

Piston Designs in Heavy-Duty Diesels

BY STEVE SCOTT

Most recently, you may encounter various piston designs within heavy-duty diesel engines. As engine technologies have evolved, the demand on internal engine parts has also increased. While aluminum pistons have worked well for decades in engines with lower cylinder pressures (approx. 1,600-1,900psi), many have been replaced by articulated steel crown and aluminum skirt (approx. 2,300-2,600psi), one piece steel (approx. 2,600-3,200psi), and two piece welded piston designs (approx. 3,500psi). As a general rule, these designs should not be mixed within an engine.

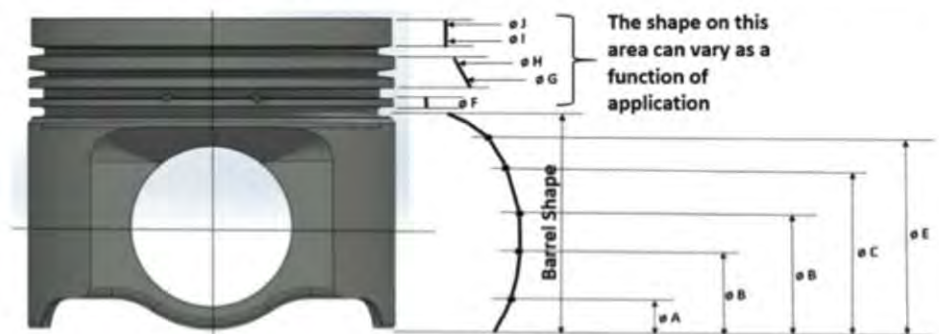
Reusing pistons from an engine is an option some consider, but it comes at a risk. Determining if the piston is reusable can be a challenge for a variety of reasons: OE's do not always publish "reusability specifications", ring land gauges can be expensive (if available), and there is no easy method to discern if the condition of the coatings and surface finishes on some pistons is sufficient for further service life. Some dimensions can be easily checked, but the exact locations to measure can vary. Piston profiles have different shapes that can only be determined with precision measurement processes. For example, the outside diameter of the crown can be machined differently than the landings below it, and the landing between the rings may be machined at varying angles. Also, most newer piston skirts are barrel shaped, where some older designs may have been tapered. The introduction of steel material (crowns and pistons) has allowed for much tighter clearances between the piston and cylinder wall due to far less thermal expansion compared to aluminum.

As you might expect, with barrel shaped piston skirts, the larger diameter is commonly 90 degrees from the pin axis, and midway up the skirt. Measuring 90 degrees from the pin axis avoids false readings from the ovality shape of the

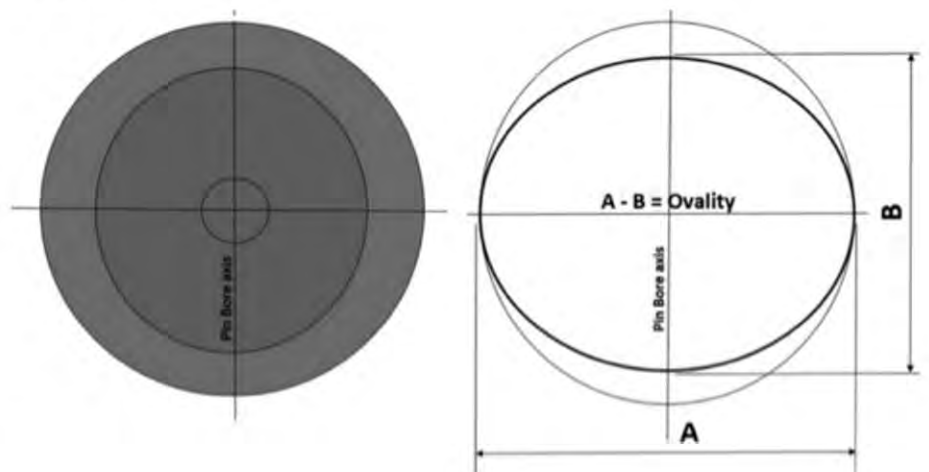
Various piston designs for heavy-duty diesel engines are shown below, from left to right: Two-piece friction welded steel, one-piece steel, articulated and aluminum.



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Ovality of piston is illustrated below.

