PISTON DESIGNS

So many designs, so little time…

BY **STEVE SCOTT**

One design fits all? Maybe, but certainly not very often where heavy-duty diesel pistons are concerned.

Piston designs have changed in recent years and the design you take out of an engine may not look like the new replacement. If it does not, you certainly need to confirm the replacement is correct before going further with a rebuild. Even greater attention should be applied where the thought of mixing different design pistons within an engine are involved.

There are four major piston designs: aluminum, articulated, one-piece steel, and two-piece friction-welded steel, but when you start looking at the various details there are far more differences than those of material and profiles. (Figure 1)

The level of the materials and workmanship a manufacturer puts into their products does vary, and those qualities can be difficult to determine. This article focuses on some of the various design features.

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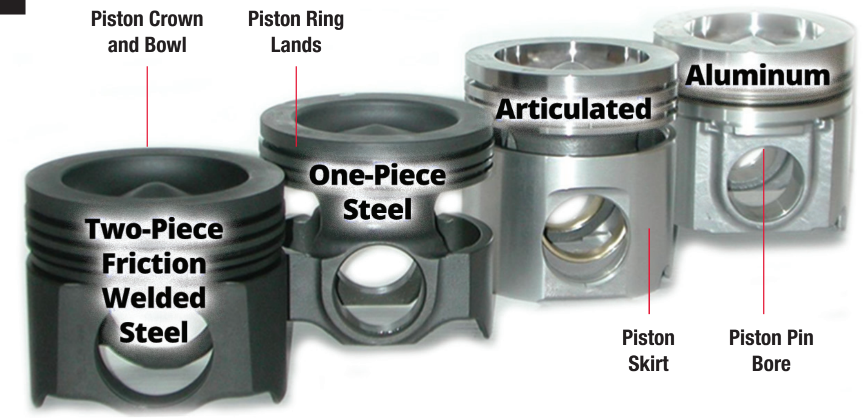

The four major piston designs are shown here, along with basic piston nomenclature.

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Piston Crown and Bowl Design Features

The contour and depth of the bowl of the piston crown affects the compression and combustion in the cylinder. This can be as simple as a flat-topped crown (Figure 2), to very detailed bowl configuration (Figure 4).

Some pistons have valve pockets (reliefs). The size, depth, and number of pockets depends on the engine applications. Pistons with valve pocket(s) are commonly directional. (Figures 5-6)

A less common feature making a piston directional is an offset pin boss. These can be difficult to identify. Offsetting the pin boss helps compensate for the rotational thrust of the engine. If a directional piston is installed incorrectly, once the head is installed the engine likely will not turn over, but if the engine does startup, it is a safe bet that it will not survive until the first oil change. (Figure 7)

Directional pistons commonly have an arrow or other indicator on the crown. Generally, the arrow points to the front of the engine. (Figure 8)

Some indicators on the crown of the piston are simply there to help the installer. This flat crowned piston is not actually directional, but the connecting rods are. This small "V" stamp in the crown is there to help the technician during assembly. The "V" goes on the same side as the numbers and tabs (tang slots) on the connecting rod. (Figures 9-12)

Aluminum pistons could be considered the older of these four material designs, but it is still current in a variety of

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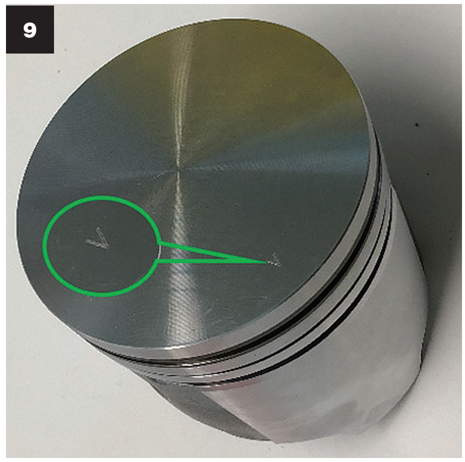

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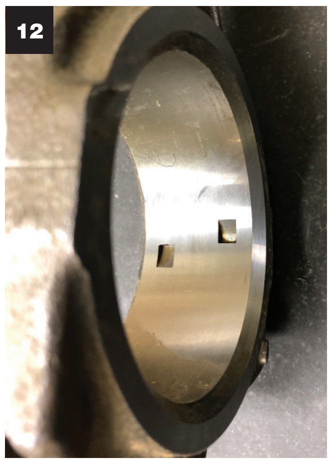

