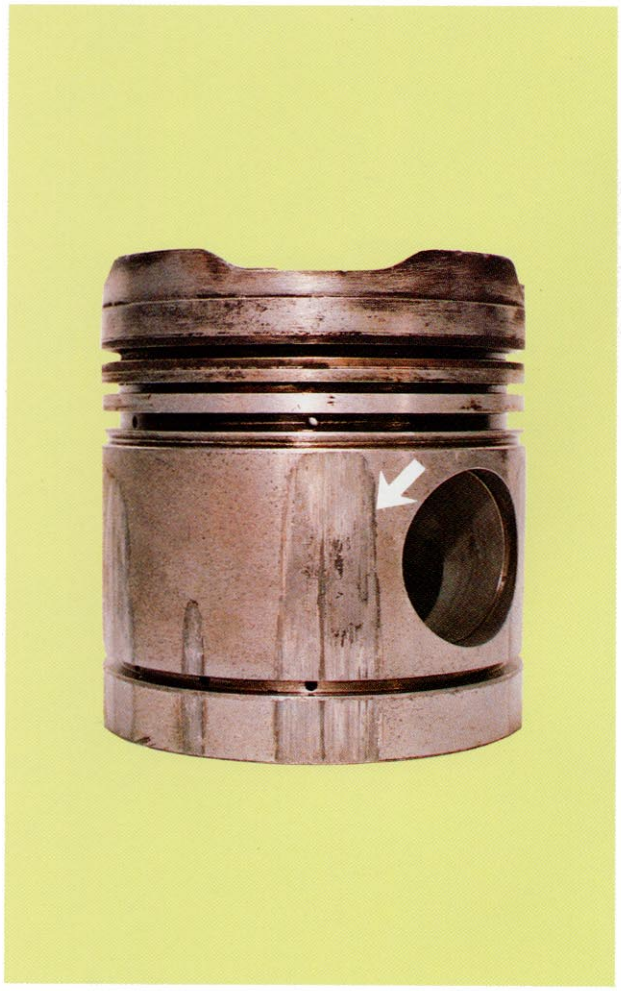
DO NOT USE AGAIN

Failure Signs

- Very severe scuffing.

Causes

- Overheating.



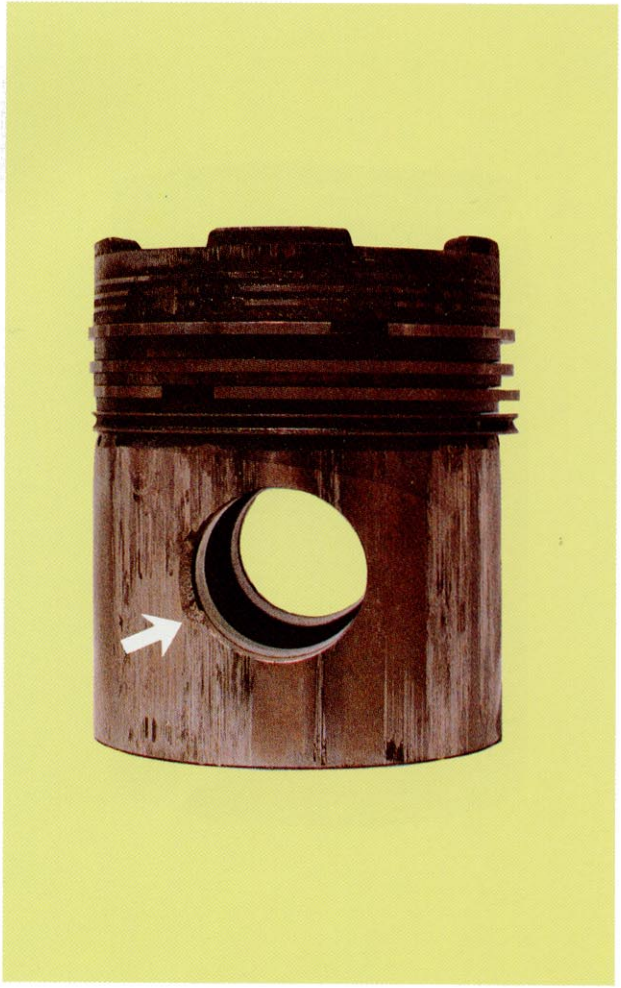
DO NOT USE AGAIN

Failure Signs

- Deep scuffing.

Causes

- Overheating.



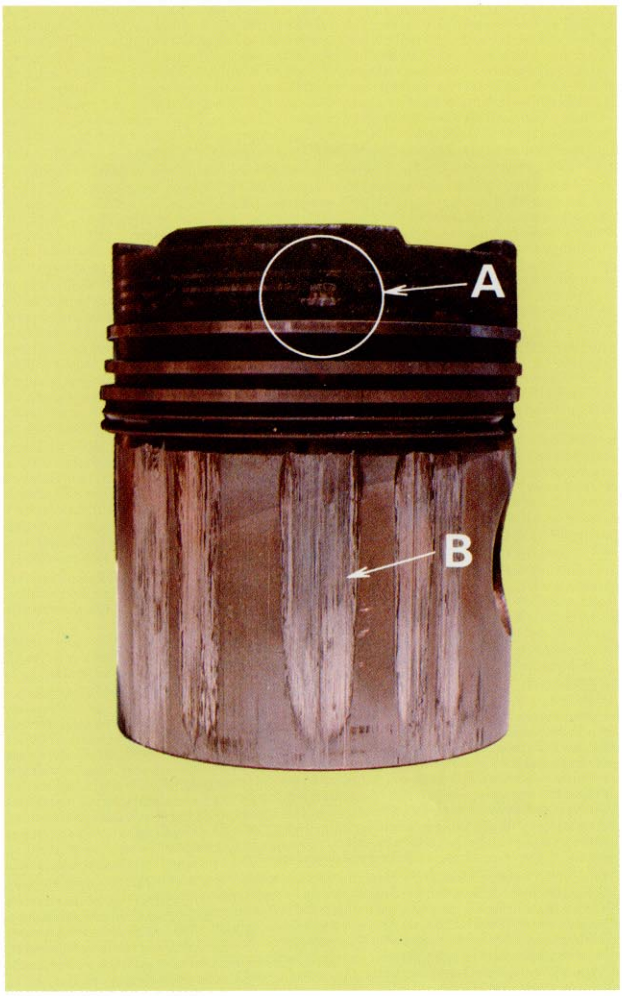
DO NOT USE AGAIN

Failure Signs

- Seizure of the piston skirt.

Causes

- Overheating.
- Overfueling.



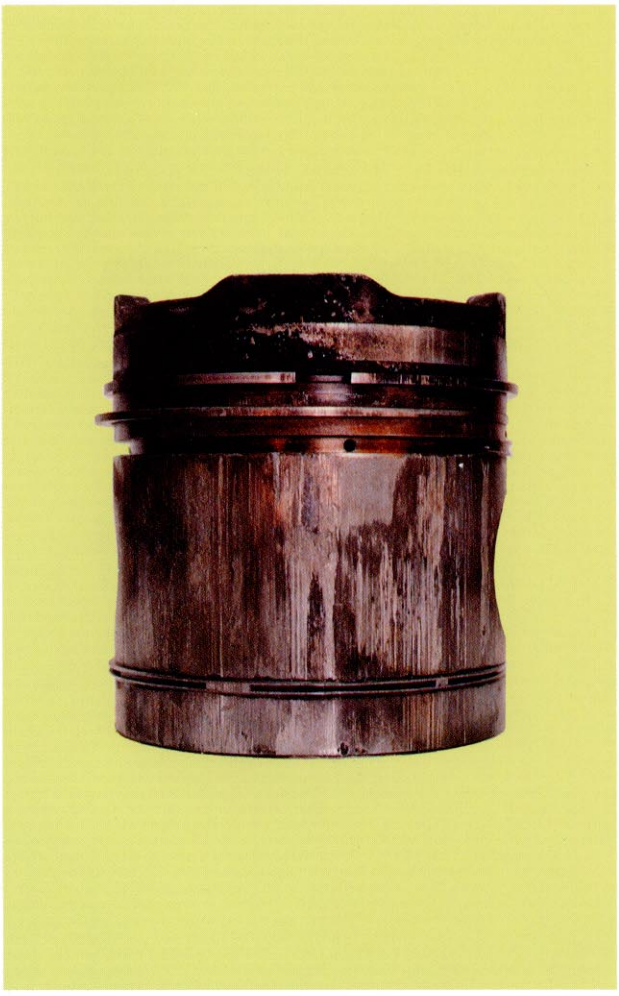
DO NOT USE AGAIN

Failure Signs

- Scuffing at both the top ring land (A) and skirt area (B).

Causes

- Use of poor quality engine oil.



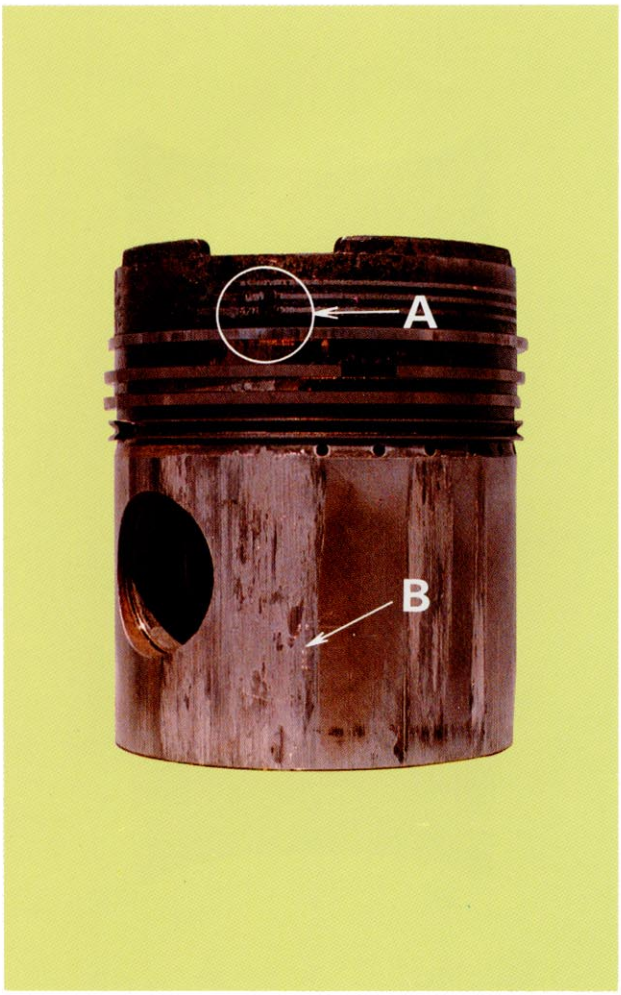
DO NOT USE AGAIN

Failure Signs

- Scuffing entirely covering the piston.

Causes

- Use of poor quality engine oil.
- Improper maintenance of engine oil exchange interval.
- Overheating.
- Overfueling.



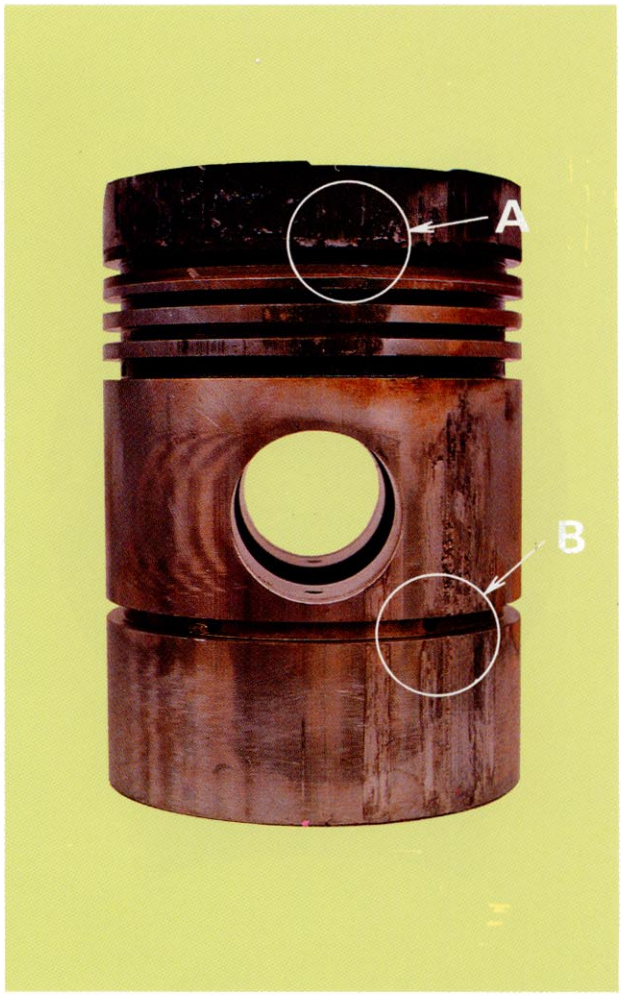
DO NOT USE AGAIN

Failure Signs

- Scuffing is spread over the ring lands (A), and skirt area (B).