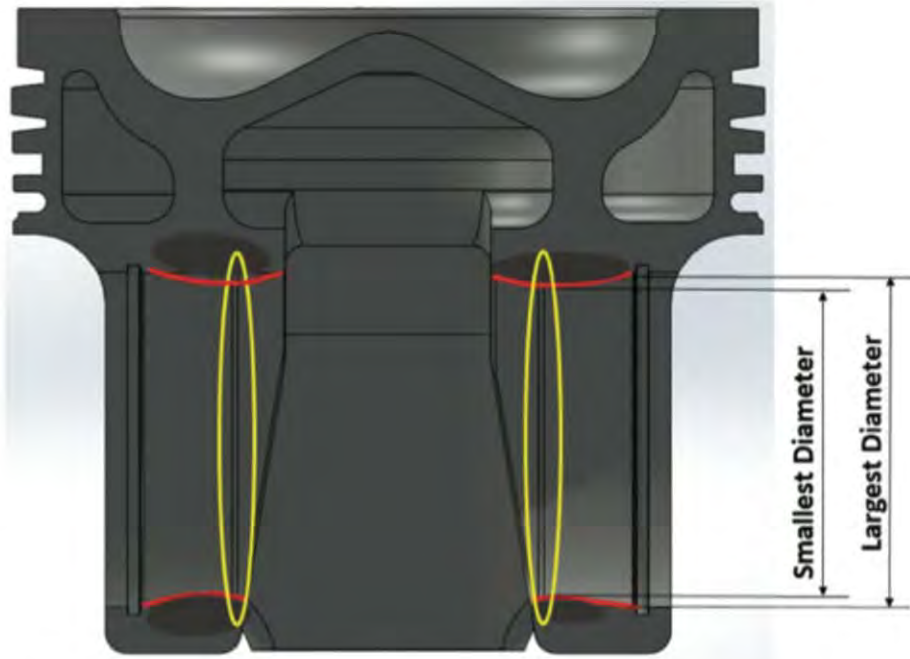


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piston skirt. This oval/elliptical shape applies mainly on the piston skirt to compensate for thermal expansion, along with side load and liner distortion that occurs when the engine is running. On some applications, elliptical shapes can also be applied on the first, second and/or third lands between the rings as well.

Another area of these pistons that has seen major revisions is the piston pin bore. For example, on some of the steel (bushingless) pistons, what may appear to be a simple cylindrical machined bore can actually have a very sophisticated bore profile/shape. The fitment of the pin to the connecting rod and piston is one that machine shops and technicians have scrutinized for years. Some piston pin bore profiles used in later model steel pistons have caused many to mistakenly believe the fitment is too loose. Actually, many of the tolerances have gotten tighter, but unique profile designs of piston pin bosses can provide more lateral movement of the piston pin when installed in only one side of the piston,




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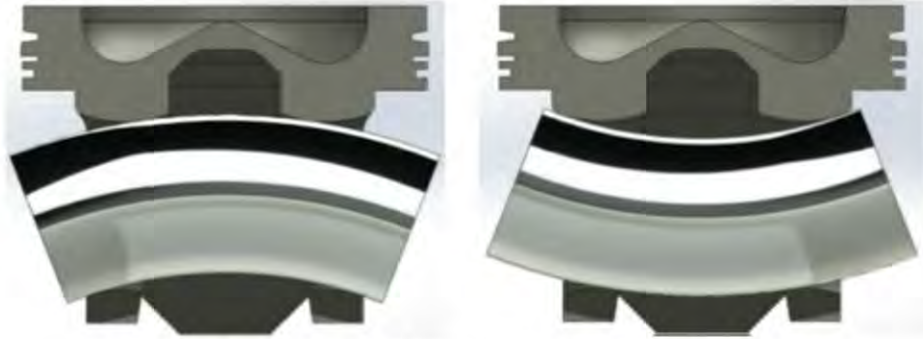
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Illustrations above show exaggerated piston pin "flex".

such as in the case of an "hourglass" shape profile. These profiles may also be asymmetrical, meaning the smallest diameter may not be in the middle of the bore, and cannot be accurately measured with a bore gauge or inside micrometers. The load from the connecting rod at the center of the piston pin can cause the pin to flex/distort. The profile allows the piston pin to flex without scuffing or seizing to the piston. This is not due to a weakness of the pin, it is the result of tremendously increased operating forces. The pin material, strength, hardness, and surface finishes have all evolved to meet the pressures/demands of these later model engines.

The example below is of a welded steel piston for a Caterpillar application. By inserting the pin approximately 25mm (1") into one side of the piston pin boss, and positioning a height gauge on the pin, we can measure almost 1.27mm (.050") movement by simply lifting the pin. A movement of 1.27mm (.050") is not a large distance, but it's

far more than what many technicians expect to find when assembling the piston assembly. The clearance has gotten tighter, but "the fit feels looser" has been the topic of many calls and emails to our tech line.

Many steel pistons do not have a bushing in the pin boss, and are coated with highly sophisticated coatings. These coatings are far more than just a dry-lubricant, they are applied in a tightly controlled environment, infusing the material on the piston to produce its anti-friction and anti-galling properties. The coatings and surface finishes of the piston pin bores, as well as the surface finish of the pin, are both critical to the working connection between the piston and connecting rod. This is why reusing these types of piston designs comes at a higher risk than some earlier design pistons. Something as simple as reversing the direction of a pin in a used piston can alter wear patterns. Any resistance that leads to seizure in piston and connecting rod connections can have catastrophic

results. This is especially true for some engines that have the mid-stop liners. Mid-stop cylinder blocks support the upper and mid-sections of the cylinder liner, but do not support the liner from the mid-section down. Restrictions (seizure) in the movement between the piston and connecting rod assembly can place extreme side loading force to the liner. And, at the bottom of the stroke where the liner is not supported, the lower section of the liner can break resulting in a catastrophic failure.

Overall, engine and piston designs have consistently been evolving towards ever increasing cylinder pressures over the past few decades. As a result, piston design complexity has evolved considerably, and we need to be aware of the changes in operating conditions that have dramatically increased demands on the internal parts of the newer engines versus those in the past. ■



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.

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