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applications. In some aluminum pistons you may find a "heat plug". This plug is designed to prevent fuel erosion on the piston crown. It is not uncommon on highly loaded engines or pistons that have been in extended service to find small cracks radiating outward around this plug. The cracks are not necessarily detrimental to the piston and some OEs publish specifications to determine the reusability of pistons having these small cracks. Heat plugs look simular to the head of an intake or exhaust valve, with a treated stem. The plug is inserted into the piston and commonly the nut is staked or tack welded to assure it stays in place. (Figures 13-14)

Pistons may or may not be "Gallery Cooled". Being gallery cooled is not limited to the aluminum pistons, it is a feature in some of the steel pistons as well. During the manufacturing process a gallery, or oil passage, is created in the crown of the piston. Engine oil is sprayed up from the

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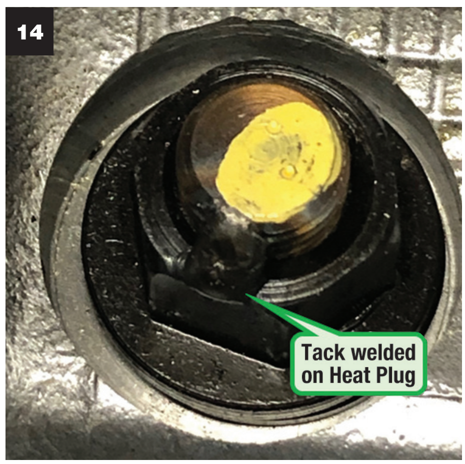

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piston cooling jet (tube) in the cylinder block into the ports in the bottom of the piston crown. Heat from the piston is absorbed into the oil and cooler oil is introduced during each stroke of the piston. Looking at the bottom of the piston, these ports are easy to see. (Figures 15-16)

This cutaway of an aluminum piston shows a dual Ni-Insert (described later in this article) and the oil gallery in the piston crown. (Figures 17-18)

The oil gallery in one-piece steel pistons is created by a dam plate inserted into the bottom of the piston crown. The design and how the plates are secured in the piston varies by manufacturer. This plate completes the oil gallery, without it the crown of the piston will likely overheat causing the piston to seize. (Figures 19-20)

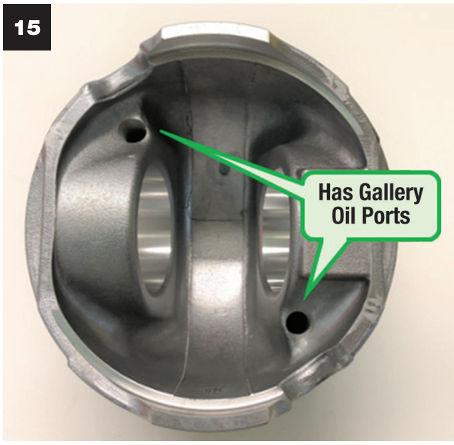
Piston Ring Land Features

One of the most questioned features involves the various oil drain back designs. The oil ring scraps excess oil from the liner wall on the downward stoke of the piston. To keep the rings from being flooded, the excess oil needs a pathway to escape. Common pathways are drain back holes in the back of the oil ring groove, drain back slotted in the bottom of the oil ring groove, or an egress system.

Oil drain holes allow the excess oil to escape through the oil ring and back into the inside of the piston body. (Figures 21-22)

Drain back slots allow the excess to flow back down the side of the piston. (Figures 23-24)

The accumulation and egress system in the welded steel pistons at first glance may be confused as being a fourth ring groove. This fourth groove serves as a reservoir for the excess oil. Reliefs are machined into the oil ring land allowing oil to



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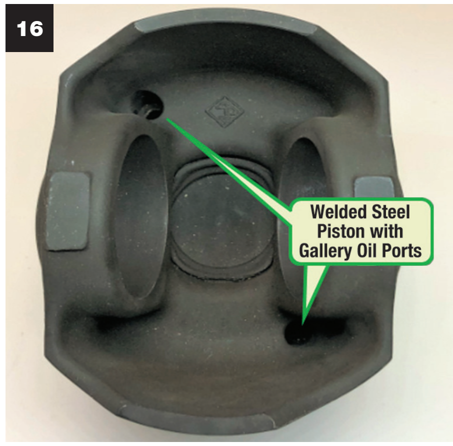

