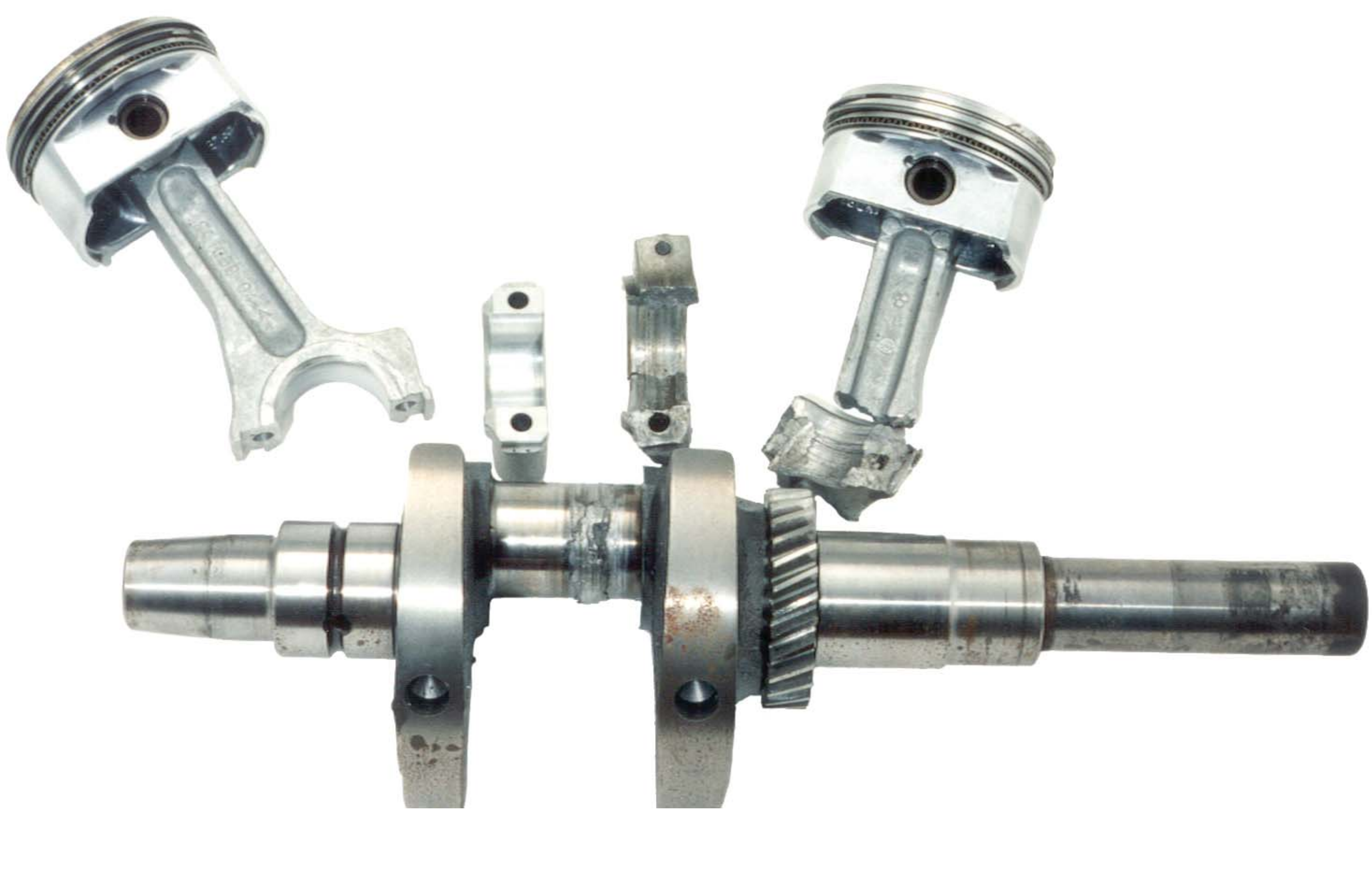
KOHLER® engines

Failure Analysis Guidebook



Failure Analysis

I. Introduction

"It couldn't have run low on oil, I just changed it three weeks ago."

"How could it get dirt in it, I blow out the air cleaner every time I use it."

Everyone involved in the service of small engines has heard similar statements at one time or another. It's human nature to blame problems on "the machine", or on someone else. Therefore, it is important for every small engine serviceman to develop the ability to accurately diagnose the cause of an engine failure. If an incorrect analysis is made, the repair may not remedy the original cause, and a repeat failure may occur.

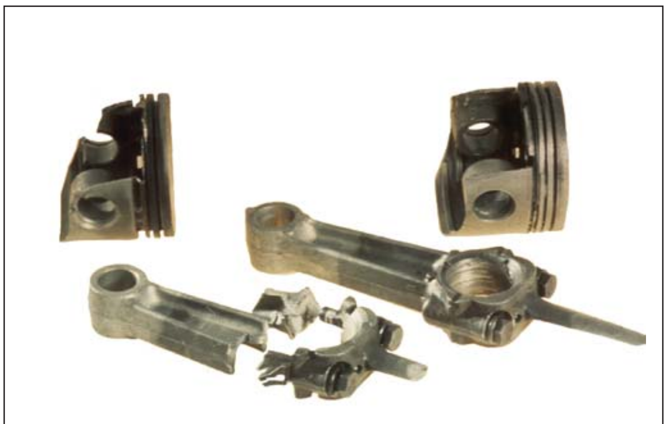


Figure 1.

Figure 1 shows two sets of parts from the same engine. The original piston failed from excessive clearance and slapping. The mechanic didn't measure the bore for wear and rebuilt the engine with standard parts. The bore wear was still present, so the new piston began slapping and broke up nearly identical to the original.

Some failures are the result of manufacturing defects, but it is a very small percentage compared to those which result from normal wear or customer neglect. You must be able to distinguish the difference to know if a failure qualifies for warranty consideration.

If the failure was due to neglect, you should provide an accurate explanation, so the customer refrains from making the same error again. The following information is provided to help you develop your expertise in analyzing engine failures.

II. Preliminary Examination

Any time an engine comes into your shop for service, you should begin by making an external examination. External conditions are often directly related to internal problems. Even if the engine is only in for routine maintenance or service, you may find indications that the customer is not providing adequate care for the engine and should be advised to change maintenance practices. If the engine has already failed, the condition of the exterior may provide valuable insight for assistance in analyzing an internal failure.

Check the following areas as part of your external examination.

A. Air Filtration

Figure 2.

Figure 2 – Make a thorough examination of the air cleaner. Remove the outer air cleaner cover and check it for damage or signs of impact.

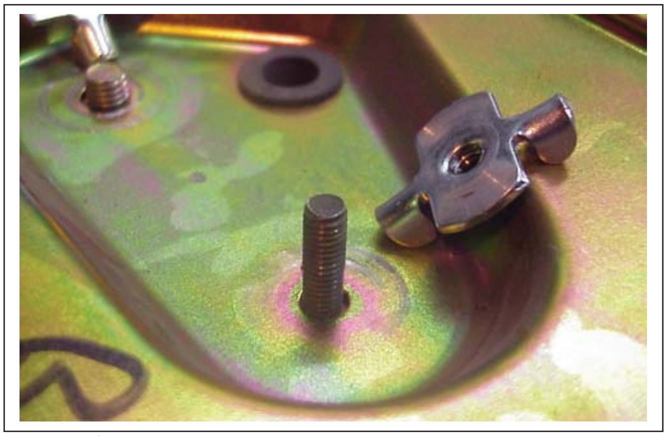


Figure 3.

Figure 3 – Most engines also have an inner cover on the air cleaner element, which provides backup protection in case the outer cover gets bumped or works loose. The inner cover may be a separate piece of stamped sheet metal, or it may be part of the element.

Three types of retainers are used on the element cover, a short rubber sleeve, a lock nut, or a wing nut. Check that the correct retainer(s) is/are there and tight. Remove the retainer(s) and look at the stud holes(s) in the element cover. If the stud holes(s) is/are wallowed out, it's an indication that the air cleaner components were loose at some time, and you're liable to find indications that dust or dirt has bypassed the system, as you continue your analysis.

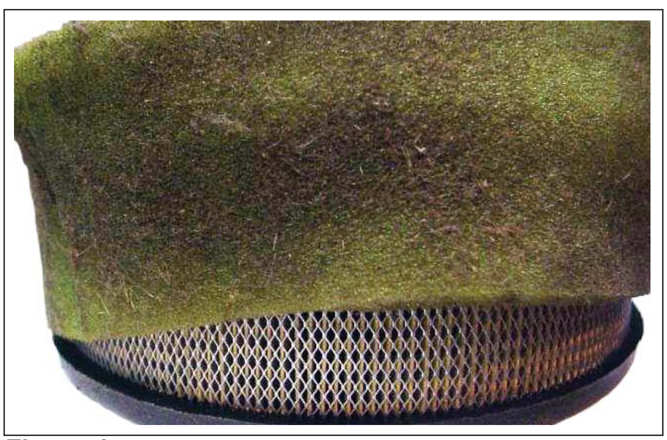


Figure 4.

Figure 4 – Carefully remove the precleaner. Check it for tears or deterioration. Does it look like it's been serviced regularly, at the recommended 25 hour interval?

Figure 5.

Figure 5 – Remove the element cover, if separate otherwise remove the whole element. If there was no rubber sleeve on the outer portion of the stud, you should find one on the inner portion. Check its condition and look for an imprint or mark on the underside of the element cover to indicate that it was making contact and sealing.

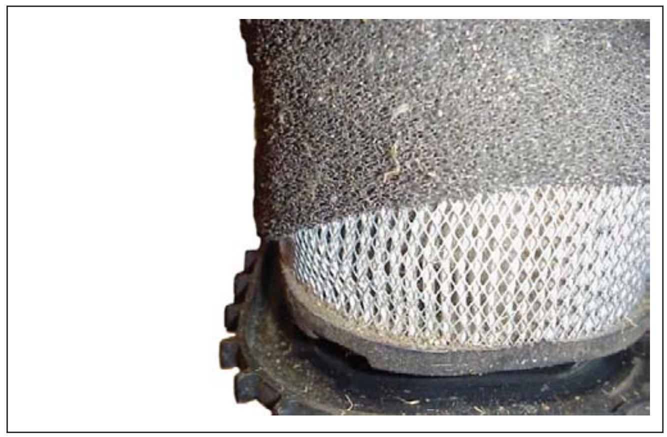


Figure 6.