Causes

- Use of poor quality engine oil.
- Improper maintenance of engine oil exchange interval.
- Overheating.



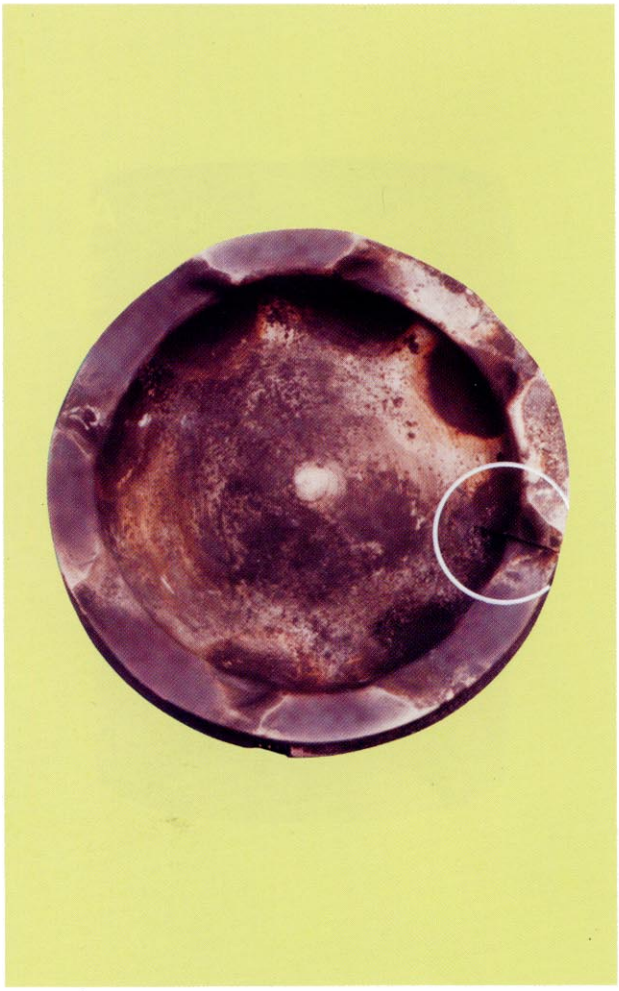
DO NOT USE AGAIN

Failure Signs

- Severe seizure and melting at top ring land area, (A) and relatively severe scuffing in skirt area (B).

Causes

- Overheating.



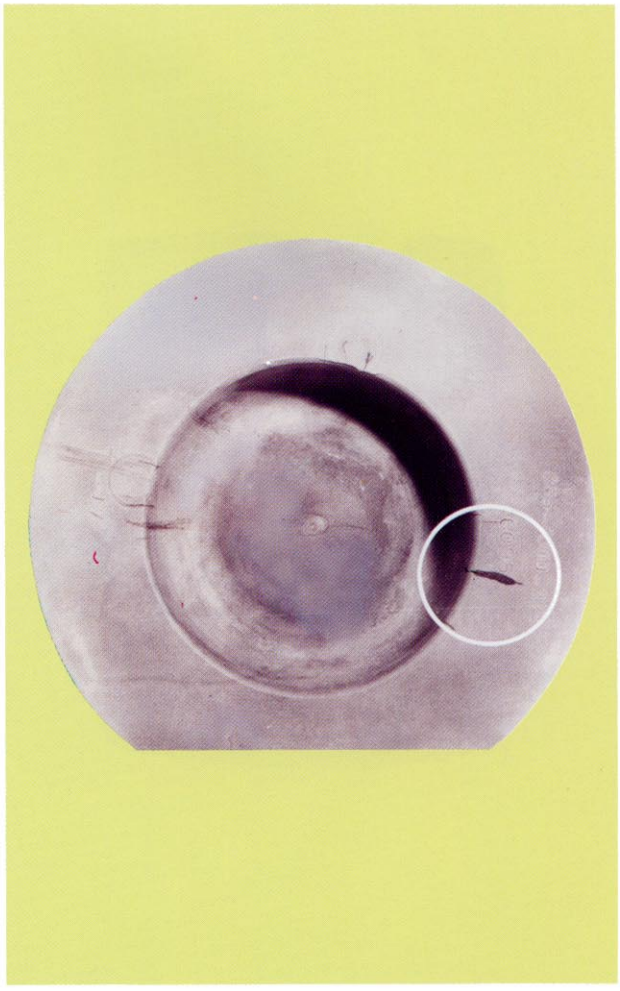
DO NOT USE AGAIN

Failure Signs

- Cracks have developed in the rim area of the piston top.

Causes

- Overfueling.
- Incorrect fuel injection timing.
- Clogged piston cooling nozzle.



DO NOT USE AGAIN

Failure Signs

- Cracks over 0.15 mm wide have developed in the area surrounding the piston's combustion chamber (in the case of a toroidal shaped combustion chamber).

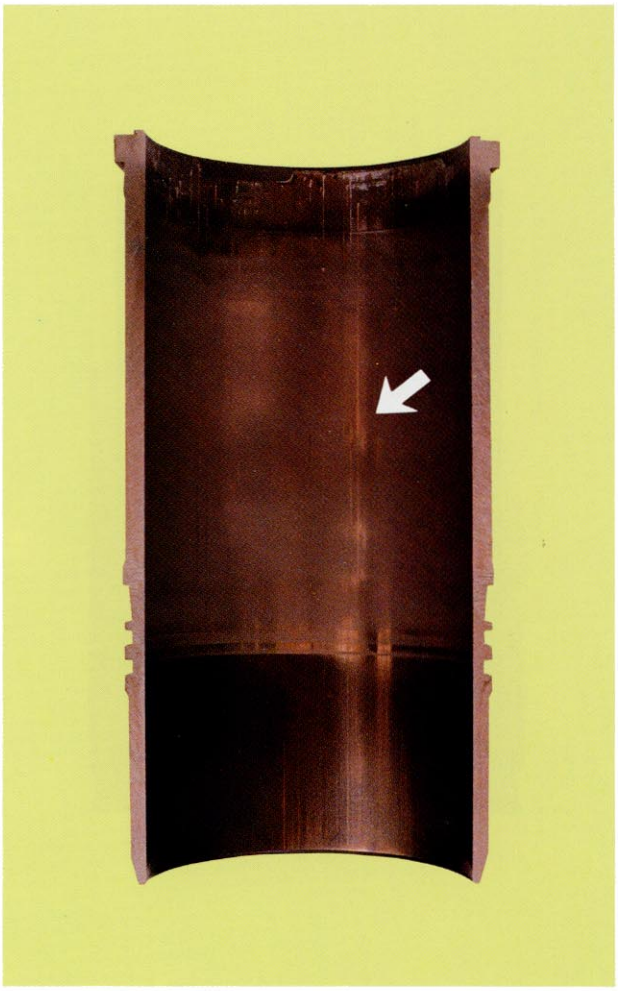
Causes

- Overfueling.
- Incorrect fuel injection timing.
- Clogged piston cooling nozzle.

USE AGAIN

Failure Signs

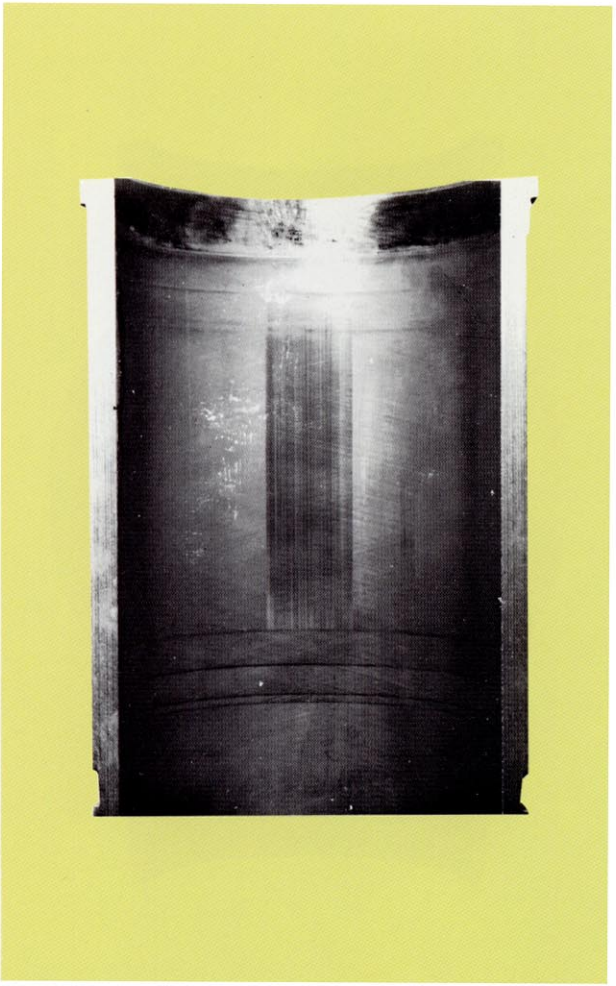
- Very slight lengthwise scratches can be seen on the inner surface of the cylinder liner, however, the cross-hatch finishing marks still remain over the entire inner surface, and its condition is generally good.



USE AFTER RECONDITIONING

Failures Signs

- There are some areas on the cylinder liner's interior surface that indicate slightly stronger contact than other areas, however, feeling the surface with a finger nail shows that such areas are smooth and not stepped.



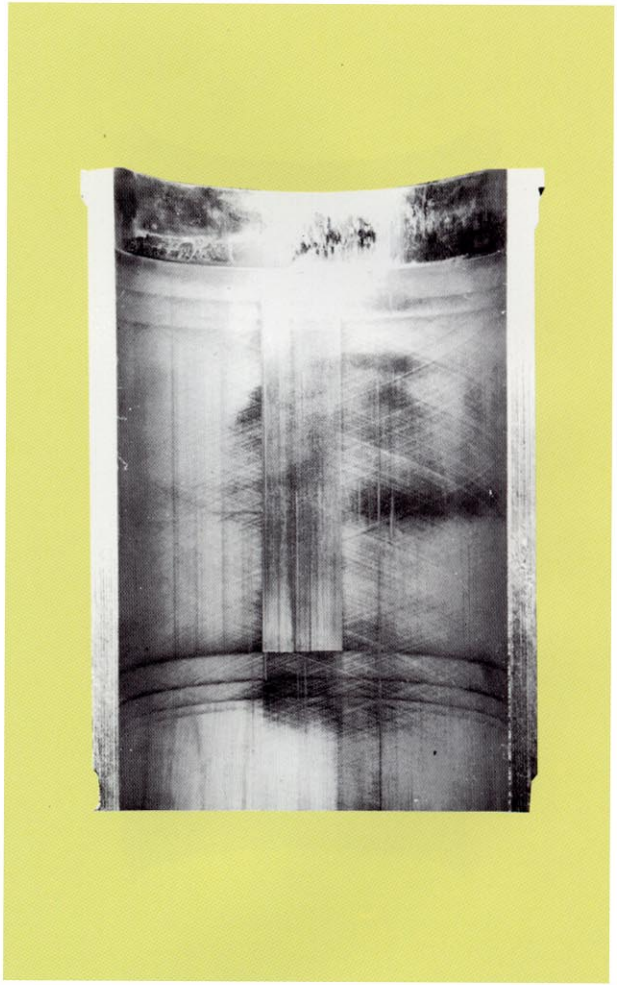
USE AFTER RECONDITIONING

Failure Signs

- Lengthwise scratches can be seen on the cylinder liner's inner surface, due to metal to metal contact by piston skirt and cylinder liner surface.
  However, since the scratches are extremely slight, the cross-hatch marks still remain.

