Failed Diesel Pistons

What the damage may tell you…

BY **STEVE SCOTT**

Let's start by looking above at the four basic designs of pistons used in diesel engines. Aluminum pistons (far right) have been around for decades. This design commonly incorporates a steel insert cast into the piston to provide added support for the piston rings. The bond between the steel insert and the aluminum piston body is critical in this design. More recent aluminum piston designs have an oil gallery cast into the crown. Engine oil is sprayed into the gallery to help cool the piston crown. The next piston design shown is an articulated design, which uses a steel piston crown and an aluminum skirt with a piston pin holding the two together. Next is a one piece steel piston, which has gained in popularity over the past decade. Finally, a steel "welded" piston is the most recent design shown, and is produced by friction welding a crown and skirt together. Depending on the manufacturer and engine model, you may find that one of the later design pistons has replaced the original piston that was in the engine. As a general rule, these design differences cannot be mixed within an engine, but there are exceptions.

These design changes are a result of market demand for increased fuel efficiency, longer service life, lower emissions, and other requirements. And, with these demands have come much higher cylinder pressures (and heat) that earlier aluminum alloys simply cannot withstand. Below is an example of the cylinder pressures these pistons may encounter.

Diesel Engine Cylinder Pressures		
Bar	Psi	Piston Type
110 130	1595 1885	Aluminum
160 180	2320 2610	Articulated
180 220	2610 3190	One Piece Steel
240	3480	Two Piece Friction Welded Steel

Differences in material and design can cause these pistons to react differently during a piston seizure condition. Aluminum pistons are more susceptible to thermal expansion, and require additional clearance in the cylinder. Steel piston designs do not expand as much, and are designed to have minimal piston to cylinder clearances. In any case, either with an aluminum or steel piston, seizure can result in a catastrophic engine failure.

Excessive temperature (heat) is the number one reason for piston seizure. However, identifying and correcting the source of the heat is critical to successfully repairing the engine. If the cause is not corrected, there's a very good probability that the engine will fail again.

The initial steps in failure analysis can be some of the most critical. Most failure analysis publications lists these major steps or processes. Not following a systematic process can jeopardize identifying and correcting the true root cause.

Examining the evidence on a seized piston may indicate whether the seizure originated at the crown, or at the skirt of the piston. In the photo above, the crown is beginning to scuff, and the damage shown is primarily around the top of the piston and progresses downward. This could be the result of over fueling, a timing problem, an air restriction, or inadequate crown cooling.

The burn pattern on the top of the piston can also give you an indication of various problems affecting the combustion.

The next photo shows the injection spray pattern high in the piston bowl. Common causes for this occurrence might be advanced injection timing causing detonation and/or lugging, resulting in fuel wash and scuffed rings.

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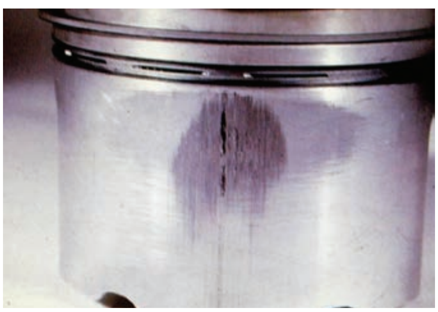
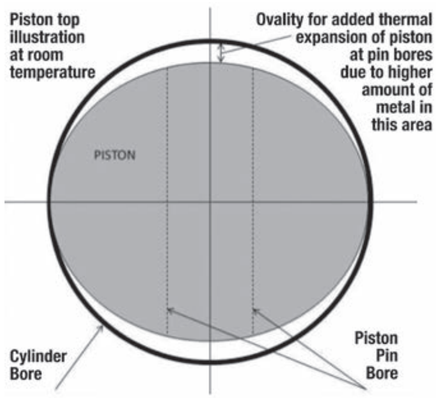
The photo below shows advanced stages of crown erosion. As the crown overheats, it softens, and the injection pressures actually erode the edge of the crown.