Figure 6 – Is the air cleaner element dirty, plugged, or damaged? Is it a genuine factory part?

Figure 7.

Figure 7 – Take a close look at the element sealing surfaces. Are there any dirt tracks across the sealing surface indicating leakage? Have the reinforcing wires punctured the rubber seal? If so, it indicates that the cover was overtightened. Protruding wires could allow leakage. This air cleaner element is obviously damaged. Note the crushed wire mesh. This is an example of an element that can not properly seal out dirt and debris. The lesson here is to check the sealing area of the paper element and the wire mesh for signs of damage due to over tightening, damage or abuse.

Figure 8.

Figure 8 – Check the element with a light for punctures in the paper filtering material. If you cannot see any light at the base of the creases, the filter should be replaced.

Figure 9.

Figure 9 – Check the inner portion of the air cleaner base plate and the carburetor throat for signs of dust or dirt. If any traces are found, recheck all of the air cleaner components to determine the source of dirt entry. Perhaps the breather hose was pulled loose from the base plate, allowing dirty entry through the hole.

B. Oil

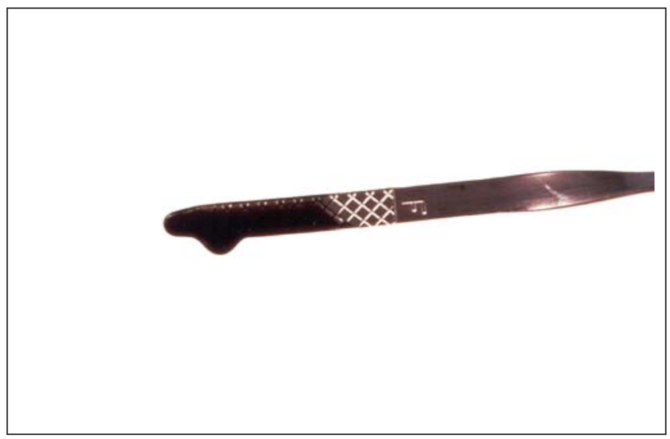


Figure 10.

Figure 10 – Pull the dipstick and check the oil. Look at the level of oil, but also note the color and consistency of the oil. Is it fresh, clean oil that was added after a failure? Or, perhaps, it’s so thick and dirty it won’t drip off the stick because it hasn’t been changed in 150 or 200 hours. When you drain the oil, measure the amount that you drain out and examine it closely. Notice again the color and consistency. Does it have an abnormal smell? Do you see any metal chips or wear particles? Do you notice any sludge? If the engine has an oil filter, notice whether is a genuine factory part.

C. External Surfaces

Figure 11.

Figure 11 – Check the overall condition of the exterior. Is the outside relatively clean, or is there an accumulation of oil, dirt, chaff, etc.? Are there any visible oil leaks? Also check for any indication that the engine may have been disassembled or repaired previously.

D. Cooling System

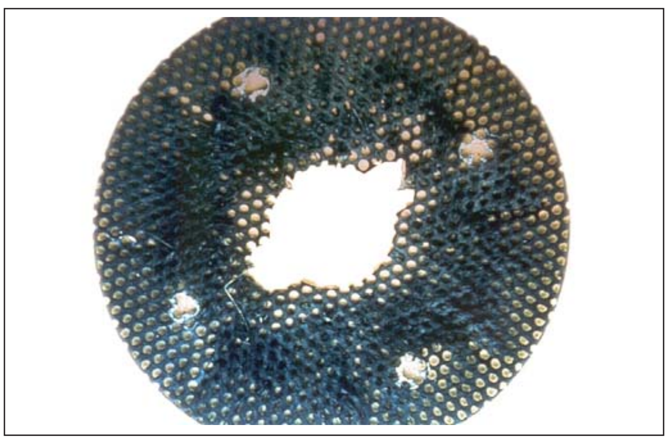


Figure 12.

Figure 12 – Is the grass screen plugged or restricted, possibly contributing to overheating?

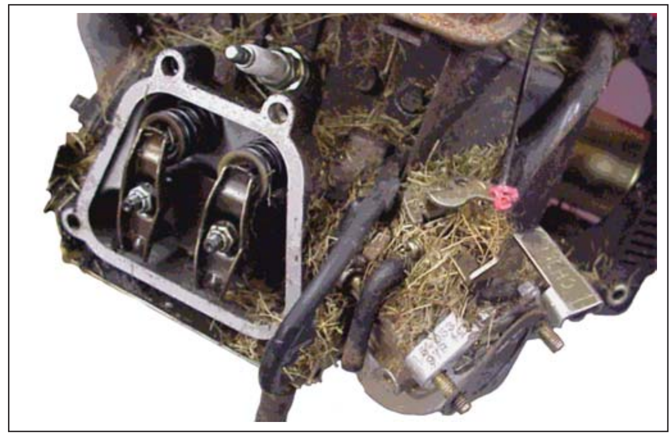


Figure 13.

Figure 13 – What about the cooling fins? The engine needs adequate air flow across the cooling fins to dissipate heat.

E. Carburetor and Intake

Figure 14.

Figure 14 – Carefully examine the carburetor and the intake manifold. Is anything broken or loose? Is there dirt or debris in the manifold/intake area? Are the mounting gaskets in the right location and are they the right ones?

F. Governor Components

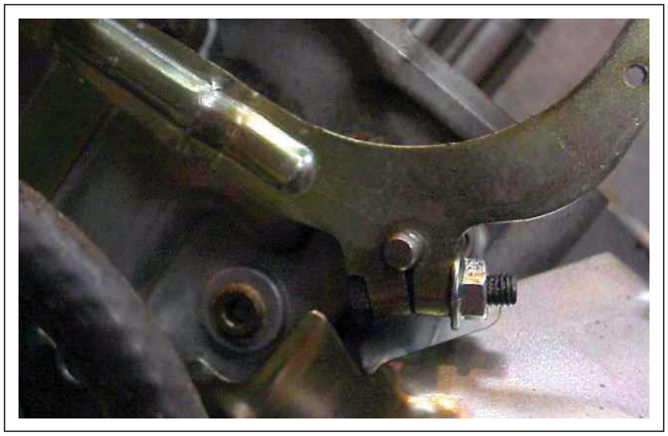


Figure 15.

Figure 15 – Check the external governor components and linkages. Are any of the pieces bent, broken, or missing? Have any non-factory modifications been made?

Figure 16.

Figure 16 – Operate the throttle control and check whether the mechanism can move freely through its normal range. Check the initial governor adjustment setting. Also note the position of the governor spring. Has it been moved?

G. Final Check

Finally, in addition to the air cleaner system which has already been checked, look for any other possible point(s) where dirt or contamination may have entered the engine.

The conditions found during your preliminary examination should be noted for future reference. The Engine Inspection Data Record, TP-2435, is available from Kohler Co. to record your findings (see sample at back of book).

If a major failure has occurred, this form should be filled out before your distributor representative arrives to make the warranty analysis inspection.

III. Disassembly

You are now ready to proceed with the disassembly and failure analysis inspection procedures. During disassembly, there are, again, specific areas that should have investigative attention.

A. Peripheral Parts

Figure 17.

Figure 17 – After the shrouds have been removed, check the cooling fins and cylinder block surfaces that were not visible earlier. Note any additional findings on the Engine Inspection Data Record.

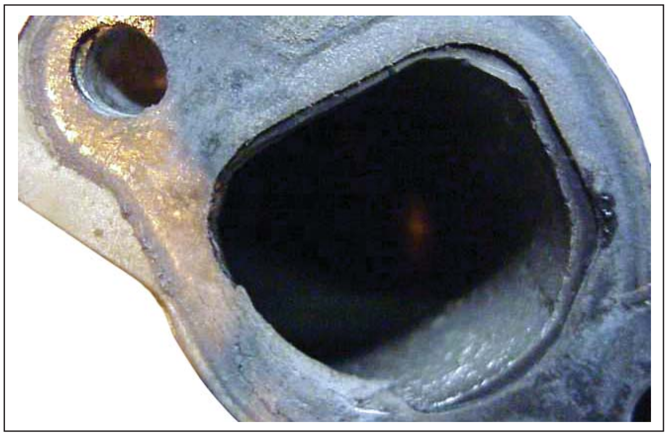


Figure 18.

Figure 18 – After removing the carburetor, check the throat of the intake manifold or intake port for traces of dust, dirt, or other contamination.

B. Cylinder Head

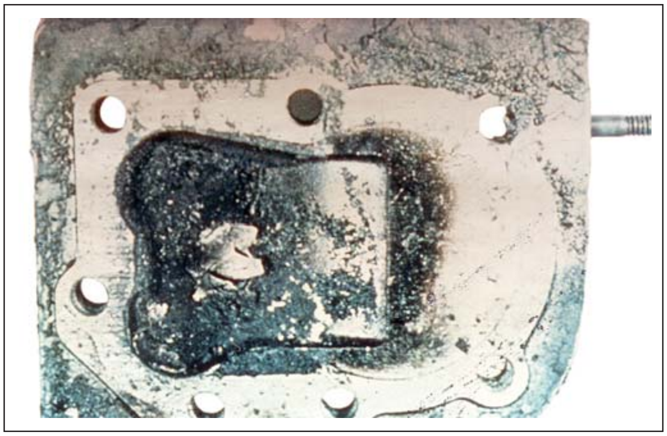


Figure 19.

Figure 19 – After removal of the spark plug(s) and cylinder head(s), check the combustion deposits, as they are often a good indicator of operating conditions. This head has heavy black oil or gummy-looking deposits, indicating that the engine was burning oil, usually from internal wear. This particular engine had so much oil entering the combustion chamber that it was starting to flush out the combustion deposits. And the head hadn't been cleaned for so long that the deposits completely cover the tip of the spark plug.

Figure 20.

Figure 20 – Here is another head with similar oily, glossy-looking deposits. A build-up of crankcase pressure (breather plugged or inoperative), forcing oil past the rings, could cause this also.