Causes

- Fuel dilution into engine oil.
- Use of engine oil with too low viscosity.
- Overheating.



DO NOT USE AGAIN

Failure Signs

- The longitudinal scratches in the cylinder liner's inner surface have deepened and spread to erase the cross-hatch marks.

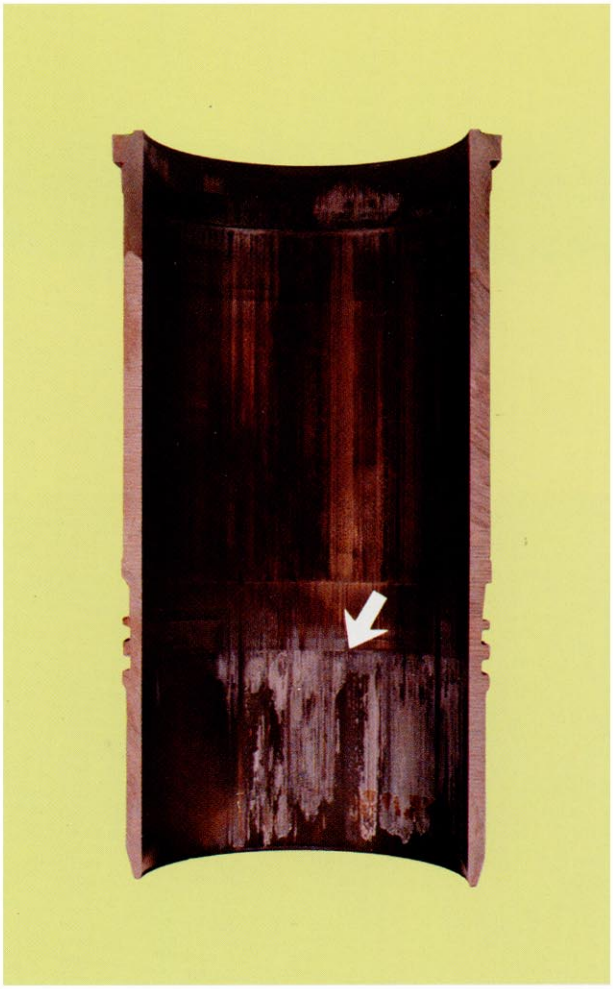
DO NOT USE AGAIN

Failure Signs

- Foreign matter has become lodged between the cylinder liner and the piston, causing deep longitudinal scratches.

Causes

- Entry of foreign matter.



DO NOT USE AGAIN

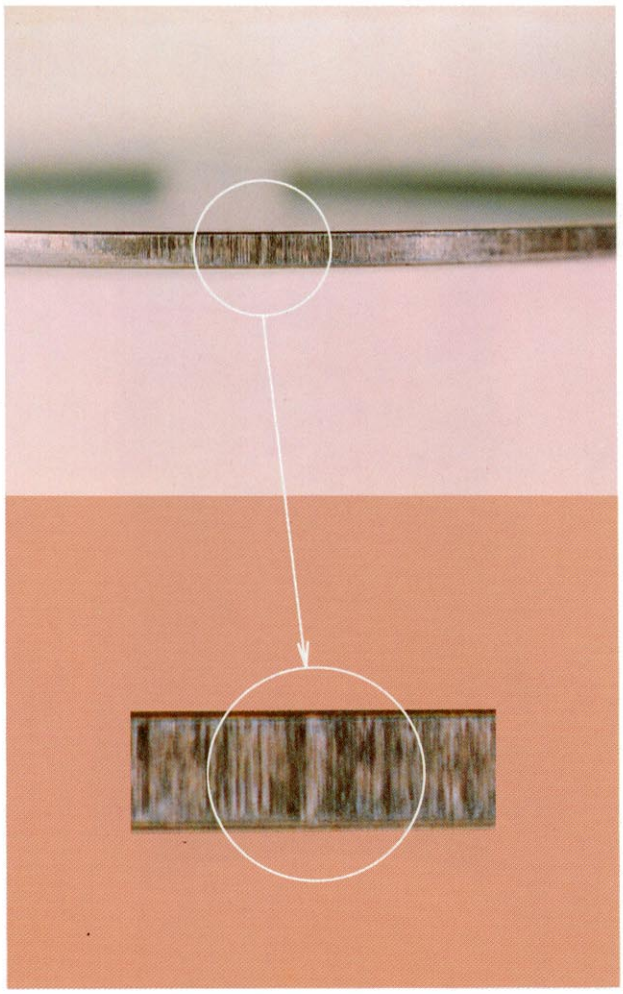
Failure Signs

- Piston seizure melting marks and lengthwise scratches can be seen on the inner surface of cylinder liner.

Causes

- Overheating.
- Overfueling.

Piston Rings



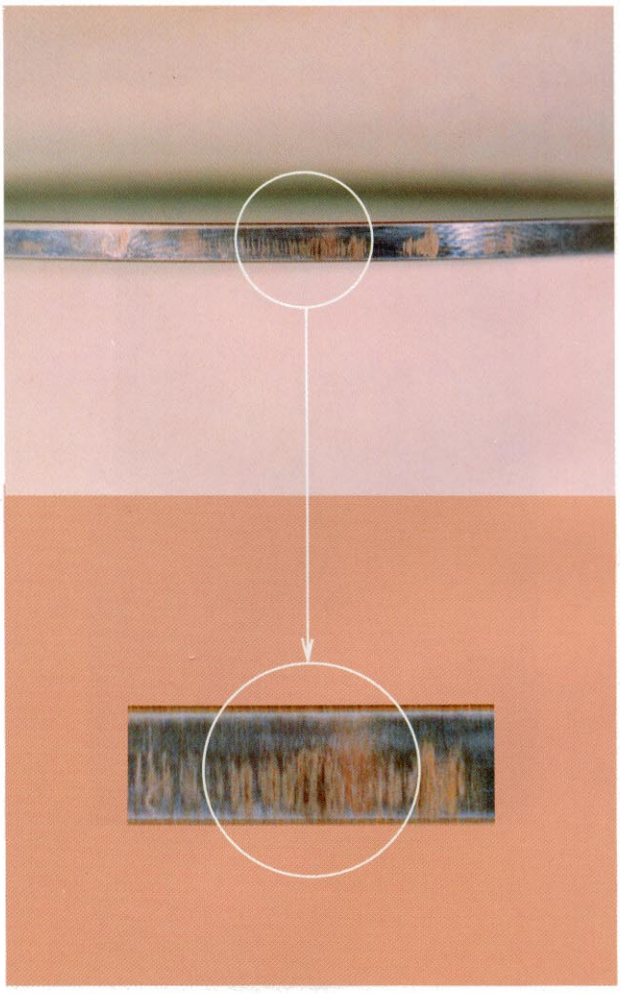
DO NOT USE AGAIN

Failure Signs

- Severe scuffing can be seen, and metal contact area is large.
- Chrome plating has been peeled off.

Causes

- Poor lubrication.
- Poor cooling.
- Overloaded operation.



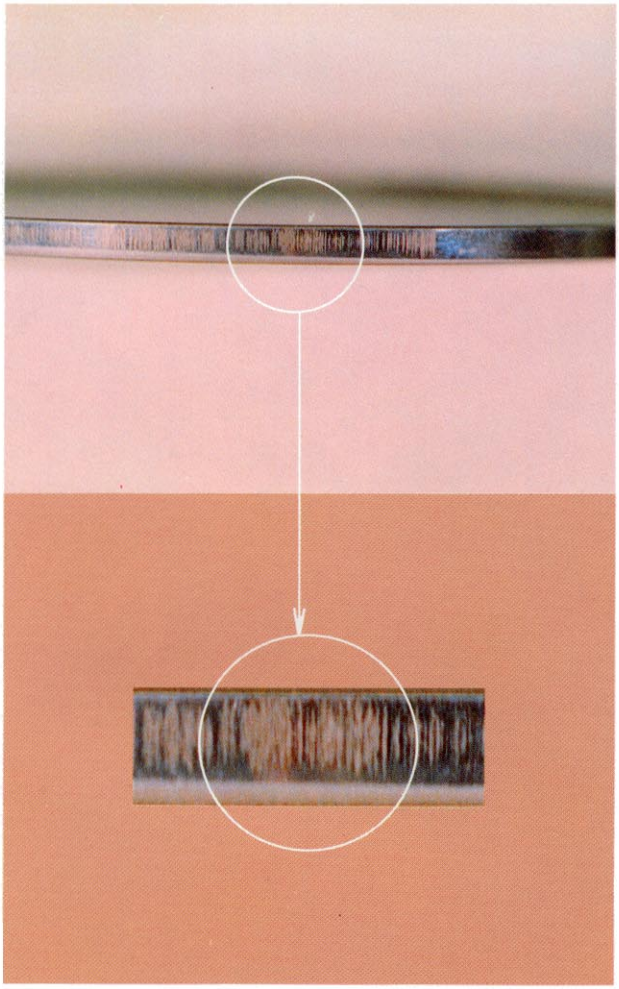
DO NOT USE AGAIN

Failures Signs

- Scuffing can be seen, and metal contact area is large.

Causes

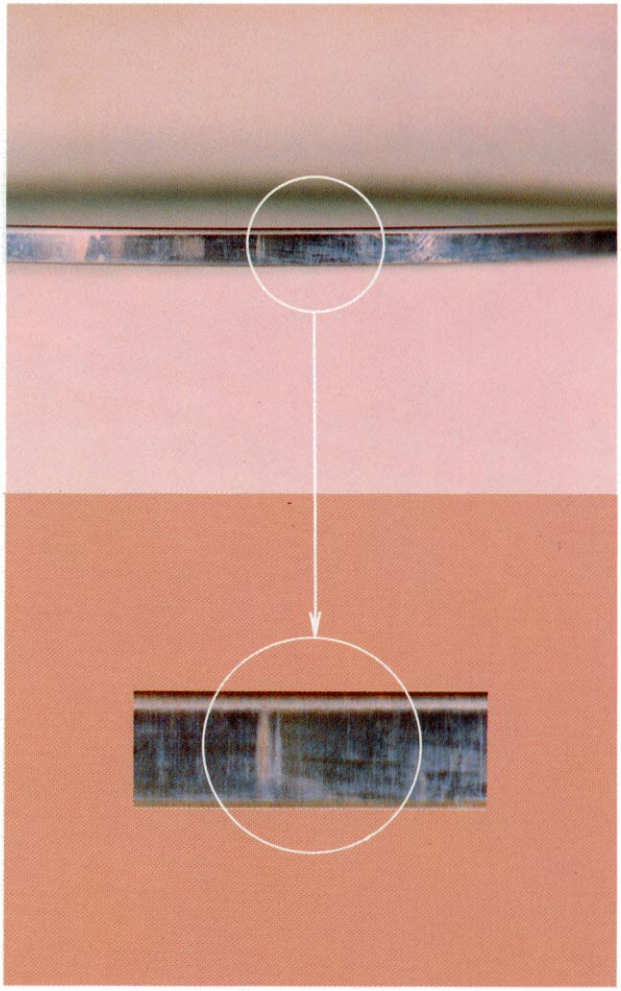
- Poor lubrication.
- Poor cooling.
- Overloaded operation.