As mentioned earlier, the aluminum piston designs are more susceptible to thermal expansion. This next photo is an example of skirt overheating; however, it can be difficult to determine the root cause. An aluminum piston is thickest at the corners of the pin bosses, and as the piston grows or expands, the clearances to the liner are reduced or eliminated and the piston begins to scuff at what is called the ¼ points of the pin boss. High coolant temperatures, lack of heat transfer, and lack of crown cooling can all contribute to this type of failure.

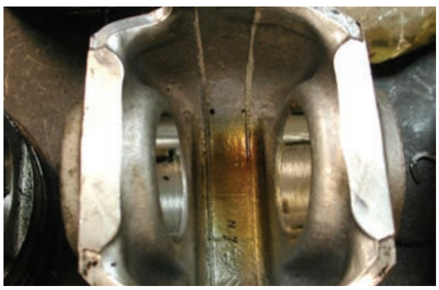
Center point scuffing on the skirt (as shown below) can indicate that the engine has been operating at high RPM or high load too quickly after start up. Depending on how severe and often repeated, this type of skirt damage can continue to expand around the entire skirt and seize the piston.



Most heavy duty pistons at room temperature are not round, they are elliptical (oval), and due to thermal expansion they change dimensionally as they reach operating temperatures. Allowing the engine to warm up gives the piston time to reach the correct operating profile.



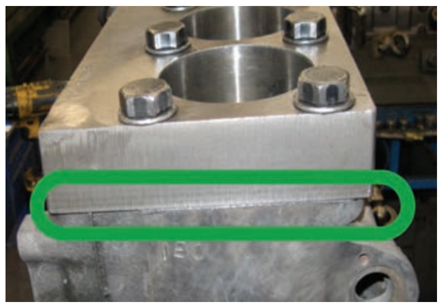
Inspecting the bottom of the piston crown can provide insight into how the piston crown was being cooled. In most engines, a piston cooling jet sprays engine oil on the underside of the piston crown. This absorbs heat from the piston crown and cools the piston skirt. The gold color shown in the photo below indicates there's been a good oil supply and moderate (not too high) crown temperatures.



The photo below indicates high crown temperatures. Cooked, burnt, or crusty oil on the underside of the piston confirms there was oil flow while the piston crown was operating at very high temperatures. Lack of discoloration under the crown can indicate that no cooling oil was reaching the crown.

These are examples of traditional aluminum piston crown operating temperatures. Later model applications use pistons designed for higher operating temperatures, such as gallery-cooled pistons, two piece articulated pistons, and one piece steel pistons, so the method for cooling the crowns can differ.

Checking maintenance records and/or checking critical event codes (on engines equipped with an ECM/electronic control module) are good sources of information. Sometimes, common causes of seizure can be identified by looking into an engine's history. If the engine has been operating successfully for an extended amount of time, you may be able to eliminate some of the possible causes. Obviously a failure could be from a defective part; however, a fitment problem between the piston and cylinder would most likely be evident shortly after assembly. Likewise, something as simple as rolling a cylinder liner o-ring during installation can distort the cylinder liner, reducing clearances and resulting in a hot spot that can lead to piston seizure.



Not all diesel engines have replaceable cylinder liners. In some engines, the cylinder bore is repaired using a machine sleeve, or by boring the cylinder oversized. Cylinder distortion in these types of engines can be a little more challenging to identify since properly machining or measuring the cylinder bores may require attaching a stress plate to simulate the same force or stress as would the cylinder head. Once the stress plate is tightened in place, the cylinder bores in the block are brought into the dimensional form or shape they will be operating in after the engine is assembled.