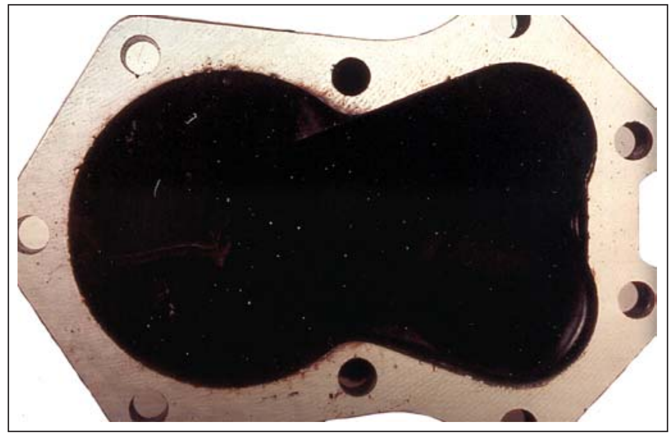


Figure 21.

Figure 21 – Soft, black, sooty deposits result from incomplete combustion. They could be due to overrich carburetor settings, a blocked air filter, or retarded timing.

Figure 22.

Figure 22 - Hard, crusty, mottled white deposits result from high combustion chamber temperatures. They could be from lean carburetion, an intake air leak, over-advanced timing, or poor quality gasoline. Deposits of this type will often be accompanied by a blown head gasket. The high temperatures and pressures that cause the white deposits also cause the head to distort and push the hot exhaust gases past the gasket. If the engine is operated with the blown gasket, the escaping hot gases can act like a torch and burn a slot through the gasket and sometimes even through the head.

C. Oil Sump

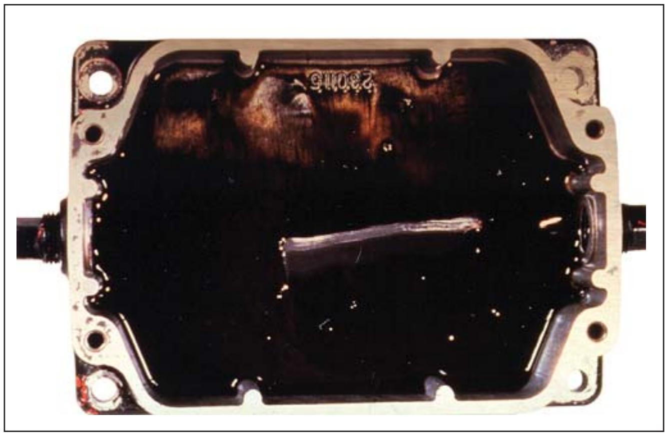


Figure 23.

Figure 23 – Check the bottom of the oil sump. A layer of sludge in the bottom of the engine indicates that contamination was entering the engine, the oil was not being changed at the recommended interval, or incorrect oil was used.

D. Valves

The valves can be very good indicators of various operating conditions. They should be closely examined as part of your failure analysis procedure.

The symptoms associated with valve problems include the following: hard starting, high fuel consumption, poor compression and loss of power, or the engine will pop and stall after a period of running. The most common problems related to valves are burning, sticking and valve erosion.

To help distinguish good from bad, we have included some examples of both.

Figure 24.

Figure 24 – This intake valve was removed from an engine in good operating condition. Notice the bright, uniform sealing ring around the face. The coke deposits on the underside of the head and upper stem are normal for an engine with some running time on it.

Figure 25.

Figure 25 – This engine was also in satisfactory running condition. However, you will notice that the “coking” is significantly worse. Possible contributing factors are: prolonged periods of idling, continuous duty at light load, “lugging” the engine during operation, running with a restricted air cleaner, or valve stem and guide wear.

The deposits are not yet interfering with normal operation, but they could if allowed to accumulate much more.

Figure 26.

Figure 26 – This is an exhaust valve from an engine in good operating condition. Again, note a good sealing ring on the face. Relatively light, brownish deposits indicate good operating conditions. An engine running under proper conditions will usually have light brown, brown, or gray deposits.

Figure 27.

Figure 27 – The white deposits, seen here, indicate very high combustion temperatures, usually due to a lean fuel mixture. The engine had only run for a short time, so the faces have not yet started to burn, but you will note that the sealing ring has already started to deteriorate.

Figure 28.

Figure 28 – Continued operation with high combustion temperatures will result in more severe burning and deterioration of the valve face.

Figure 29.

Figure 29 – Valve burning will also occur if there are conditions present which prevent the valve from closing or sealing properly. Here we see deposit accumulation around the entire circumference of the face. This would normally indicate that the valve was not closing completely. Perhaps the tappet clearance was incorrectly set, or combustion deposits may have flaked loose in the head and lodged between the valve and seat. Because the valve is not sealing, it will start to burn with continued operation.

Figure 30.

Figure 30 – When the exhaust valve is burned, or not sealing, the fuel burn is no longer contained within the combustion chamber. Each time the engine fires, a burst of flame passes the valve. As the face continues to burn and deteriorate, the combustion leakage begins to act like a torch. The valve material on the underside of the head and neck begins to burn away, a condition referred to as valve erosion.

Figure 31.

Figure 31 – If the initial valve burning was due to extreme combustion temperatures (lean mixture, etc.), the blistered white deposits may also show up in the area of erosion.

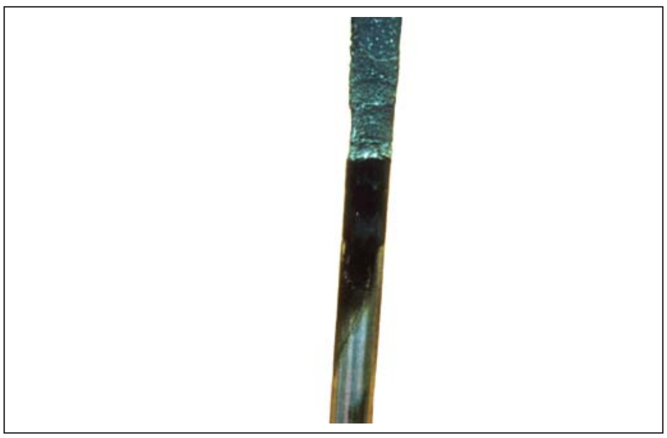


Figure 32.

Figure 32 – Another, fairly common valve-related problem is valve sticking. It is usually caused by an accumulation of burned oil deposits on the valve stem and in the guide.

The customer will usually complain that the engine runs anywhere from 15 to 90 minutes, then loses power or "pops" out the exhaust and stalls. It normally will not restart until the engine cools for 10-15 minutes and a metallic snap is heard.

The burned oil deposits normally responsible for valve sticking are due to elevated temperatures in the valve guide area. The problem will usually show up during hot weather, especially on an engine that doesn't get adequate maintenance.

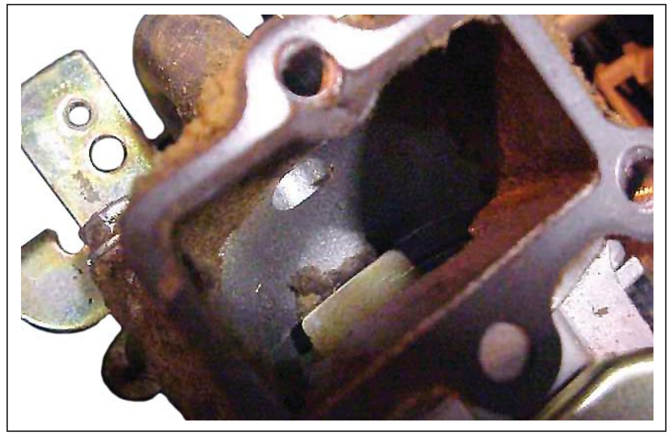


Figure 33.

Figure 33 – If a valve stem shows signs of abrasive material or scoring, check the carburetor inlet and air cleaner base for signs of dirt bypassing the air filter or precleaner.

Figure 34.

Figure 34 – If your preliminary examination of the engine indicated the possibility of dust or dirt entry, check the stem of the intake valve(s) for further confirmation. The valve stems should appear shiny like the one on the left. If contamination has been entering through the air intake, the stems will have dull wear patterns where they travel in the guides.

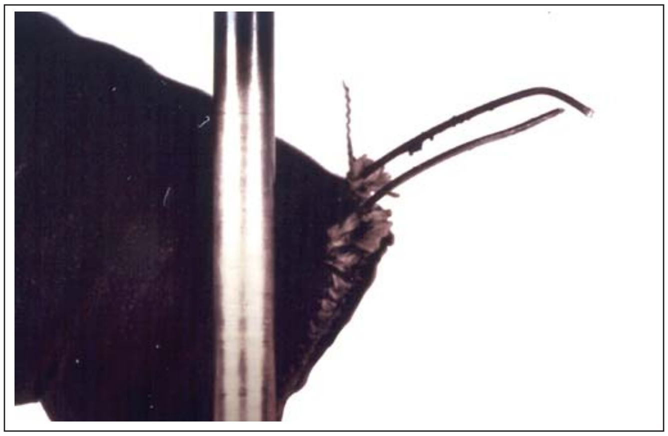


Figure 35.

Figure 35 – In this example, the dirt entry was due to a leaking remote air filtration system. Again notice the “buffed” appearance of the valve stem.

Also notice the air cleaner hose which was used. Wire reinforced hose should never be used with a remote air cleaner. The wire does not compress under the clamps, preventing a good seal, and allowing unfiltered air to enter at the joints.

E. Major Components
The cylinder/crankcase, crankshaft, connecting rod, and piston assembly are usually considered to be the major components of an engine. They are the parts that confine the energy of combustion and transmit the power of that energy to the piece of equipment to perform work. Because of the tremendous forces and stresses they must withstand, they are the components with the most critical running tolerances. They are also the components most subject to failure.

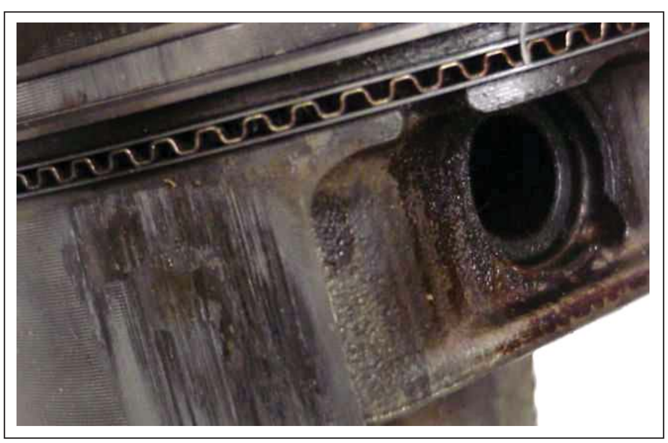


Figure 36.

Figure 36 – Be careful when disassembling the major components, so you do not disturb or destroy any critical evidence.