DO NOT USE AGAIN

Failure Signs

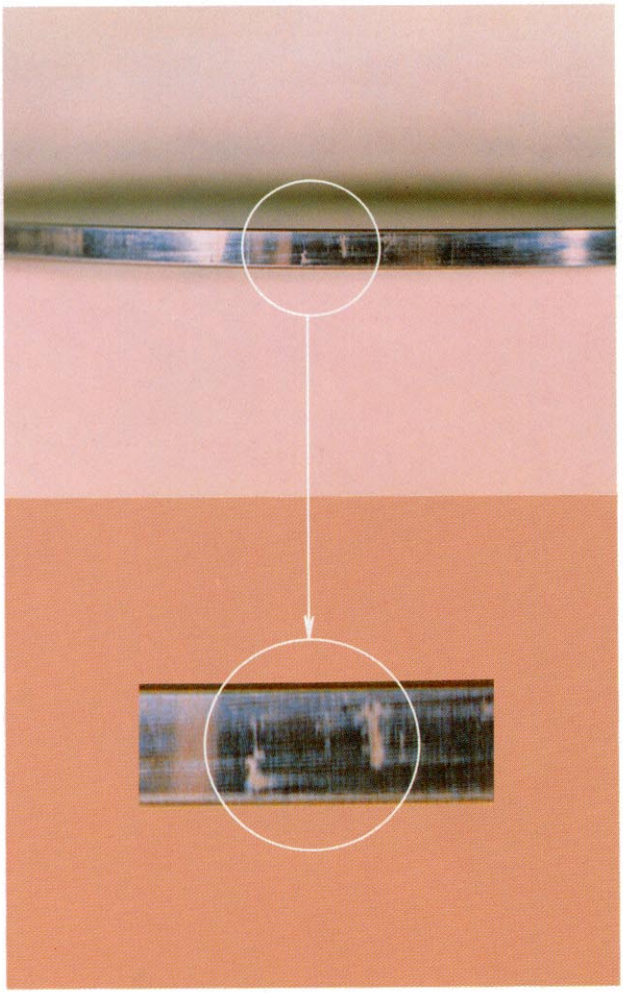
- Relatively severe scuffing can be seen, with a large area of contacting.



DO NOT USE AGAIN

Failure Signs

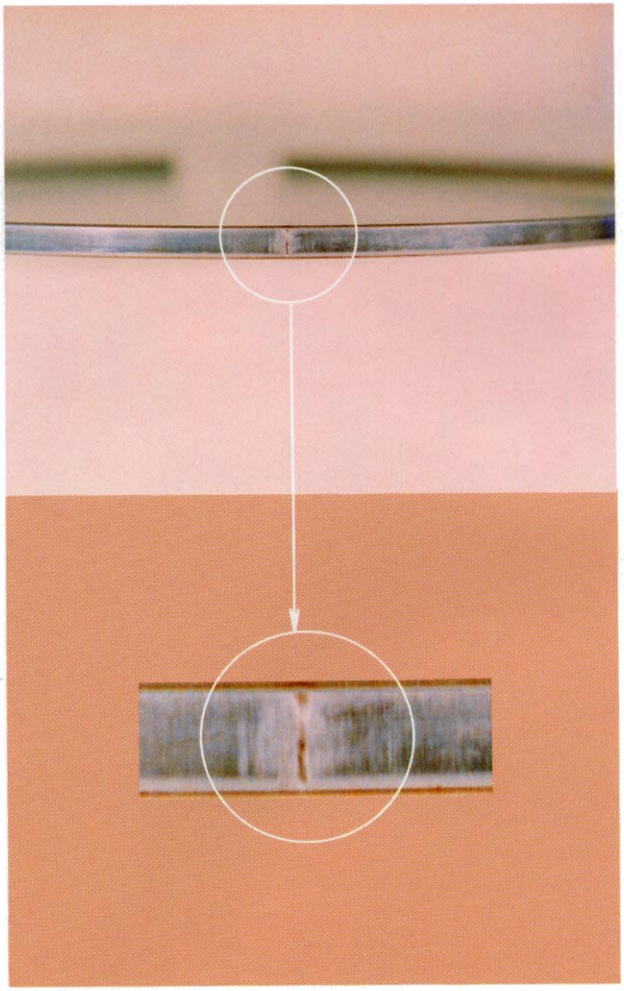
- Scuffing with metal-to-metal contacting.



DO NOT USE AGAIN

Failure Signs

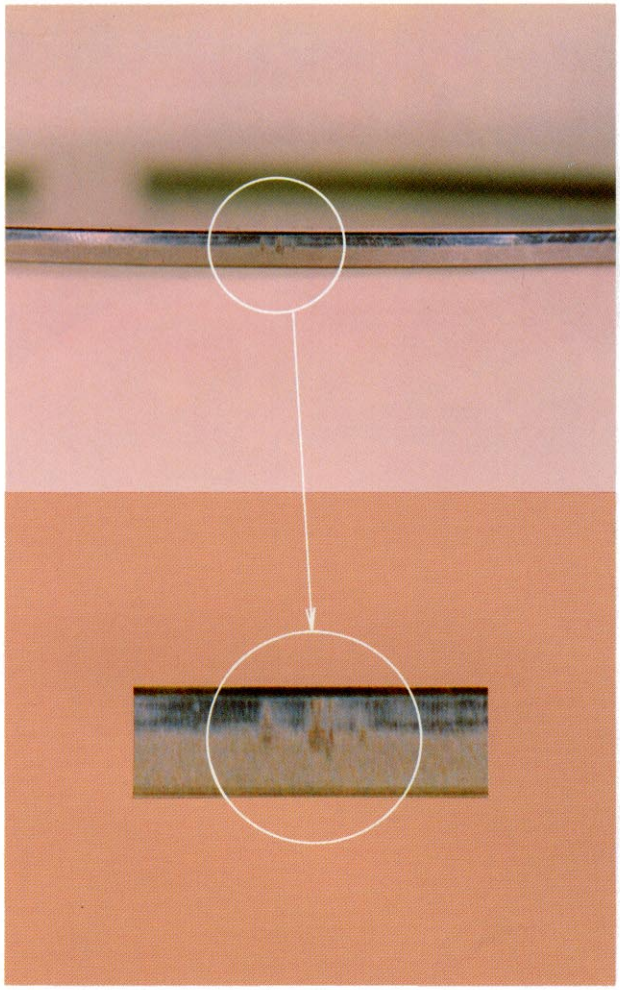
- Scuffing with wide contacting area, and discoloring of strong contacting areas.
  (Cracks in the chrome plating is suspected in these areas.)



DO NOT USE AGAIN

Failure Signs

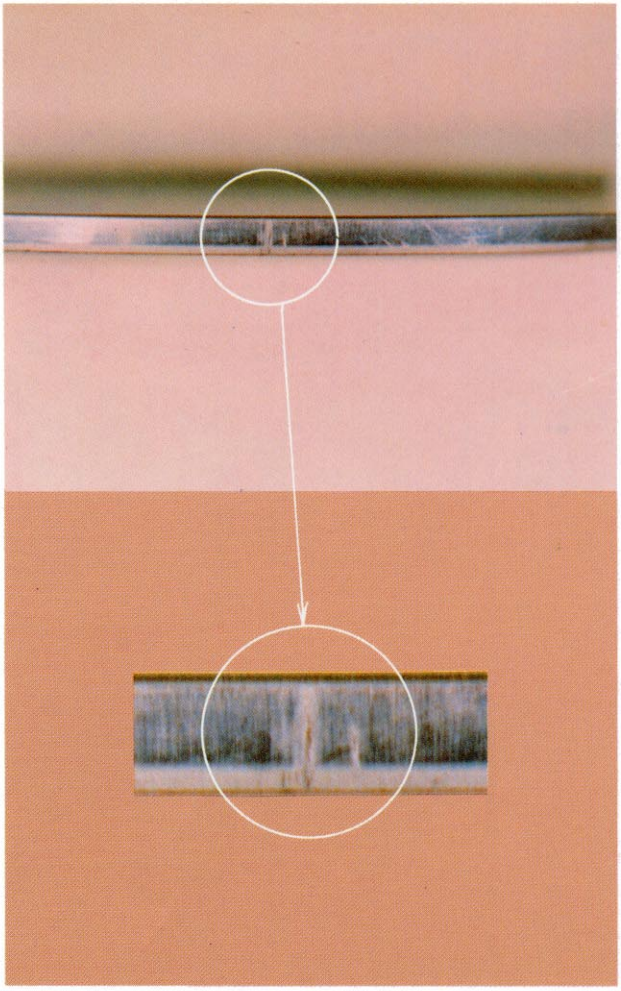
- Scuffing with wide contacting area.
  Heavy scratching, large enough to be felt by the finger-nail, and damage and absence of the chrome plating.
- The deep scratch may develop into a notch that will cause breakage.



DO NOT USE AGAIN

Failure Signs

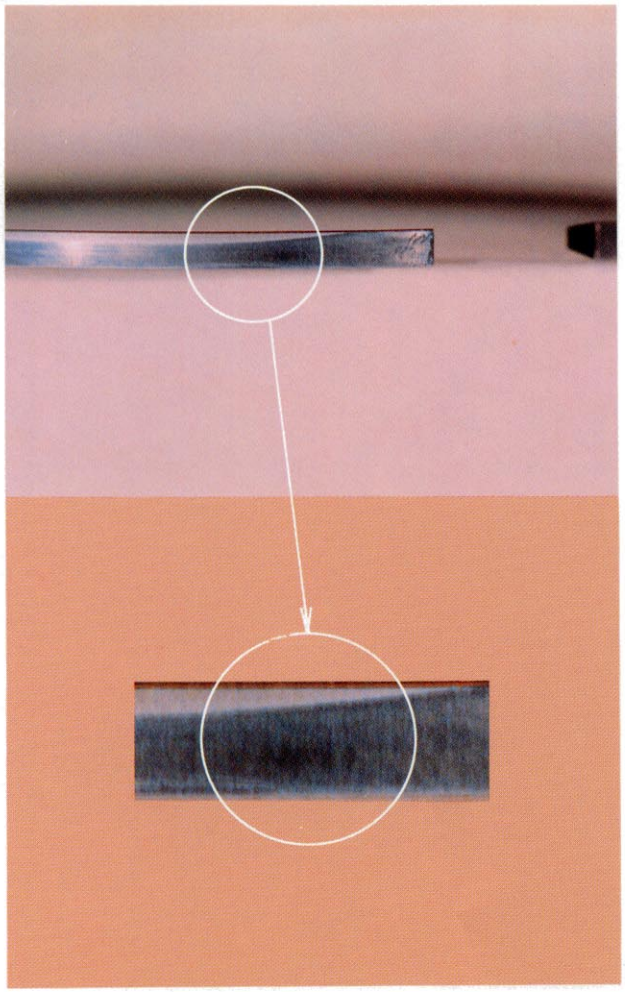
- Scuffing can be observed.
- Depth of the scratch mark is such that it can be just felt by the finger-nail.



DO NOT USE AGAIN

Failure Signs

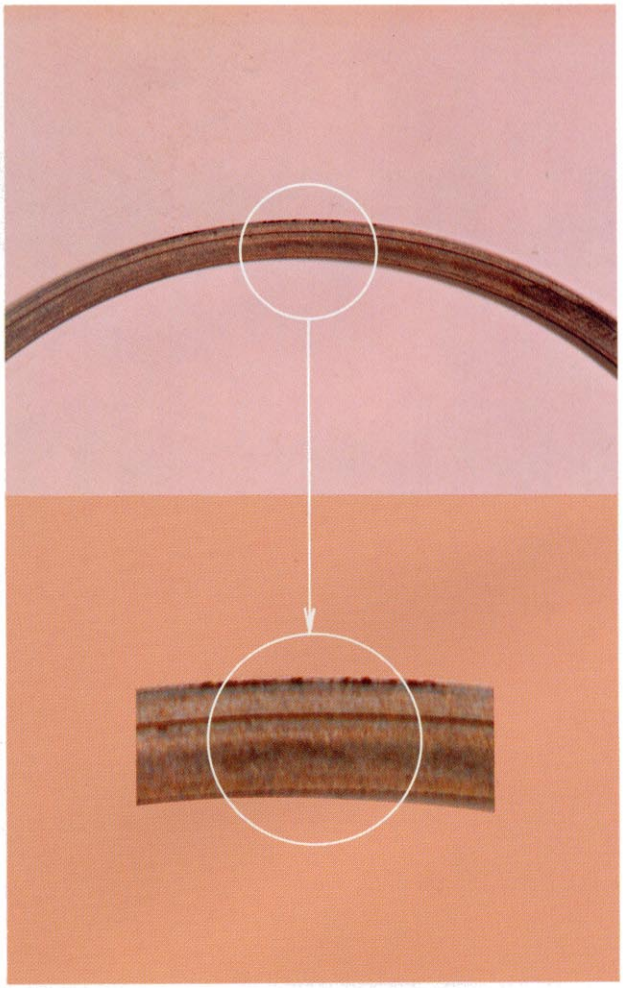
- Scuffing can be observed, depth of the scratches can be felt with the finger-nail.