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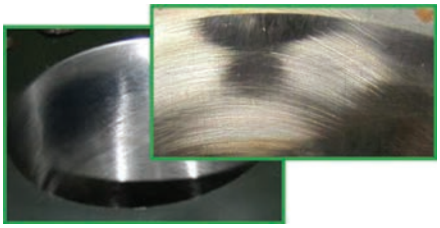
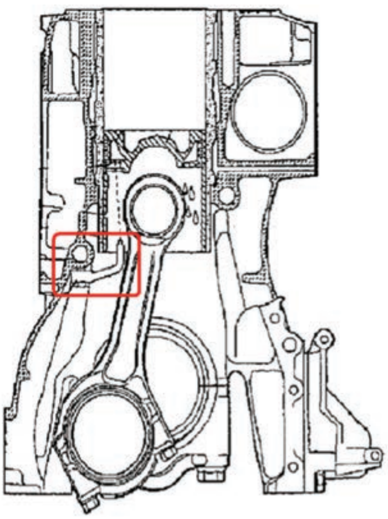
If a block that distorts in its free state is honed round without a stress plate, the cylinders will not stay round when the engine is reassembled.

The photos below show polishing on the high spots of a cylinder. While the piston rings can conform to some amount of distortion in the cylinder wall, they cannot conform to larger amounts of variations as shown here. Cylinder bore distortion can result in oil consumption, compression loss and piston seizure in more severe cases.

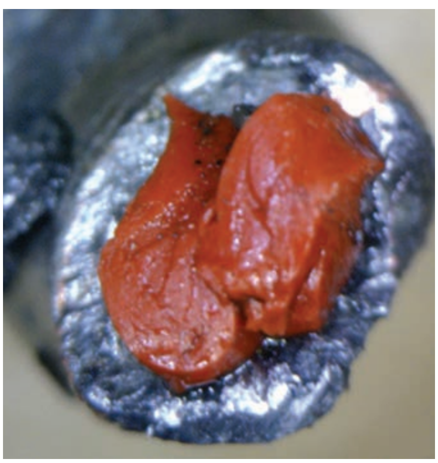


Another component that has contributed to more than its share of piston seizures is the piston cooling jet (or tube) used in some diesel engines. There are several different designs of these tubes, some have a single spray tube, others have twin tubes, and some are made from metal and others are plastic. These tubes spray engine oil up to the bottom of the pistons to cool the piston crowns. Depending on the application, some are adjustable and others are not. One thing they have in common is if they get damaged, plugged, or misaligned, then they can cause piston seizure. If the cooler tube is broken, you may find a small polished or impact area on the tube or piston skirt where the tube was contacting the piston. If not removed, these tubes can also be damaged or broken when the piston and connecting rod assemblies are being installed.



Attention to details during a failure investigation can sometimes uncover some "not-so-common" root causes. The photos below are from an engine that seized a piston and continued to operate until the piston and connecting rod exited the side of the cylinder block.

Sorting through the miscellaneous broken pieces found the piston cooling tubes, shown below. Closer examination discovered red sealant packed in one of the tubes. This sealant blocked the oil flow and resulted in a catastrophic failure. Gasket sealants may have their uses, but excessive amounts or even pieces that come loose can cause major problems.



In addition to the piston being cooled by the lube oil, approx. 1/3 of the piston's heat is transferred through the piston ring to the cylinder liner, and removed by the engine coolant. The engine's cooling system, and the condition of the coolant, is vital to this process. Weak coolant can lead to scale deposits building up on the outside of the liners (as shown in the photo below) and passages of the block, creating a thermal barrier. A 1/16" thick build up of scale can reduce the engines' cooling systems efficiency by 40% (or more) according to various studies. If the heat cannot properly dissipate through the rings, then the piston can overheat.

In summary, cylinder components are designed to withstand the demands of the operational parameters of the engine. Like any other part or component, if those conditions or demands go beyond the limits, then there's a risk of failure. Identifying the root cause and correcting the problem is the key to successfully repairing the engine.■

Steve Scott joined the service department at IPD in 1982, working with parts, service and sales for a variety of equipment, diesel, and natural gas engines. Since 2004, he has been the director of product development and technical support for IPD. For more information, email sscott@ipdparts.com.