Leave the parts in their original state as much as possible, until the failure analysis procedure has been completed. Do not clean anything unless it is necessary to make an accurate inspection.

IV. Analyzing the Failure

A. Pistons and Rings

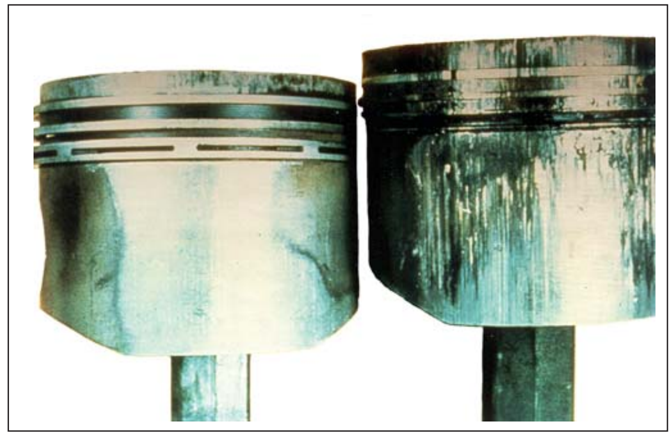


Figure 37.

Figure 37 – Problems relating to the piston and rings will usually fall into one of two categories, excessive wear or piston seizure.

Figure 38.

Figure 38 – Excessive wear can often be detected visually, even before any measurements are taken. From normal operation, the wear pattern on the thrust face of a piston will cover about 20-40% of the face. If it cover 50% or more, with visible vertical scratches, you know there has been contamination between the piston and cylinder wall causing excessive wear.

The erosion at the very top edge of the piston is also due to the wear. As the rings wear, oil consumption increases resulting in more combustion deposits, and a carbon ridge forms at the top of the cylinder.

In the area near the exhaust valve, the carbon becomes very hard and abrasive from the exhaust temperatures. When the piston repeatedly hits those hard deposits, the material is gradually eaten away. The newer Mahle pistons, used in most Kohler engines today, have the top land machined to a smaller diameter to allow more clearance and help prevent this type of damage.

Figure 39.

Figure 39 – Damage from contamination entering an engine can occur over an extended period of time with very slight leakage, or it can be quite rapid, if a significant amount of dirt is entering. This damage occurred in just 15 hours of running from ingesting about 1/4 teaspoon of dust per hour.

If a customer punctured their air cleaner element by using compressed air, or assembled the air cleaner incorrectly, that the element was not sealing, then ran the engine for a week or two before discovering the error, the engine could already be worn beyond acceptable limits.

Figure 40.

Figure 40 – If the engine is running hot (blocked screen or fins) and ingesting dirt at the same time, the wear will occur even more rapidly. This Command engine was completely worn out after just 125 hours of operation. The oil ring rails are so badly worn that the expander was rubbing the cylinder walls.

Figure 41.

Figure 41 – On the other hand, heavy ring wear, with little or no bore wear, indicates that high operating temperatures were present, but little or no dirt.

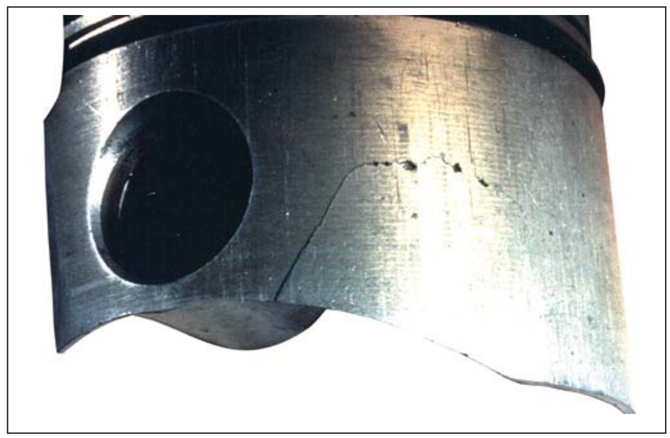


Figure 42.

Figure 42 – If a customer ignores the first signs of wear (oil consumption and blue exhaust smoke) and continues to run the engine, the wear will progress to the point that the piston begins to “slap” because of the excessive running clearance. The piston slap puts increased stress on the piston skirts and they can begin to crack.

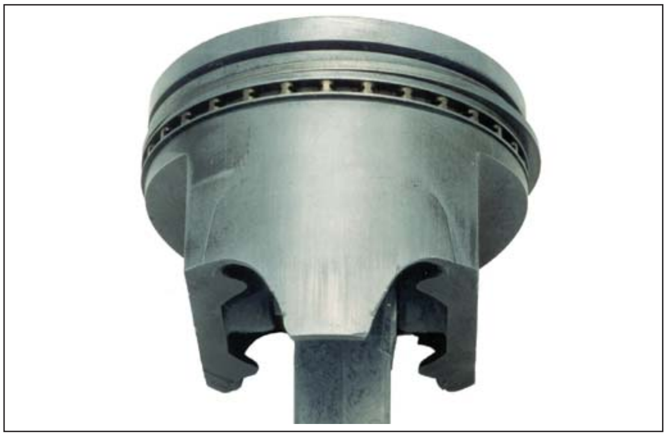


Figure 43.

Figure 43 – With continued operation, the cracks will progress across the thrust face and/or up toward the oil ring groove.

Figure 44.

Figure 44 – In some cases, just the lower portion of the skirt will break off.

Figure 45.

Figure 45 – In other cases the whole piston will break up. The customer will not be able to ignore it any longer.

Figure 46.

Figure 46 – A customer that doesn't maintain a twin cylinder engine ends up with double trouble.

Figure 47.

Figure 47 – This engine ran for only 6 hours following a rebuild. The piston ring end gaps go as high as .042 in., and the crankpin was .007 in. undersize.

Always scrub the cylinder with hot water, detergent, and a brush after it has been bored or honed. Use sufficient detergent to provide good sudsing action. This way, you can be certain that the machining oil is broken down to allow complete removal of the grit particles from the pores of the iron.

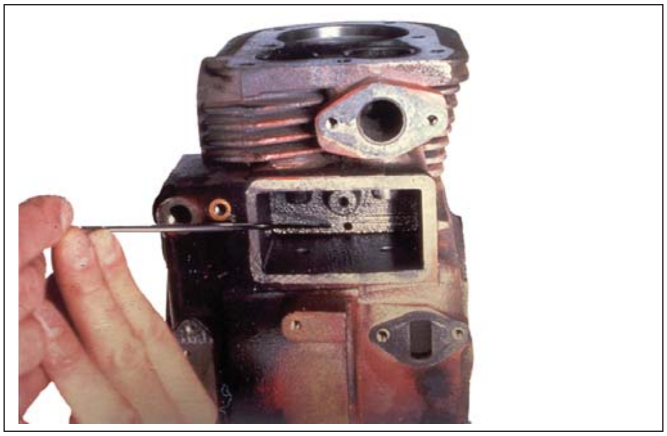


Figure 48.

Figure 48 – On a single cylinder block, also be certain to clean and flush out the oil drain hole which goes from the valve chamber into the cylinder.

Figure 49.

Figure 49 – Piston seizure is also visually obvious, but it can be a little more difficult to analyze. There are a number of possible causes, but the appearance doesn't vary much from one to another. Possible causes include overheating from insufficient cooling air, lack of lubrication, insufficient running clearance, oil additives, and contamination or foreign material in the engine. This is one instance where your preliminary examination may be very helpful. Did you find dirty, thick oxidized oil in the engine? Was the cooling system restricted?

You may also find other indicators on other portions of the seized piston.

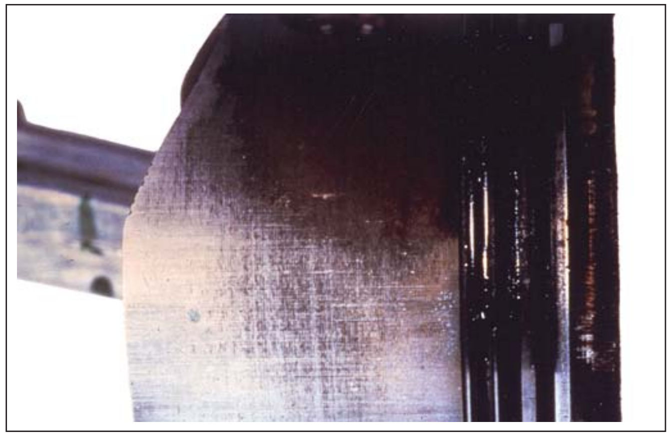


Figure 50.

Figure 50 – The scoring on a seized piston is sometimes just on the primary thrust face. Look at the opposite thrust face and the sides for other possible indicators.

Figure 51.

Figure 51 – This piston shows evidence of overheating. Notice the dark brown deposits as well as the blackened area near the wrist pin. This is severely overheated oil starting to bake. Your next challenge would be to see what is causing this condition.

Figure 52.

Figure 52 – This engine had high combustion temperatures and restricted cooling, resulting in very black, scorched deposits.

Figure 53.

Figure 53 – Severe oxidation or use of an oil additive can cause a complete breakdown of the oil. The deposits will appear to be a cross between axle grease and tar.

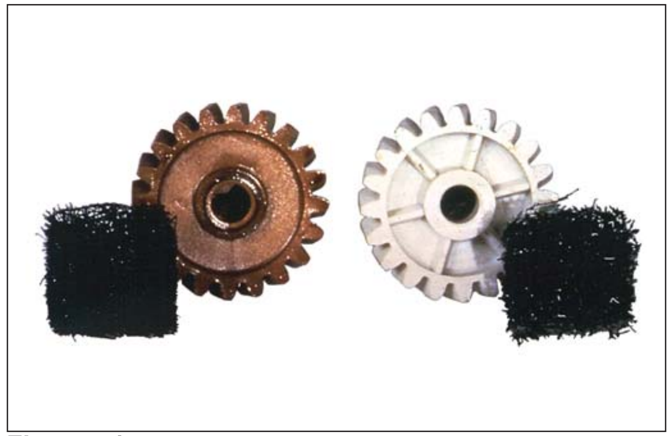


Figure 54.

Figure 54 – If the piston has signs of overheating and/or oxidized oil, look at the governor gear and breather filter for further confirmation. The governor gear takes on a dark orange or rust color when exposed to overheated oil. The breather filter will also be discolored with burned oil deposits. In severe cases it may be so brittle that it crumbles.