DO NOT USE AGAIN

Failure Signs

- Excessive wear.



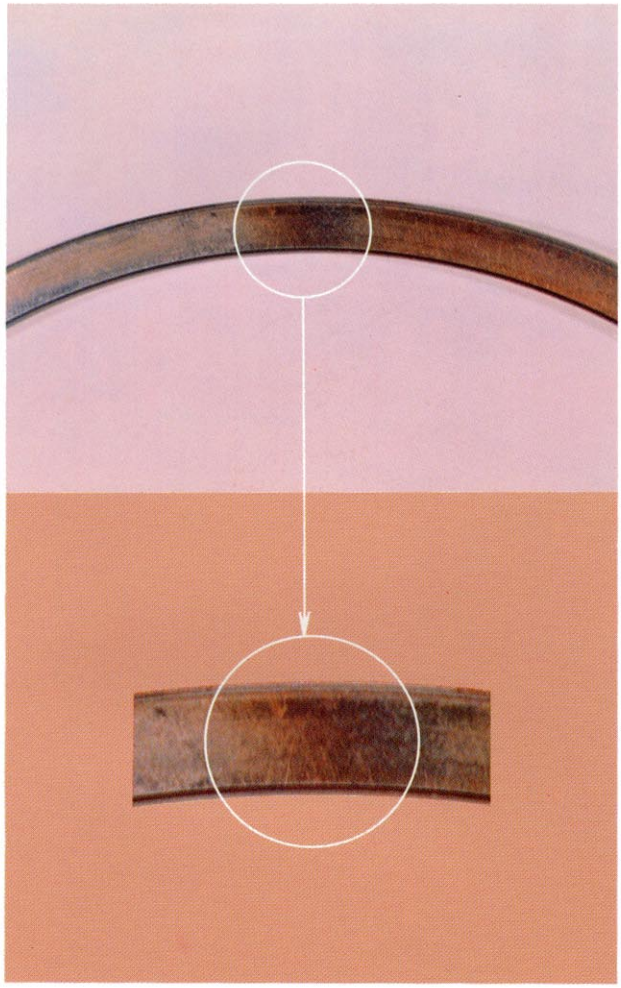
DO NOT USE AGAIN

Failure Signs

- Stepped wear discernable by the finger-nail, can be detected on the top and bottom surfaces of the piston ring.

Causes

- Poor maintenance of the airintake system has caused entry of dust.



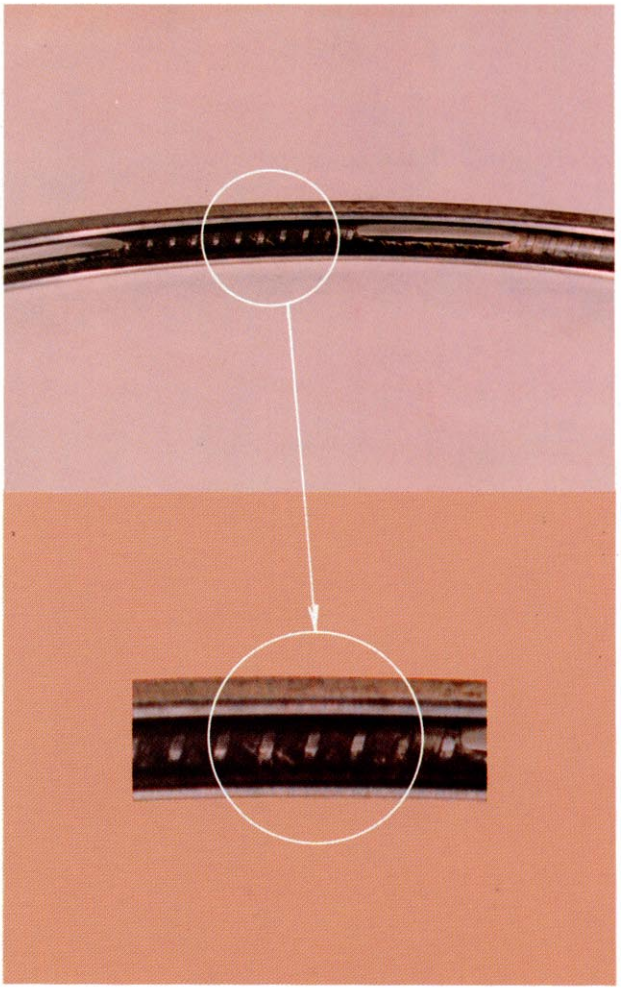
USE AGAIN

Failure Signs

- Partial discoloration can be seen in the piston ring's top and bottom surface.

Causes

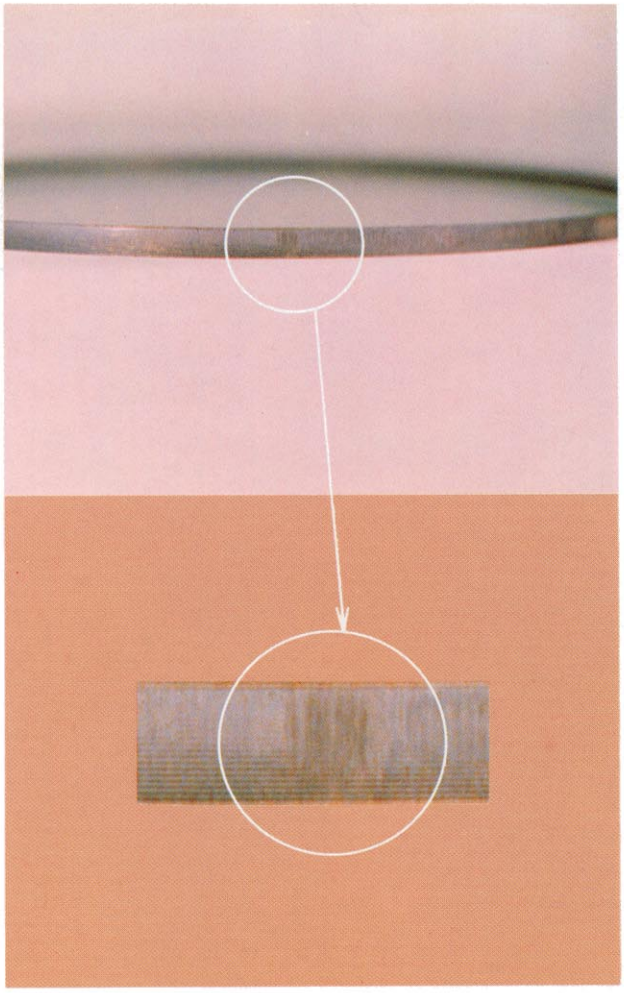
- Overheating.
- Poor lubrication.
- Overloaded operation.



USE AGAIN

Failure Signs

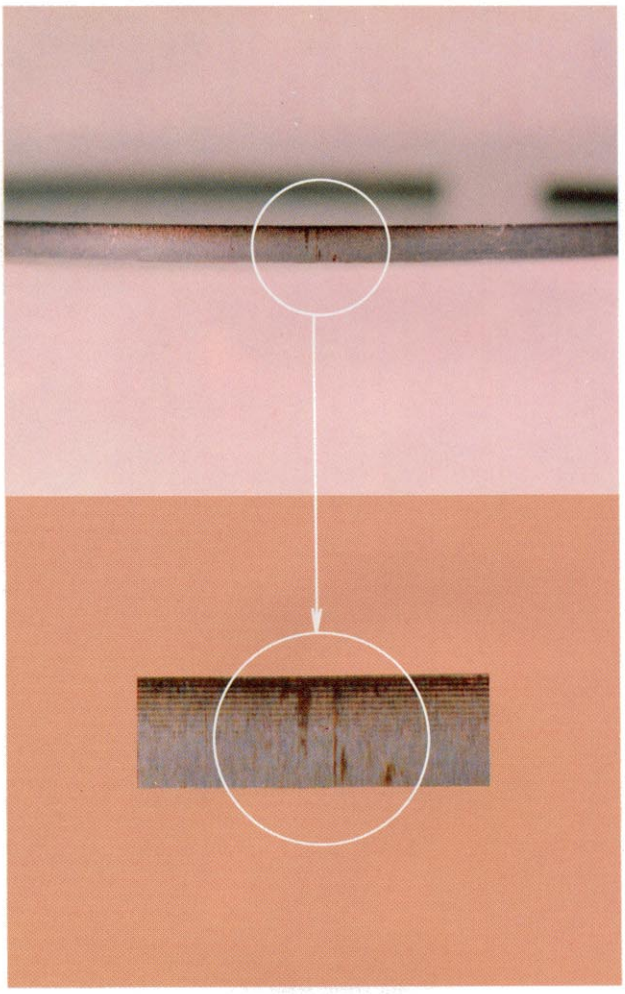
- Marks that can be felt with the finger-nail can be seen on the ring's inner circumference, caused by interference of the spring.



DO NOT USE AGAIN

Failure Signs

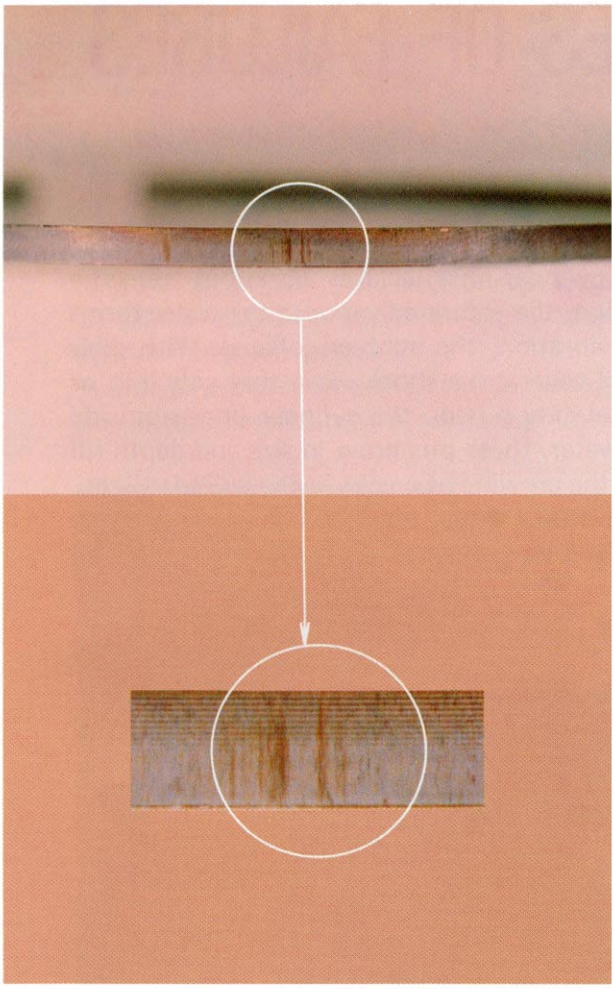
- Some scuffing can be seen, and scratches can be barely discerned by the finger-nail.



DO NOT USE AGAIN

Failure Signs

- Scuffing with scratches that can be readily discerned by the finger-nail.



DO NOT USE AGAIN

Failure Signs

- Scuffing with discoloration can be seen in areas where the contacting was heavy.

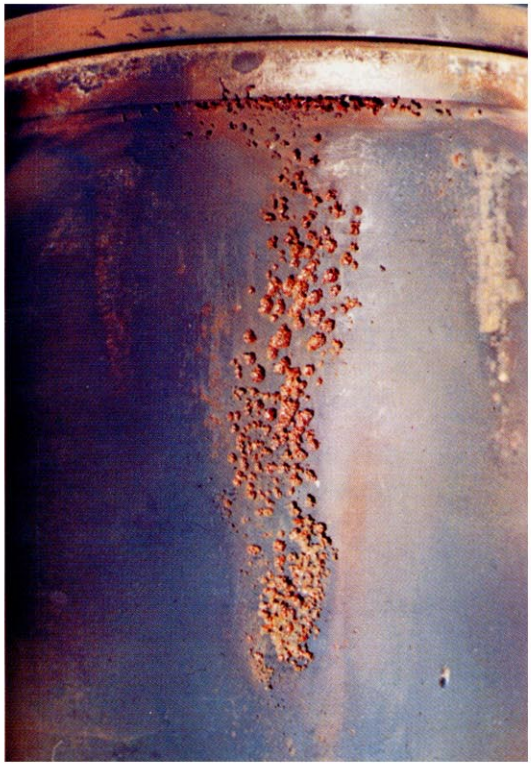
TYPICAL EXAMPLES OF FAILURES

Cylinder Liner Failures

Cavitation

A part of the cooling water surrounding the cylinder liner receives vibrations from the latter, first at the low pressure phase of a vibration, the saturated vapor in the water forms bubbles and at the high pressure phase of the vibration, the bubbles collapse. With their collapse, water rushes in to fill the void and this generates a shock wave that eats into or erodes the metal surface. The symptoms appear at tiny pits on the cylinder liner's outside wall surface that is in contact with the cooling water, these pits grow in size and depth till they penetrate the cylinder liner wall and induce the growing of cracks in the cylinder liner.