Figure 55.

Figure 55 – Seizures due to insufficient running clearance will usually result in scoring without any other signs. The scoring may show up on both thrust faces, heavier on the primary face (toward the valves).

B. Connecting Rods

Connecting rod failures will provide some of the greatest challenges to your failure analysis expertise. Sometimes the indicators will be pretty clear. However, in other cases, they may be difficult to spot, or there may be two or three indicators that seem to contradict each other. The rod may be broken in such small pieces that it's difficult to find any failure indicators.

Your preliminary examination of the engine may provide some valuable assistance where the rod failure indicators are elusive or unclear.

Figure 56.

Figure 56 – There are many different failure modes on connecting rods, but some of them are more common or prevalent than others. A few years ago, a task force at Kohler Co. analyzed more than 400 connecting rod failures. When they compiled their data, nearly 75% of the failures they had looked at were similar to the rod in this photo, so this could be considered a "typical" connecting rod failure.

The connecting rod had seized onto the crankshaft, melting and searing the aluminum on the bearing surface in the process. The exterior surfaces are dark, with burned oil deposits around the journal area. Often, the burned oil deposits will extend part way up the beam and down onto the dipper (if it's a splash-lube rod). The rod may be fractured, possibly a single break, or several pieces, Sometimes, on twin cylinder engines, the engine keeps on running on the opposite cylinder after one rod has failed, and the broken rod gets smashed into many tiny fragments. Those are probably the most difficult to analyze, because the pieces are so small it's difficult to find and identify any good failure indicators.

Figure 57.

Figure 57 – All of these rods failed by seizing onto the crankpin. While there are many similarities, if you look closely, there are also some subtle differences. To correctly analyze rod failures, you will need to identify both. The similarities will usually help you determine a general failure category (lack of oil, manufacturing defect, etc.). The differences will help you distinguish one from another, and often provide clues to the circumstances or conditions that caused that particular failure.

Where, then, should we look to determine the cause of failure? Actually there are four areas that should be scrutinized before a decision is made.

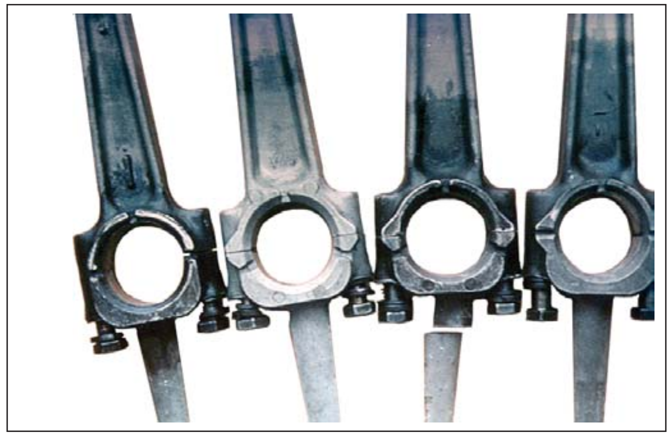


Figure 58.

Figure 58 – The first area to examine is the journal area and the dipper (if it has one). Did the rod seize, causing the aluminum on the bearing surface to smear and transfer? Is the outside of the journal area discolored/ darkened? Are there burned oil deposits present? Do the burned oil deposits extend down onto the dipper? What is the condition of the dipper (intact, broken, nicked or scraped, discolored)?

The first rod on the left is very similar to Figure 56. It seized on the crank and it has burned oil deposits on the outside of the journal. A seizure results when there is inadequate lubrication between the crankshaft and the rod. The burned oil deposits indicate there was some oil present, but it wasn't providing adequate lubrication. The engine was probably run low on oil.

The second rod had some running time, but it never had failure or problem. It is included in the photograph to help you distinguish color variations.

The third rod has a broken dipper. The lighter color of the broken segment indicates that the break occurred before the rod seized. In fact, the broken dipper caused the failure. If the color had been the same on both sides of the break, it would have indicated that the dipper broke after the seizure and the cause of failure would have to be found elsewhere.

The last rod came from an engine that was started with no oil. The bearing surface is smeared, and the rod is darkened from the heat of the seizure, but there are no burned oil deposits because there was no oil present.

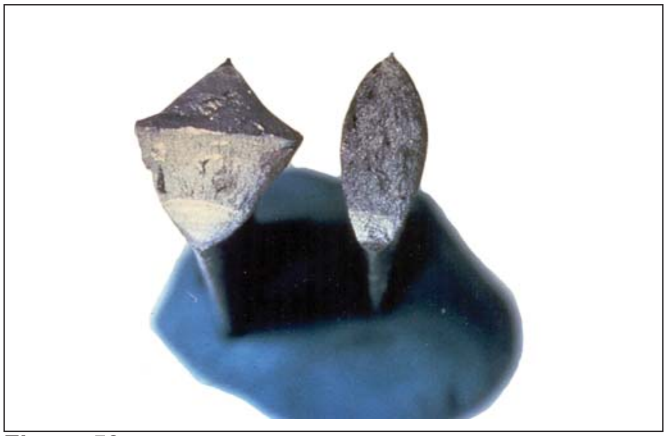


Figure 59.

Figure 59 – If the dipper is broken, look closely at the break surface. Is it a tensile break or a fatigue break?

Figure 60.

Figure 60 – A tensile break results from a single sharp blow that breaks off the dipper. The dipper will have a nick or scrape where it was hit, and the break surface will be quite rough, because the metal has been torn apart. You might also notice a "feather" pattern, which can indicate the direction of the breaking force.

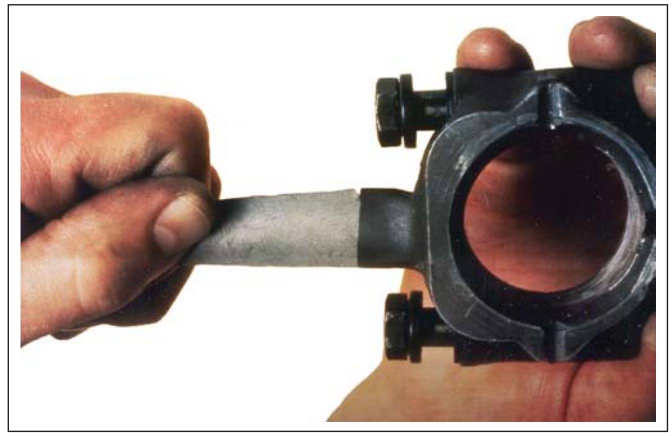


Figure 61.

Figure 61 – A fatigue break usually results from damage done prior to, or during assembly. If the rod is dropped on the dipper, or the dipper is bumped against the workbench, a small stress crack can be created in the aluminum. The forces of operation, along with repeated heating and cooling, will cause increased metal fatigue around the crack. The crack will spread until the dipper finally separates and drops into the oil pan.

Figure 62.

Figure 62 – After the dipper drops off, the rod will seize because the oil is no longer being circulated to the bearing surface. The high friction temperatures generated during seizure cause the oil to burn around the journal area and down to the break line. A definite color variation will be obvious at the break line.

Figure 63.

Figure 63 – The break surface of a fatigue break will be smoother than a tensile break. Often the fatigue process leaves semi-circular markings, called beach marks, on the break surface. The center of the markings is the point at which the break originated. Here the dipper was bumped or damaged from the side.

Figure 64.

Figure 64 – Examination of this break surface confirms that it is a fatigue break, and also reveals the cause of the break, a casting defect.

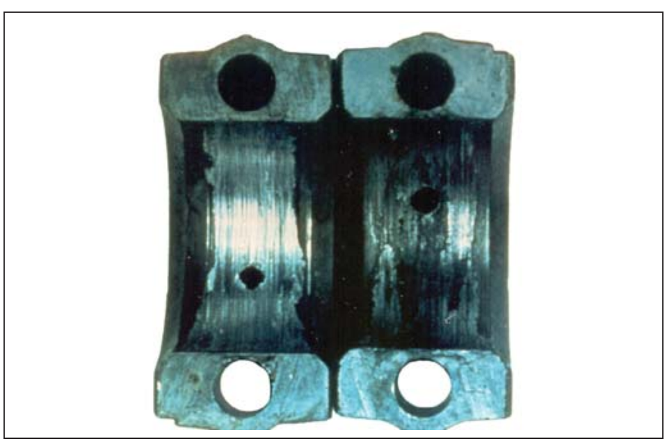


Figure 65.

Figure 65 – The second area of examination is the bearing surface of the rod. The bearing surface will often be smeared, but it can still reveal clues about the conditions at the time of failure. These two rod caps are a good example. Notice the difference in color.

The cap on the right has streaks of burned oil blended with the smeared aluminum, indicating that there was some oil present, but not enough for adequate lubrication. It's from an engine that was run low on oil. The cap on the left has only the bright, smeared aluminum, no traces of oil. It was from an engine started without oil.

Figure 66.

Figure 66 – What led up to this failure? If you guessed it was another engine started without oil, you're right.

Figure 67.

Figure 67 – Here you see shiny, smeared aluminum in the center of the bearing surface, and no discoloration on the outer surfaces. The failure was due to insufficient running clearance between the rod and crankshaft. The rod had been overtightened and the bearing area collapsed, squeezing out the film of lubricating oil. The engine had oil in it, which cooled the outer surfaces, but it couldn't reach the center of the bearing surface.

Figure 68.

Figure 68 – The aluminum in a forged connecting rod appears brighter than a die cast rod. This is a forged rod that failed from running without oil. The smeared aluminum is very bright with no burned oil deposits. Because a forging is stronger than a die casting, you may also notice some unusual twisting or distortion.

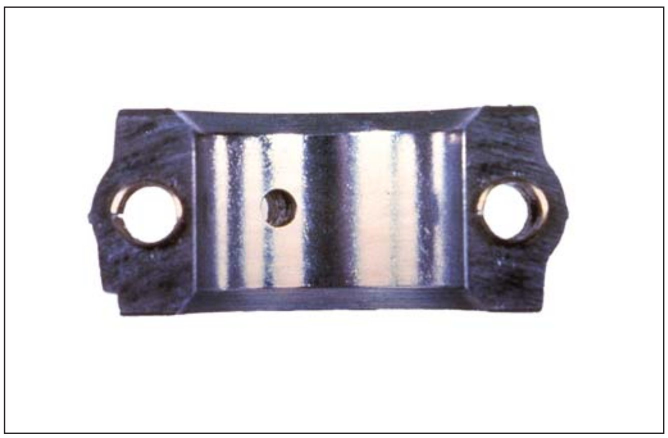


Figure 69.

Figure 69 – If a connecting rod has not seized, the bearing surface can also be a wear indicator.

The final finishing operation on a connecting rod leaves a textured, but highly polished surface finish. If there is dirt in an engine, it combines with the oil and works like a buffing compound on the bearing surface. The highest loading occurs at the top and bottom of the stroke, so the top and bottom of the journal will show wear first.

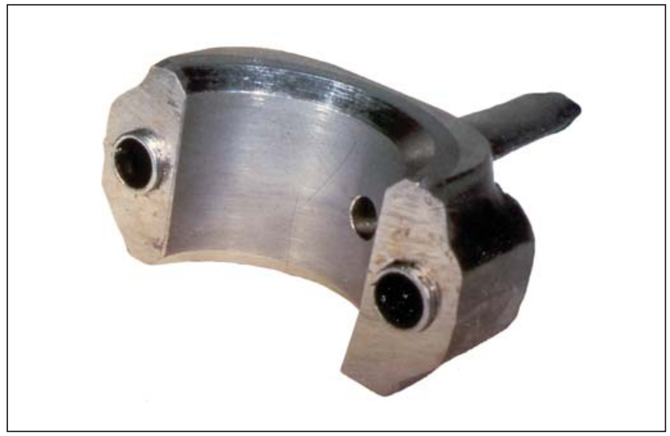


Figure 70.

Figure 70 – This rod is from an engine that ran for 15 hours with dirt in the crankcase. The original surface finish has been worn off leaving a dull, satin appearance.

Figure 71.

Figure 71 – If there is a heavy concentration of dirt, or the particles are large and abrasive (honing grit), you may see a “dirt” trail around the center of the bearing surface. The dirt entering through the oil hole gets pounded into the surface of the aluminum, leaving a trail around the bearing, in line with the hole.

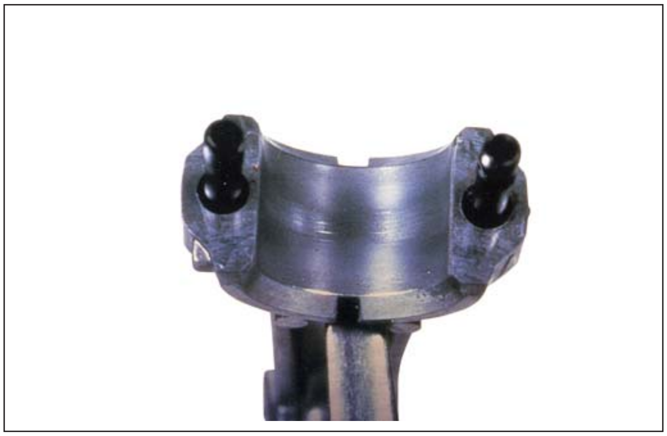


Figure 72.

Figure 72 – This connecting rod came from the engine mentioned earlier (Figure 47) where the block was not cleaned properly after honing. Again note the worn bearing surface with the abrasive trail in line with the oil hole.

Figure 73.

Figure 73 – This rod came from another engine that was not cleaned properly prior to rebuilding. After only 6 hours of running, the crankpin was worn .008 in. undersize. The rod had started pounding because of the excessive running clearance, causing the aluminum to begin smearing. The customer became alarmed when the engine started knocking and losing speed. Within one more hour of running, a total seizure would have occurred.

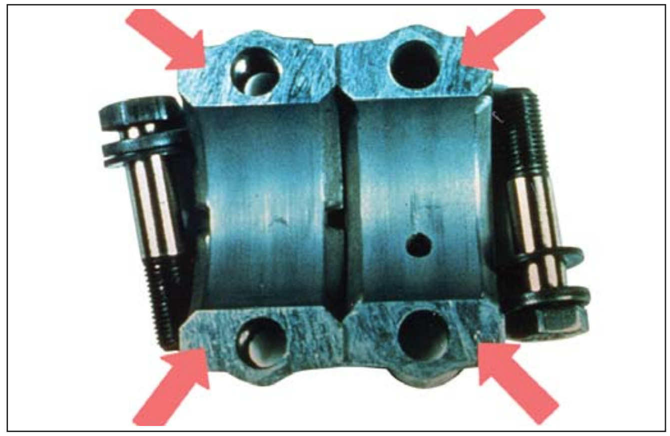


Figure 74.

Figure 74 – The mating surfaces of the connecting rod are the third area that should be inspected.

The machining marks that you see here are normal. They are made by the saw blade when the rod is out.

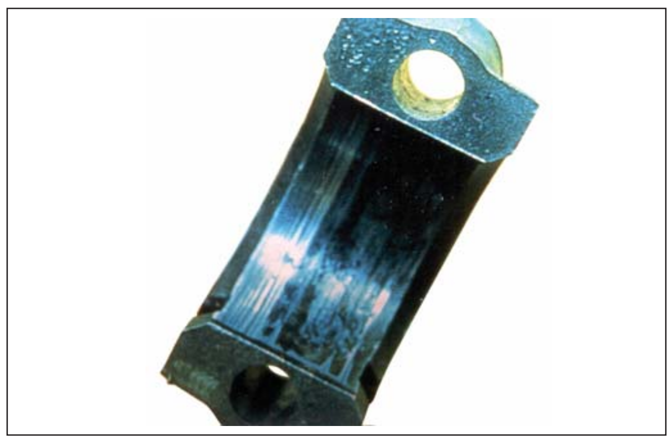


Figure 75.

Figure 75 – Here you cannot see any of the saw blade markings. Instead the mating surface has a hammered or peened appearance. The rod bolts were not tightened properly and the peening results from the two sections of the rod pounding together as the bolts backed out.

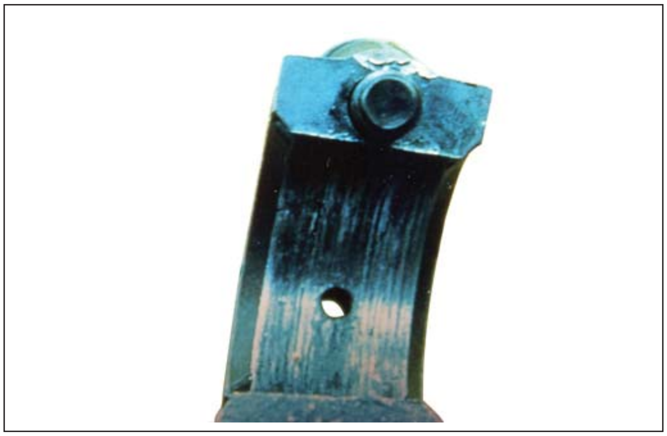


Figure 76.

Figure 76 – Here is another example of undertightening. In this case, the bolts were just loose enough for the rod sections to work against each other, but not loose enough for them to hammer. The result is a dull gray finish on the mating surface known as "fretting." If magnified, this "fretting" would look like the "peening" you saw in the last slide. This condition will not be seen on Posi-Lock rods.

Figure 77.

Figure 77 – This piece has just a small peened area near the outer edge of the mating surface. The looseness here resulted from the high temperatures generated by the seizure. The bolts had been tightened properly and only began to yield when the rod started to seize. This type of peening is secondary. The cause of the failure was insufficient lubrication.

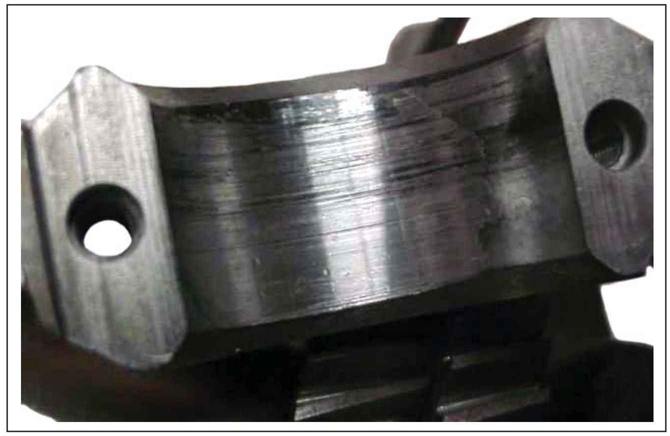


Figure 78.

Figure 78 – This rod cap shows signs of scoring and aluminum smearing. If you look closely it has a double layer of aluminum on the right hand side. This engine was started with no oil; it seized and was freed up. It was restarted and shortly after it seized again because the aluminum transfer from the first seizure left insufficient running clearance. The lesson here is make sure there is oil in the engine before starting.

Figure 79.

Figure 79 – This is a shot of a rod bolt that was loose. This came early within its life cycle. Notice the elongation of the hole where the bolt comes through. You can also notice where the bolt wore a groove into the rod cap.

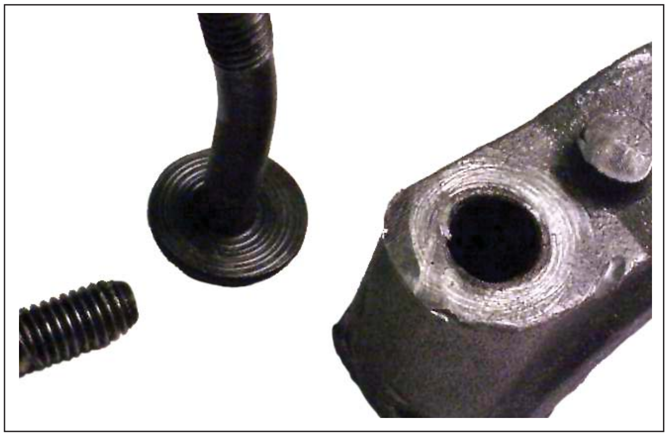


Figure 80.

Figure 80 – This is a shot of the rod you saw in Figure 79. Again notice the way the bolt is elongated and how there is no sign of heat or burned oil.

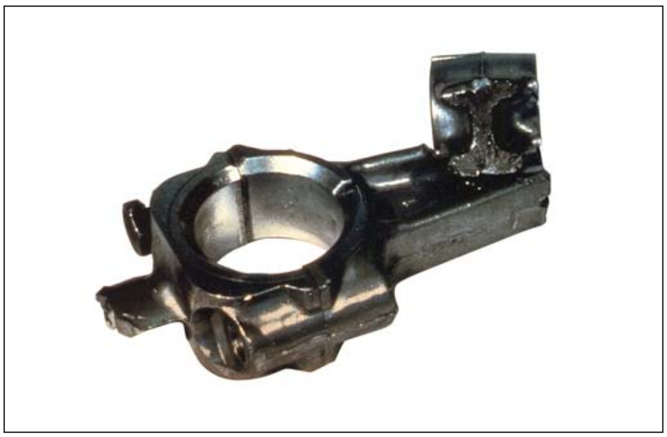


Figure 81.