The cylinder liner wall side that receives the piston's thrust force and the opposite side are most susceptible to cavitation erosion which is concentrated more on the upper and lower parts of the cylinder liner.



Causes

- Abnormal and excessive vibration of the cylinder liner.
- Mixing of air (aeration) in the cooling water because of insufficient filling.
- Use of unsuitable cooling water.
- Dirt and foreign matter in the cooling water.

More specifically, the erosion develops where flow of the cooling water is retarded, as circular or streaked corrosion areas, mainly at the lower part of the cylinder liner or the cylinder liner seal parts.

Sludge produced by the erosion, scum, water fur, etc. tend to retard the water flow and this in turn accelerates the cavitation erosion.

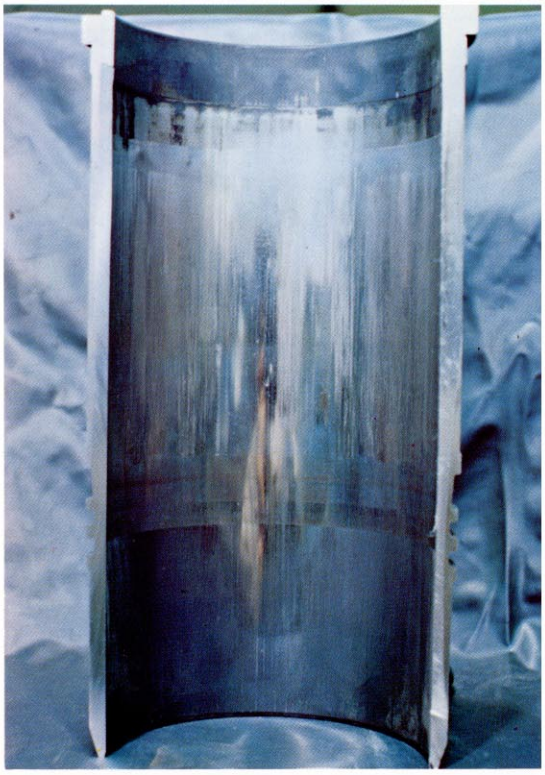
Cause

- Abnormal vibration of the cylinder liner.
- Use of unsuitable cooling water.
- Mixing of air (aeration) due to insufficient cooling water.
- Ineffective corrosion resistor.

Pistons Failures

Scuffing

The piston is in direct contact with the combustion gases and expands with the heat produced, but contracts when it is cooled by the engine oil, through the piston rings. When running, the piston continuously expands and contracts, so that if the clearance between the piston and the cylinder liner is too large or small, the oil film will be destroyed and the piston will make metal-to-metal contact with the cylinder liner, thereby producing seizure and scuffing. Symptoms appear as lengthwise seizure streaks in a part of the piston, particularly in the areas at right angles from the piston pin.

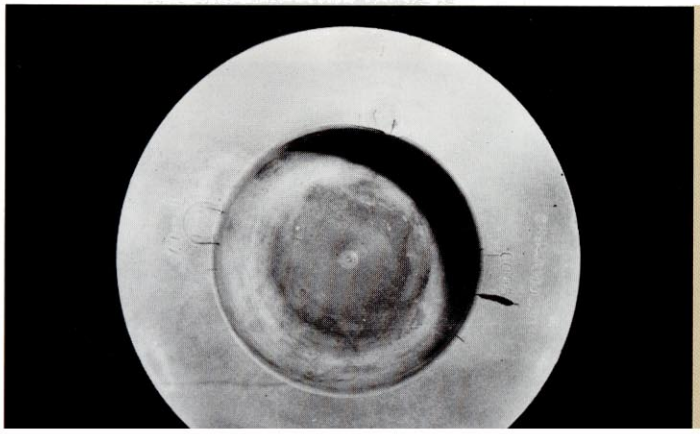


Causes

- Excessive expansion of the piston due to overheating.
- Sudden running under heavy load conditions and abrupt stopping.
- Use of unsuitable engine oil.
- Engine oil is insufficient, and pressure is low.
- Abnormal rise in engine oil temperature.
- Improper piston clearance.
- Entry of dust and foreign matter through the air intake system.

Hair Cracks

When the engine is running, the top surface of the piston is subjected to the high heat of combustion gases, and tends to expand, however the piston's perifery which is being cooled resists the expansion and causes stresses to develop in the heated area. If these stresses exceed the material's yield point, plastic deformation will occur and metal fatigue from heating and high temperature will cause cracks to develop.



A crack developed in the radial direction from the combustion chamber's edge towards the piston body's perifery caused by the temperature difference in the radial direction.

Cracks developed as a result of the heat stresses and combustion pressure stresses caused by the temperature difference in the piston top in the thickness direction.

Causes

- Localized overheating caused by mistiming of the fuel-injection.
- Overload running at high speed.
- Poor spraying of the injected fuel.
- Overfueling.

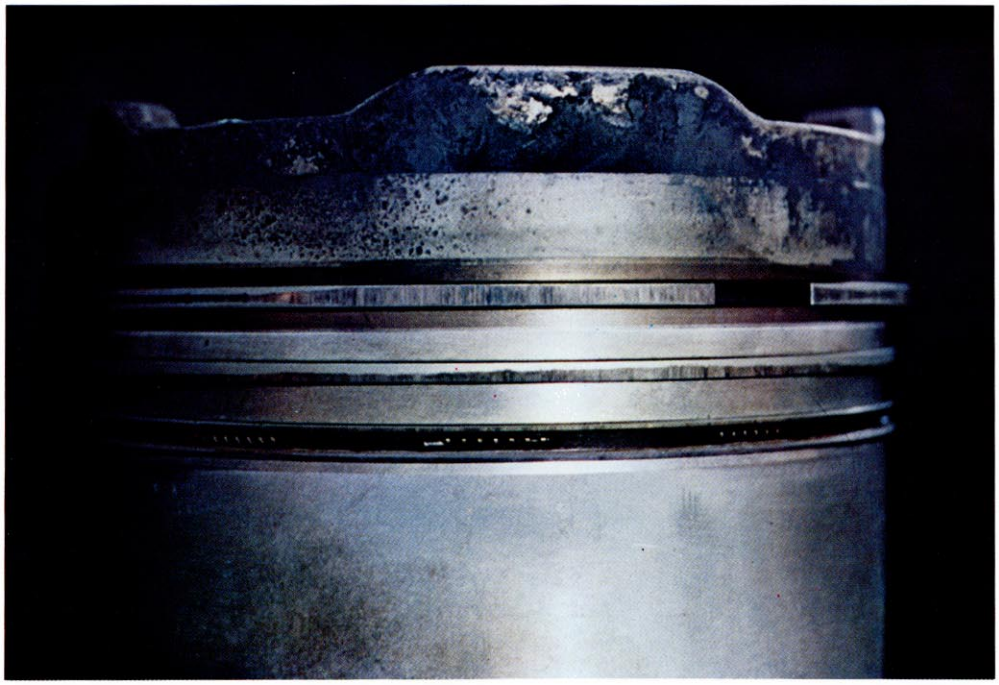
Piston Ring Failures

Scuffing of Piston Rings

Piston rings are always in contact with the cylinder liner wall and slide along the cylinder's axis. During the running-in period in particular, minute protrusions on both ring and cylinder liner sliding surfaces make microscopic metal-to-metal contact, as the engine is run under severe lubrication conditions.

If foreign matter enters from the air intake system, the protective oil film will be destroyed and seizure marks will develop.

Failures appear as scuffing marks on the entire perifery of the top ring and second ring.



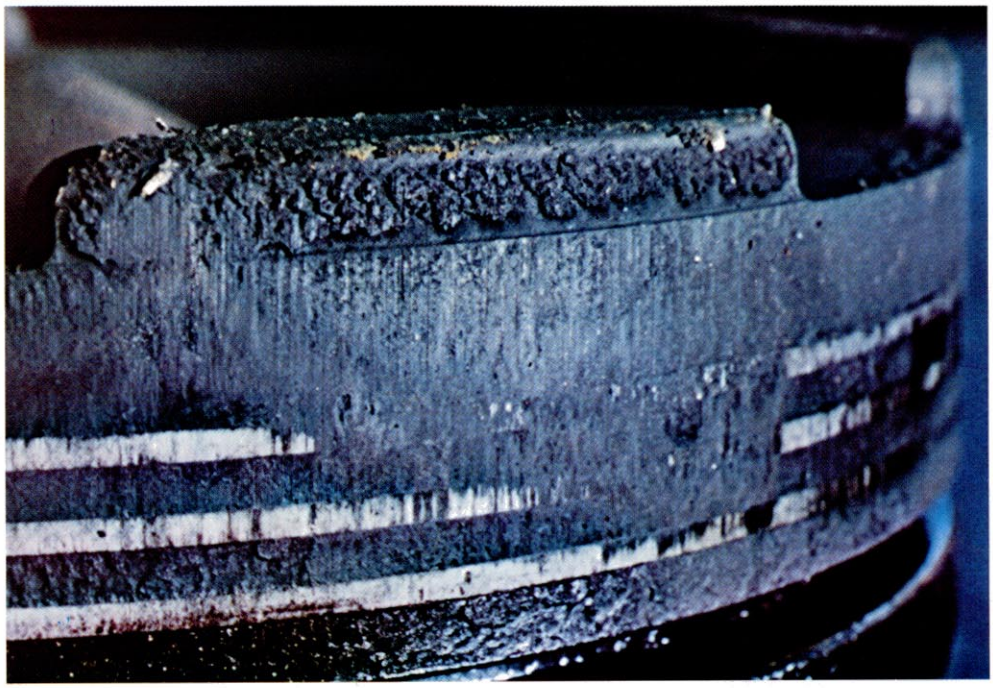
Causes

- Sudden acceleration to high speeds before sufficient running-in of engine.
- Entrance of dust and foreign matter through the air intake system.
- Use of improper engine oil.
- Scratches and damage on the piston rings.

Piston Ring Sticking

When high temperature sludge, low temperature sludge, or foreign matter clog the piston ring grooves, or when the rings become deformed at high temperature to clasp the grooves tightly, piston ring sticking will occur.

Symptoms appear in the case of high temperature sludge as, sticking of the top ring as a result of high temperature sludge deposits that have filled the top-piston ring grooves. In the case of low temperature sludge, the water and oil contained in the sludge is deposited in the lower ring grooves of the piston during low temperature running of the engine, causing sticking of the oil ring and the ring directly above it.



Causes

- Deterioration and oxidation of the engine oil.
- Too long an interval between engine oil changes.
- Dust and foreign matter enter from the air intake system.
- High speed running under overload conditions. Or, running at low temperatures.
- Use of poor quality fuel.

FAILURES AND THEIR CAUSES

Among the essential parts of an engine, the piston in particular, is subjected to compressive stresses, high temperature and high explosive pressure through its combustion, and repeatedly slides up and down at high speed using the cylinder liner as a guide.

Failures are the result of multiple causes, and the maintenance of lubricating oil and cooling water, and correct and proper operation and maintenance are essential factors in their prevention.