Figure 81 – This connecting rod broke in the beam, but has no other visible damage and did not seize. When we look at the break surface, there is no sign of fatigue or a casting defect, just a tensile break of a good casting. This failure was caused by engine overspeed.

C. Combination Failures

Many failures involve more than one engine component. When two or more parts have failed, or been damaged during failure, analysis can be more difficult.

In those situations, look at each individual component to see if it actually failed, and why, or if it just received secondary damage. Then look at the parts collectively. If more than one part failed, try to develop a logical sequence. Weigh all of the evidence before making a decision.

Figure 82.

Figure 82 – Our first example includes a broken connecting rod and a broken governor gear. The rod bearing surface looks like it ran without oil. Notice, however, that the dipper is broken, and not discolored. The dipper broke first and caused the rod to seize. But the real culprit here is the governor gear. One of the roll pins backed out and the flyweight separated from the gear, breaking the gear in the process. The flyweight dropped into the oil pan and knocked the dipper off the rod.

If we had looked at only the rod bearing, we may have concluded that the engine was run without oil, and we would have been dead wrong.

Study all of the evidence and be certain that your decision incorporates everything you see.

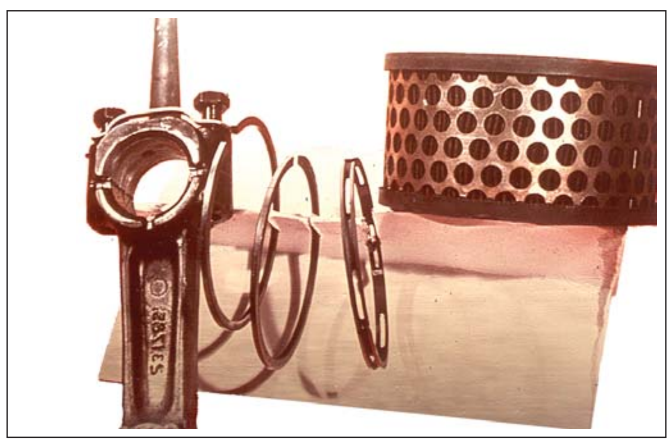


Figure 83.

Figure 83 – A high percentage of small engine failures result from customer neglect. Here you can see the dirty air cleaner, considerable wear on the piston rings, and traces of dirty, burned oil on the connecting rod. There is a color change line on the dipper, but it was only about 3/8 inch from the tip, so the oil level was well below the "low" mark on the dipstick at the time of failure.

Figure 84.

Figure 84 – This rod shows signs of aluminum transfer with burned oil deposits. The rod seized from inadequate lubrication. As it locked up on the crankshaft, the turning force of the flywheel and crankshaft caused the connecting rod to snap in the beam, and tried to pull the rod apart at the fastener joint. The aluminum thread transferred to the rod bolt is a secondary occurrence and not a loose rod bolt.

Figure 85.

Figure 85 – This rod broke toward the bottom. Notice the slight smear of aluminum and blackened oil. The piston shows signs of overheating. This could have been caused by an improper honing/oversize procedure, where the piston to bore clearance was too tight, causing the stress and failure of the connecting rod. Notice that the rod bolt is sheared.

Figure 86.

Figure 86 – This connecting rod shows multiple breaks. The break in the middle of the beam was a secondary break; in other words, it occurred after the rod seized to the crankshaft. The bearing surface indicates that the initial seizure was from insufficient lubrication.

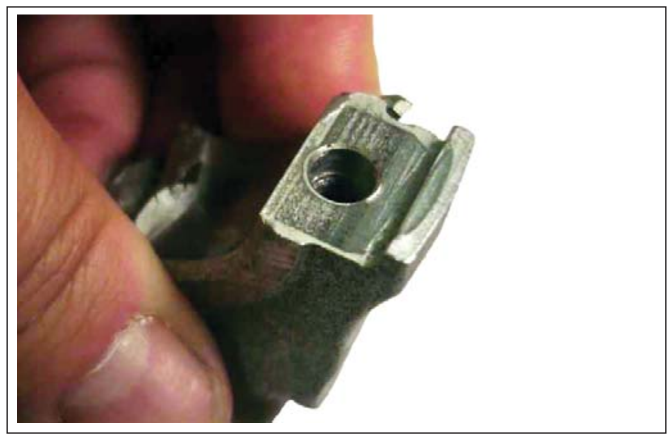


Figure 87.

Figure 87 – Sometimes you may only have a small amount of evidence to look at to make a determination as to what happened. This lower rod cap shows some peening and shifting. This could have been caused by a loose rod bolt. Again you have to look for other signs, and/or ask questions of the owner and/or of the engine itself. In this case the unit had plenty of lubrication. The failure occurred shortly after an overhaul by a service technician who forgot to torque the rod bolt to proper specifications.

Figure 88.

Figure 88 – This is a head assembly from a Command Engine. Notice the heavy carbon deposit on the face of the head and valves. The combustion deposits appear to be wet or shiny. This is an indication that excessive oil was entering the combustion chamber.

Figure 89.

Figure 89 – This is a close up of a Command head gasket. Notice the RTV sealant around the return passages. Someone wanted to get a positive seal between the head and block and applied RTV. This is not necessary if the surface areas are clean and dry as well as making sure there is no warpage. It is also good practice to check the recommended replacement data when it comes to the retaining fasteners.

Figure 90.

Figure 90 – Here is a close-up of the piston and wrist pin area. Notice the blackened and burnt deposits in the wrist pin area as well as the rest of the piston skirt. This can be caused by multiple factors. Some which would be poor oil quality, infrequent oil changes and/or overheating.

Figure 91.

Figure 91 – This is a typical starter motor winding burned up due to overheating. Again, your job as a technician is to determine what can cause this to occur. Was it due to overcranking and not allowing it to cool down? Was it do to parasitic loads? Improper voltage, etc.

Figure 92.

Figure 93.

Figure 92 - On the crankshafts look for signs of dirt wear, lack of lubrication and or side loading. Note condition of all bearing surfaces. In this case, notice the PTO bearing shows signs of severe scoring. This could indicate a lubrication or excessive side load problem. It could also be caused by a faulty electric clutch.

You Call the Failure

The following four (4) pictures are parts that have failed.
Take a look at the pictures and try to decide what could have caused each failure.

Figure 94.

Figure 95.

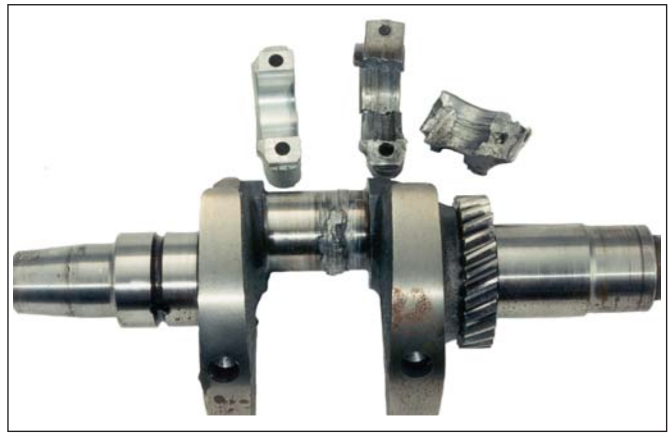


Figure 96.

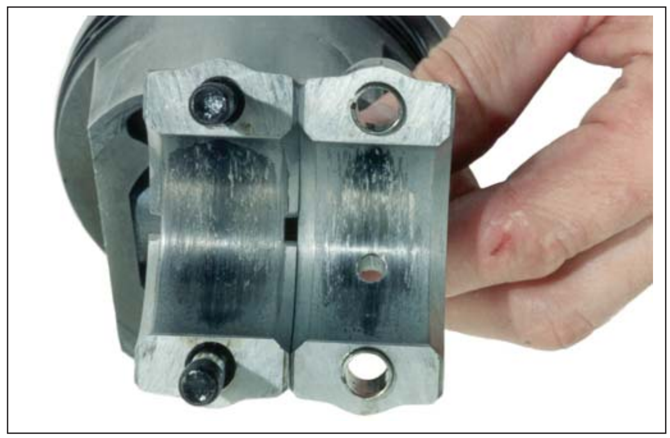


Figure 97.

D. Summary
Failure analysis is an important part of the small engine repair business. Some failures can be interesting and challenging. Others can be quite puzzling, almost exasperating. But if you follow the steps outlined in this booklet, you'll be more successful in reaching a logical, correct decision and completing the proper repair.

Figure 98.

- Make a thorough preliminary examination to help determine the conditions under which the engine was operated and pick up any external signs of factors that may have contributed to the failure. In some cases, there will be very obvious indicators, but not always. This engine ran for over two hours, no load, with no oil in the crankcase, but there are no external indicators of that.

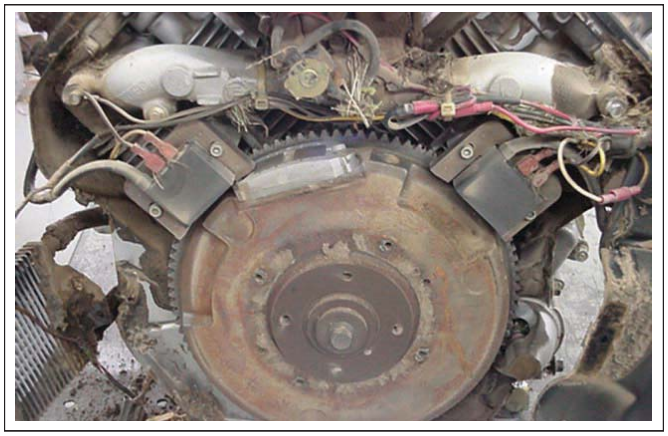


Figure 99.

- Carefully disassemble the engine and examine all of the components. Even though some parts weren't involved in the actual failure, they may still provide some indicators to assist you in reaching a correct decision. If you are fortunate the location of the failure is or will be obvious.