Lubricating Oil

The sliding surfaces of engine parts are 'lubricated, cooled, cleaned, and sealed', by the lubricating oil. As oxidation of the oil, however, progresses with the high temperatures to which it is exposed, blow-by of the combustion gases causes soiling of the oil, or mixing of water and fuel etc., will cause a drop in oil viscosity or deterioration of its properties as a lubricant. Furthermore, the selection of the type of engine oil most suitable for the ambient temperature is of great importance. If the viscosity is too high, difficulty in starting or increased friction loss will result whereas, if it is too low, the oil film will breakdown and metal-to-metal contact occur resulting in damage such as seizures etc.

Cooling Water

The cylinder liner's outer wall is surrounded by a water jacket, that cools the cylinder liner and prevents temperature rise in the combustion chamber. If unsuitable cooling water, e.g. hard or corrosive water, is used or if the quantity of cooling water is insufficient, or the function of the corrosion resistor has deteriorated, water furring or rust will develop and cause blocking of the coolant's flow resulting in inefficient cooling and overheating, which eventually will cause cavitation and erosion by pitting.

Air Intake (Dust)

Construction equipments usually operate under extremely dusty conditions, so that removal of the dust by an air-cleaner and filter is always resorted to. Breakage of the air-cleaner element, damage of the gaskets in the air-intake system, loosening of the clamps etc. will cause dust to be sucked into the engine, which in turn will result in damage to the piston ring's oil film and sliding surface, to cause scuffing and sticking of the piston rings.

Machine Operation

In running the engine, sufficient time should be allowed for engine warm-up, and care should be taken to see that the proper oil-pressure and temperature are maintained. Also, high engine speeds under heavy loading, sudden accelerations, or stops should be avoided. Unless the running-in of the engine has been completed, never attempt to suddenly accelerate the engine or operate it under heavy load conditions, otherwise the pistons, cylinder liners and other sliding parts that are still tight-fitting, will be run at high speeds to cause seizures and damage to them.

PREVENTIVE MAINTENANCE

Constant attention should be paid to check engine condition for, exhaust coloration, blow-by pressure, overheating, excessive oil consumption, low engine oil pressure, abnormal noise emission etc.

Furthermore, the proper follow-through of maintenance procedures outlined in the "operation and maintenance manual" will prevent the occurrence of the majority of failures. The customers' attention to the following items should be insisted upon in particular.

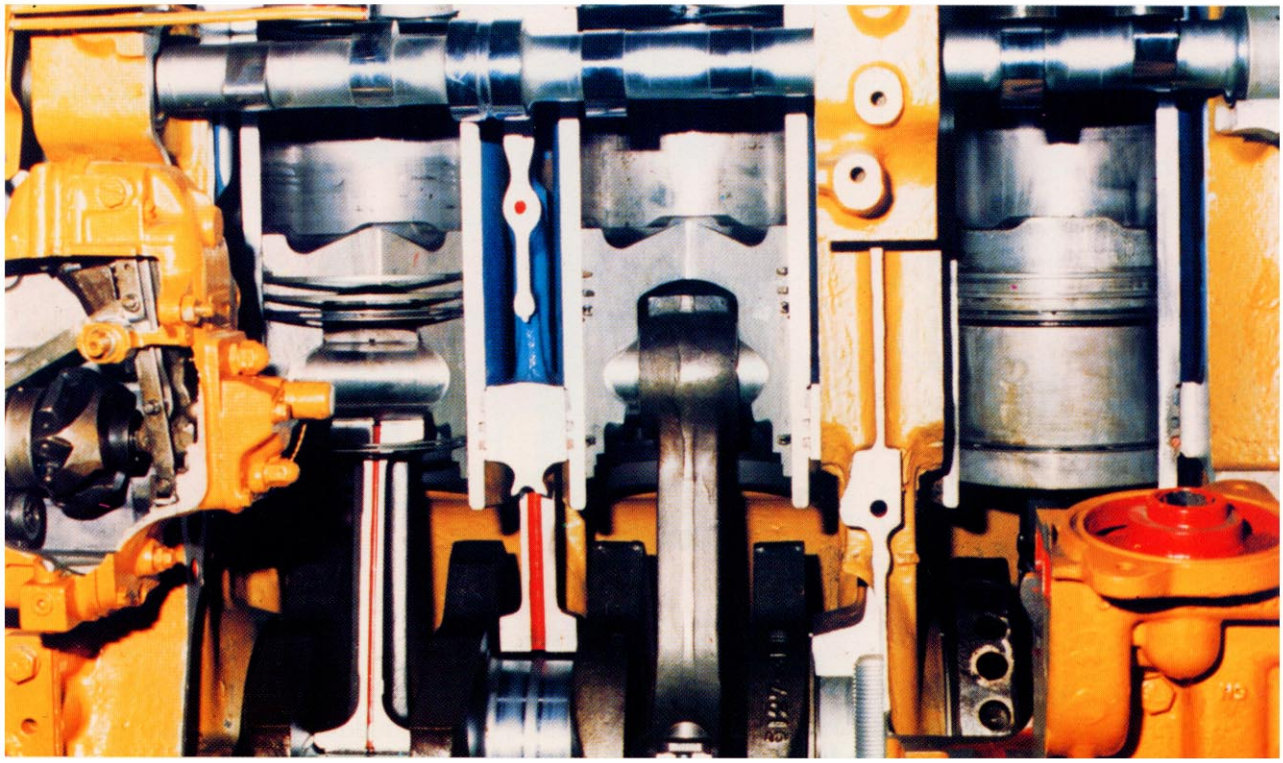
(1) Use Komatsu's specified lubricating oil, change engine oil at the designated intervals, and change oil type to match ambient temperature.
(2) Only use soft water (e.g. city-main water), never use dirty water, always fill the radiator completely; never run the engine with insufficient cooling water.
(3) Give sufficient time to warm-up the engine, refrain from sudden overloading, rapid engine acceleration, or sudden engine stopping.

The below-listed measuring instruments are available for correct failure determination.

Measuring instruments	Part Number	Measuring items
Blow-by checker	790-201-1502	To measure blow-by
Hydraulic tester	790-301-1103	Hydraulic oil pressure
Thermistor kit	790-500-1300	Water and oil temperature
Engine oil checker	799-201-6000	Water and fuel oil mixed in engine oil
Water tester	799-202-7000	Quality of water used for cooling
Smoke tester	Available on the market	Color of exhaust gas

Refer to the section on "Testing and adjusting", in the Shop Manual.

CONSTRUCTION AND FUNCTION

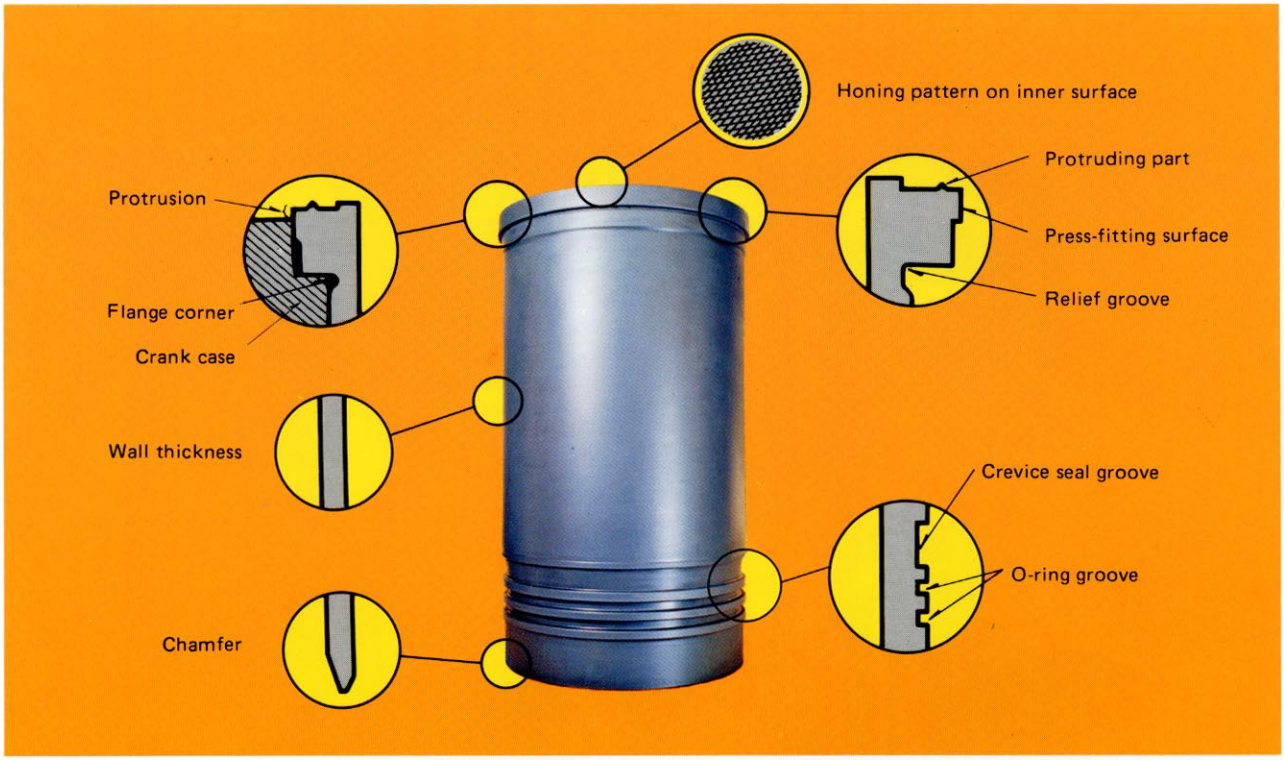


The cylinder liner and piston in conjunction with the cylinder head forms the combustion chamber.

Hot air is compressed and attains a high temperature in the formed chamber, into which the fuel is injected and fired, and the high pressure gas resulting from the explosive combustion pushes the piston down.

The up and down motion of the pistons guided by the cylinder liners is transmitted to the crankshaft by the connecting rods to change the reciprocal motion of the pistons to rotational motion of the crankshaft.

The compression rings installed in the piston keep the combustion chamber gas-tight, while the oil ring returns the engine oil spent in lubricating and cooling the piston, to the engine's oil pan, and prevents oil from seeping up into the combustion chamber.



Cylinder Liners

Construction of the Cylinder Liner

Since most of the engines used in construction equipments are of the water-cooled type, the cylinder liners used are of the replaceable cylindrical 'wet' type that is surrounded by the coolant.

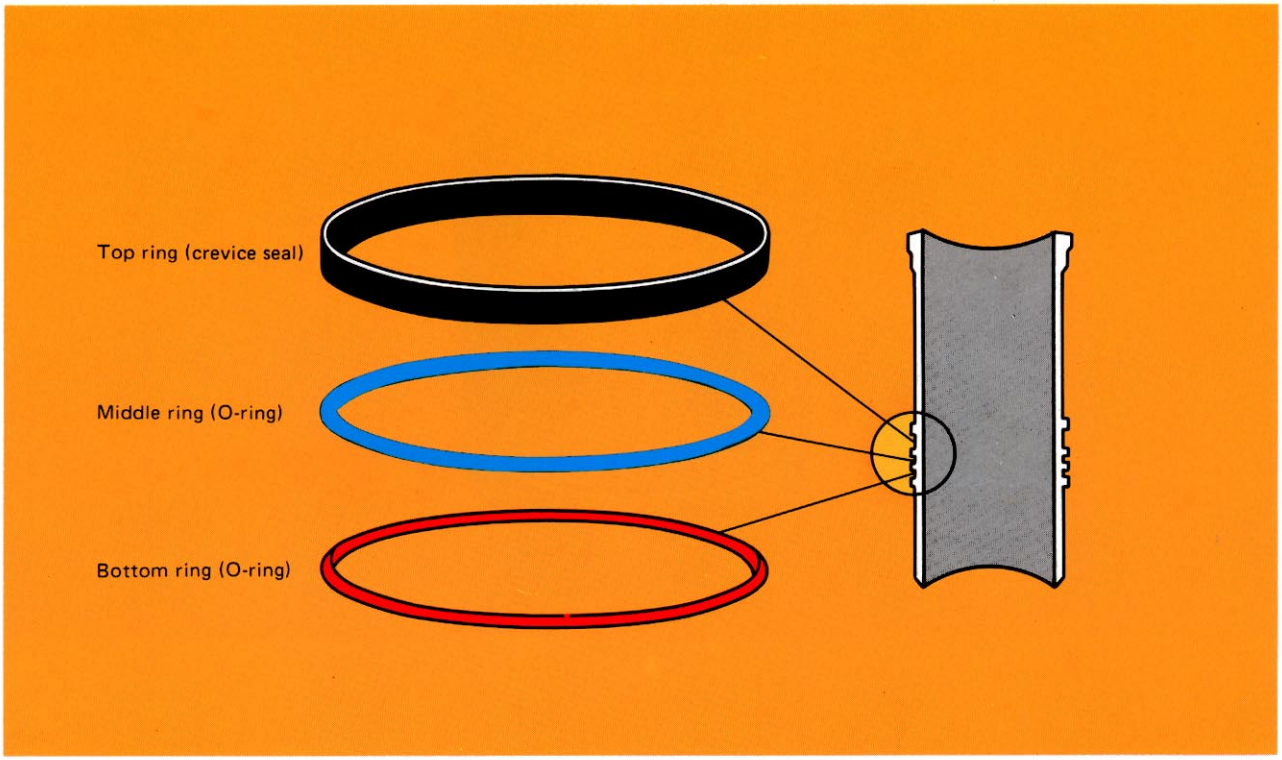
The illustration shows the nomenclature of a cylinder liner.

The external surface of the 'wet' type cylinder liner is directly cooled by the cooling-water, the top part is sealed off by the cylinder liner's flanged surface while the lower part is sealed by the cylinder liner's sealing rings.

Functions of the Cylinder Liner

The cylinder liner forms a part of the combustion chamber – completed by the piston top and cylinder head. And as such, must perform the following functions.

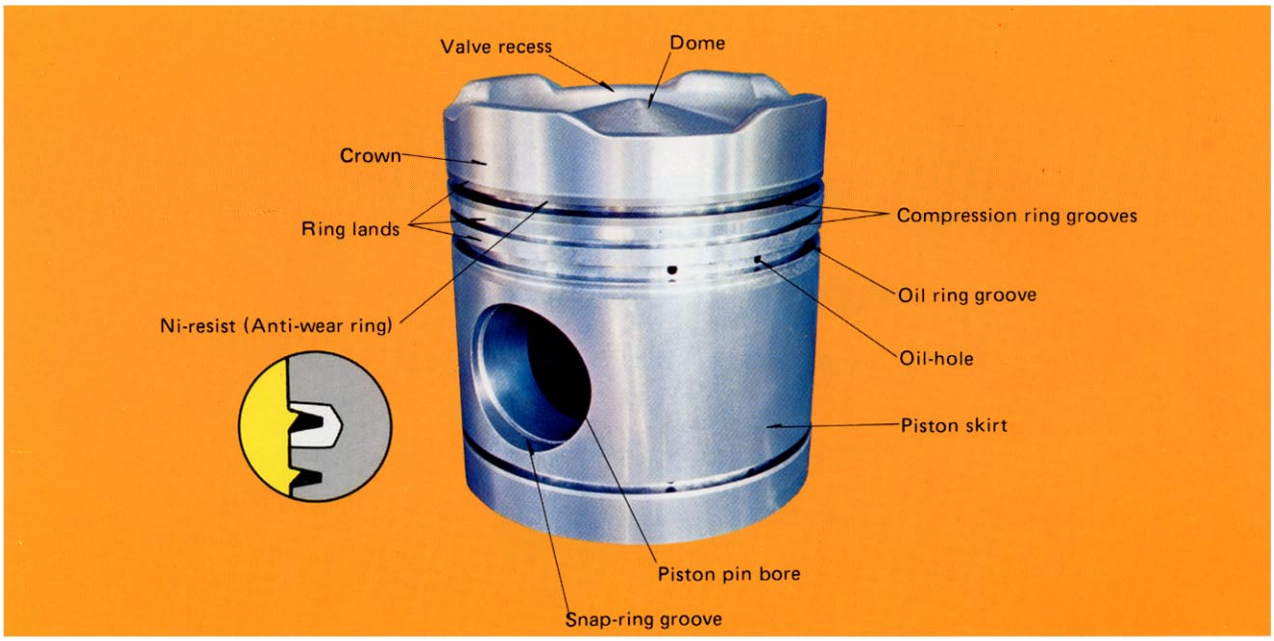
1) Standup against the extremely high combustion pressure.
2) Be able to transfer the high heat of combustion away from the chamber.
3) The seal between the water jacket and chamber must be complete with no leakage of the coolant.
4) Be of simple construction permitting easy checking and replacing of the individual parts.



Types and Shapes of Cylinder Liner Seal Ring

Crevice seal, Nytrile-rubber O-ring, Silicone-rubber O-ring, are the three types used as cylinder liner seal rings. The order in which they are usually assembled is shown in the illustration.

Type	Properties	Location
Crevice seal (Wide rubber ring)	• Durable. • Resistance to heat, water and vibration is excellent.	Top ring
Nytrile-rubber (O-ring)	• Durable. • Resistance to heat, and water is excellent.	Middle ring
Silicone-rubber (O-ring)	• Resistance to oil, high pressure, and heat is excellent.	Bottom ring

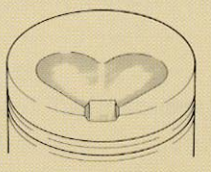
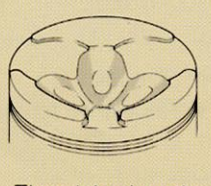
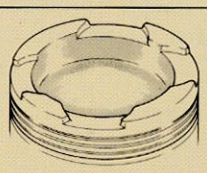
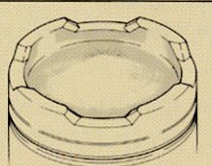
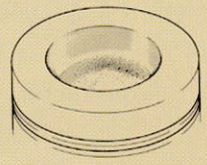


Pistons

Construction of the Piston

The top part of the piston takes on different shapes according to; combustion system, type of nozzle, fuel injection angle and location.

The illustration below shows the shapes of essential parts of a piston and their nomenclature.

Combustion system	Piston-head shape		
Pre-combution chamber type	 Two-lobe shaped	 Three-lobe shaped	
Direct fuel-injection type	 Toroidal shallow bowl shape	 Toroidal shallow bowl shape	 Toroidal deep bowl shape

Function of the Piston

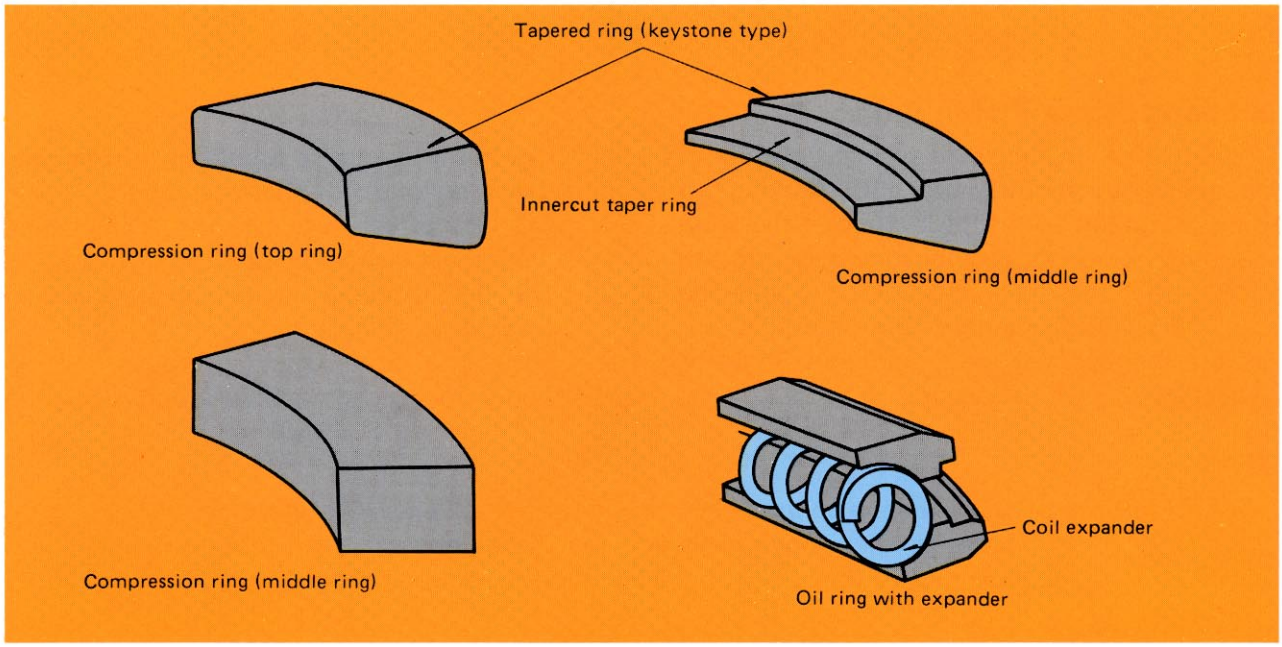
The piston forms a part of the engine's combustion chamber, together with the cylinder head, and cylinder liner. Its shape controls the mixing of the injected fuel and air, while the entire piston body transfers the explosive pressure to the crankshaft through the connecting rod. The piston also transfer the heat generated by the combustion through the piston rings and must have the following characteristics.

1) High durability under high temperatures and good heat transfer.
2) Low in mass (light weight).
3) Low thermal expansion coefficient.
4) High strength and resistance to ageing, good wearing properties, and ample strength.

Piston Ring

Construction of the Piston Rings

Piston rings differ according to, engine type, and where they are installed. The following illustration shows their basic designs.



Since the piston ring has a great effect on the oil consumption, as well as the wear and damage sustained by the cylinder liner, the number of rings and their shape should be matched to the engine type.

Examples of piston ring combinations

Top ring	Keystone taper	Flat barrel	Keystone barrel	Oblong barrle	Oblong barrle	Keystone taper	Keystone barrel
Second ring	Taper face	Taper face	Taper innercut		Innercut	Innercut	Keystone innercut
Third ring						Coil expander	Keystone innercut
Oil ring	expander	Coil expander	Coil expander		Coil expander	Coil expander	Double keystone

Functions of the Piston Ring

Piston rings are subjected to high pressure at high temperatures, they also must stand-up to sliding motion at high speeds while at the same time must keep the combustion gas pressure sealed within the upper chamber. For this the piston rings must maintain an unbroken oil-film on the cylinder wall, and must transfer the heat away from the piston.

To perform the above functions, piston rings must have the following characteristics.

1) Sealing effect against the combustion gases must be complete.
2) No * "fluttering" in their motion should be evident.
3) Fittability to piston ring groove and cylinder liner is good and wear only slight.

* Fluttering: is a phenomenon which occurs when an excessive gap develops between the groove walls and the piston ring sides to cause movement every time the piston's direction of motion changes.

BASIC MATERIALS

Since, cylinder liners, pistons and piston rings, are parts that operate under severe conditions; compared with other engine parts, the following materials are used to fill the various requirements.

Part name	Materials	Requirements
Cylinder Liners	Special cast-iron containing Ni, Cr, Cu and Mo	• Durability, • Wear resistant, • Friction resistant
Pistons	Aluminum alloys containing Si, Ni and Cu	• Heat resistant, • High thermal conductivity, • Wear resistant
Piston rings	Special cast-iron	• Heat resistant, • Wear resistant

SURFACE TREATMENT FOR CYLINDER LINERS AND PISTON RINGS

In large engines operated under heavy load conditions, it is customary to treat the surface of the cylinder liners, and piston rings to enhance their wear resistance, anti-scuffing and anti-friction properties.

Part name		Surface treatment (Type A)	Surface treatment (Type B)
Cylinder Liner		* Tuftride treatment	** Luberite treatment
Piston rings	Top ring	Hard-chrome plating	Chrome plating
	2nd ring		*** Parkerizing
	3rd ring		Parkerizing
	Oil ring		Chrome plating

*** Tuftride treatment**
An alkaline bath treatment for improving wear, scuffing, and corrosion resisting properties.

**** Luberite treatment**
A phosphate bath treatment for improving initial running in, anti-scuffing, and anti-corrosion properties.

***** Parkerizing treatment**
Formation of a phosphate-film by this treatment provides for enhanced initial running-in, and anti-wear properties.

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