- Weigh all of the evidence against your experience as a professional small engine repairman. Your final decision should incorporate all of the evidence and provide a logical, sensible explanation for the failure which occurred. Running an engine out of gas doesn't cause a connecting rod failure, but running it out of oil probably will.

Once you have made an assumption, back up your decision with facts and measurements.

Figure 100. Carbon – Due to what?

Figure 102. Take Precise Measurements.

Figure 101. Rolled Material – Caused by what?

KOHLER engines

Engine Inspection Data Record

To facilitate accurate evaluation:

- enter as much information as possible
- provide as many dimensions as possible.
- mark location of break or crack on drawing
- record conditions found with check mark (X) whenever possible

SECTION 1 OWNER AND EQUIPMENT INFORMATION

Owner's Name	Street Address		
City	State	Zip Code	Phone No. ( ) –
Model No.	Spec. No.		Serial No.
Type of Equipment		Manufacturer of Equipment	
Date Purchased	Date Failed	Hours Used	Times Used
Previous Repairs ☐ YES ☐ NO	Warranty Claim No.		

USAGE/MAINTENANCE INFORMATION

Oil type: ☐ 30W ☐ 10W-30 10W-40 ☐ 5W-20 5W-30 ☐ Other ______	Hours since last oil change?
How often is the oil level checked? ☐ Everytime ☐ Never ☐ Other ______	Must oil be added between changes? ☐ Yes ☐ No ☐ How much? ______
Was an oil additive used? ☐ Yes ☐ No What brand? ______	How often is the air cleaner checked? Precleaner ______ Element ______
Was it ever replaced or cleaned? Precleaner: ☐ Yes ☐ No Element: ☐ Yes ☐ No	How recently? Precleaner ______ Element ______
Were any adjustments made to the carburetor or governor? ☐ Yes ☐ No If yes, specify ______	By whom? ☐ Customer ☐ Dealer

PRELIMINARY EXAMINATION

Air Cleaner Assembly

Type: ☐ Dry ☐ Precleaner ☐ Remote ☐ Oil Bath ☐ Tri-Phase

1. Wing Nut: ☐ Factory Original ☐ Non-standard replacement | Wing nut seal: ☐ Intact ☐ Separated ☐ Missing
2. Outer Cover: ☐ Good condition ☐ Center hole oblong ☐ Other damage (specify) ______
3. Precleaner: ☐ Clean ☐ Dirty ☐ Plugged ☐ Oiled ☐ Dry ☐ Torn ☐ Other damage ______
4. Inner Cover: ☐ Retaining seal/nut in place ☐ Center hole oblong ☐ Distorted ☐ Other damage ______
5. Element: ☐ Clean ☐ Dusty ☐ Dirty ☐ Plugged ☐ Missing ☐ Dry ☐ Non-factory replacement ☐ Other damage ______
6. Element seals: ☐ Pliable ☐ Hard ☐ Sealing ☐ Leaking ☐ Other damage ______
7. Air cleaner base: ☐ Tight ☐ Loose ☐ Screw(s) missing ☐ Distorted/Cracked ☐ Breather hose detached ☐ Other damage ______

Crankcase Oil

1. Amount on dipstick: ☐ Overfilled ☐ Full ☐ Above "add" ☐ Below "add" ☐ No reading
2. Condition of oil: ☐ New ☐ Used ☐ Dirty ☐ Black ☐ Thick/Sticky ☐ Burnt smelling ☐ Fuel diluted
3. Quantity of oil: Amount drained: ______ Amount req'd. ______

Observations: ☐ Metal chips present ☐ Sludge present ☐ Non-factory oil filter

TP-2435

(Continued on page 2)

Preliminary Examination (Cont.)

Cooling System

1. Flywheel Screen:
☐ Clean ☐ Plugged ☐ Partially blocked (%) ______

2. Cooling fins:
☐ Clean ☐ Plugged ☐ Partially blocked (%) ______

3. Engine exterior:
☐ Clean ☐ Dirty ☐ Oily ☐ Evidence of prior disassembly or repair ☐ Visible oil leaks (where) ______

Carburetor and Fuel Supply

1. Condition of carburetor:
☐ Okay ☐ Broken ☐ Loose ☐ Shafts worn ☐ Dirt in throat

2. Settings:
☐ Main fuel adj. ______ ☐ Idle fuel adj. ______

3. Condition of fuel:
☐ Clean ☐ Fresh ☐ Stale ☐ Contaminated (water, debris, etc.)

Governor

1. Components:
☐ Intact ☐ Missing ☐ Modified ☐ Bent/Broken

2. Function:
☐ Operative ☐ Inoperative ☐ Modified ☐ Misadjusted

Dirt Ingestion

1. Is there evidence of possible dirty entry via:
☐ Air cleaner ☐ Carburetor ☐ Breather ☐ Gasket/Seal ☐ Oil fill opening ☐ Other ______

Spark Plug

Spark Plug	Cylinder 1	Cylinder 2	Combustion Deposits	Cylinder 1	Cylinder 2
Gap	in.	in.	Light	☐	☐
Make			Heavy	☐	☐
Number			Color	☐	☐

SECTION 2 EVALUATION PERFORMED BY

Evaluator	Date
Company Name	Type of Acct. ☐ Central Distributor ☐ Service Distributor ☐ Service Dealer
Address	

City	State	Zip Code	Phone No.

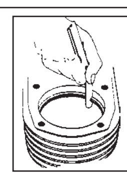
TEAR DOWN ANALYSIS

VALVES	CYLINDER 1		CYLINDER 2	
Stuck	☐	☐	☐	☐
Face Burned	☐	☐	☐	☐
Bent	☐	☐	☐	☐
Guide Worn	☐	☐	☐	☐
Not Damaged	☐	☐	☐	☐

CLEARANCE: (COLD)	CYLINDER 1	CYLINDER 2
Intake	in.	in.
Exhaust	in.	in.

CONNECTING ROD	CYLINDER 1	CYLINDER 2
Discolored	☐	☐
Broken	☐	☐
Bearing Scored	☐	☐
Cap Screws Loose	☐	☐
Dipper Bent	☐	☐
Dipper Broken	☐	☐
Rod Seized to Crankpin	☐	☐
Rod OK - Not Damaged	☐	☐

PISTON RINGS	CYLINDER 1	CYLINDER 2
Production Rings	☐	☐
Service Rings	☐	☐
Rings Free in Grooves	☐	☐
Rings Stuck in Grooves	☐	☐
End Gap: Top Center Oil	 ______ in. ______ in. ______ in.	 ______ in. ______ in. ______ in.

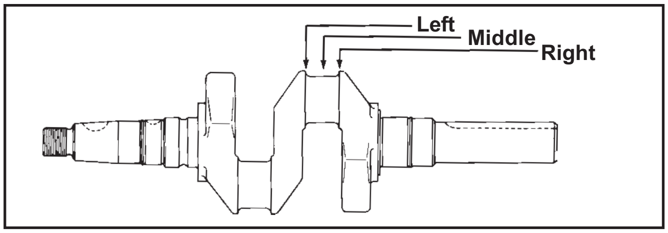


Note: For Crankshaft, Pistons & Cylinder Bore Measurements – See Page 3.

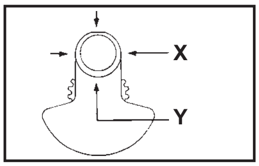
(Continued on page 3)

Tear Down Analysis *(continued)*

CRANKSHAFT ROD JOURNAL



	CYLINDER 1	CYLINDER 1
Scored	☐	☐
Worn	☐	☐
Unmeasureable	☐	☐
Broken	☐	☐
Not Damaged	☐	☐
Others		
Maximum Wear Spec.		

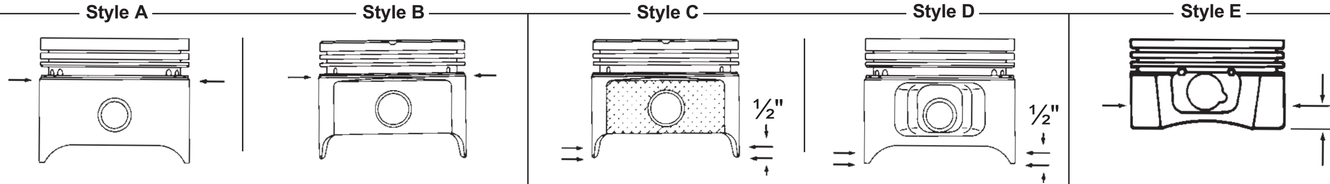


	CYLINDER 1		CYLINDER 2		MAX. OUT OF ROUND
	X	Y	X	Y	
Left					
Middle					
Right					
Max. Taper					

PISTON

Select the following piston type and measure diameter using appropriate method.

Style A — Style B — Style C — Style D — Style E



Measure just below oil ring groove and at right angle to piston pin. (Style A, Style B)

Measure 1/2 inch above the bottom of the skirt and at right angle to piston pin. (Style C, Style D)

Measure 6 mm (0.24 in.) above the bottom of piston skirt at right angles to piston pin. (Style E)

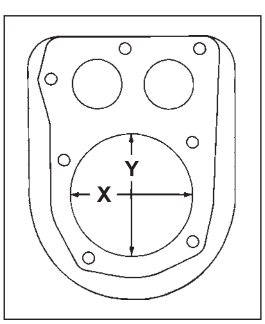
	CYLINDER 1	CYLINDER 2
Scored	☐	☐
Worn	☐	☐
Cracked	☐	☐
Broken	☐	☐
Ring Grooves Worn	☐	☐
Galled	☐	☐
Discolored	☐	☐

	CYLINDER 1	CYLINDER 2
Scratched	☐	☐
Not Damaged	☐	☐
Others ______		

	CYLINDER 1	CYLINDER 2
Piston Diameter	______	______

CYLINDER BORE

	CYLINDER 1	CYLINDER 2
Bore Scored	☐	☐
Worn	☐	☐
Not Damaged	☐	☐
Others ______		
MAXIMUM WEAR SPEC. ______		



	CYLINDER 1		CYLINDER 2		MAX. OUT OF ROUND
	X	Y			
Top					
Center					
Bottom					
Max. Taper					

KOHLER engines

BORN TO RUN™

ENGINE DIVISION, KOHLER CO., KOHLER, WISCONSIN 53044

FORM NO.:	TP-2298-B
ISSUED:	1/79
REVISED:	2/02
MAILED:	

LITHO IN U.S.A.