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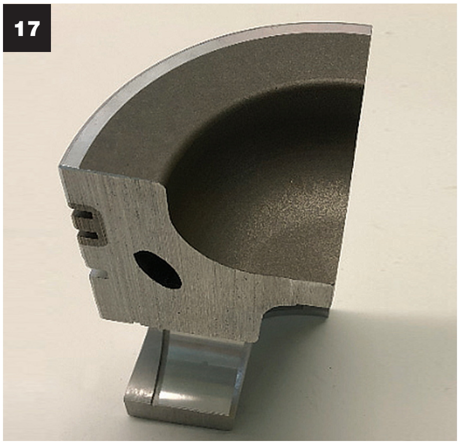
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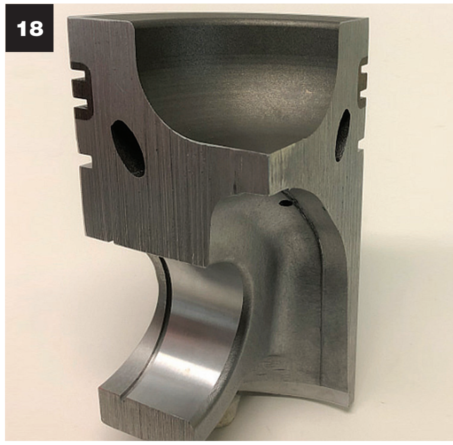
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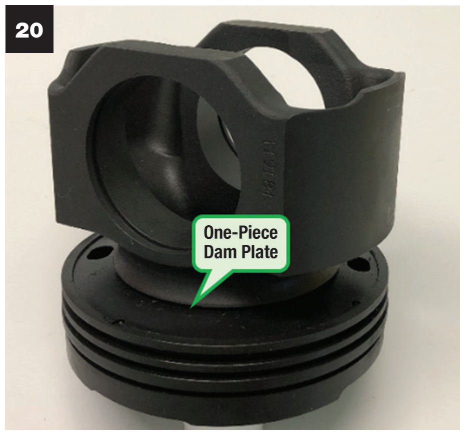

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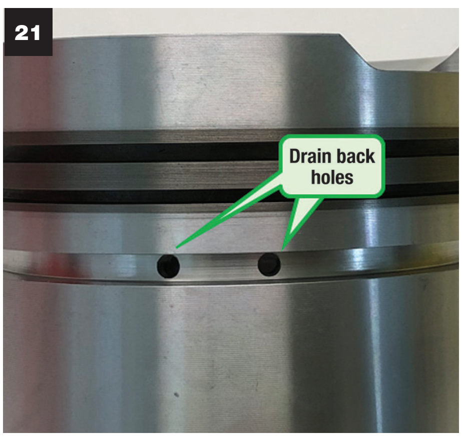

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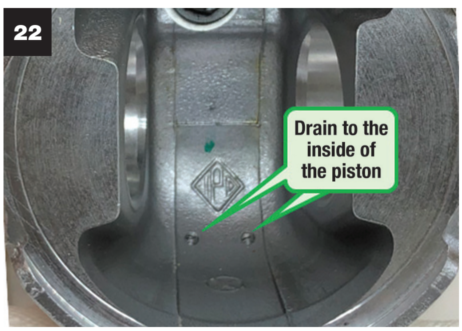

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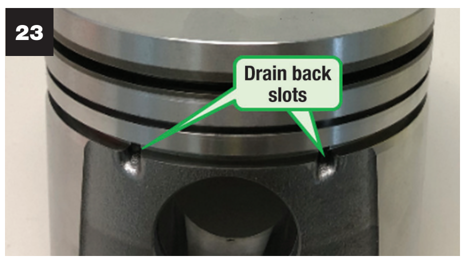

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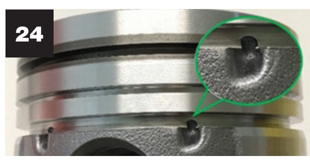
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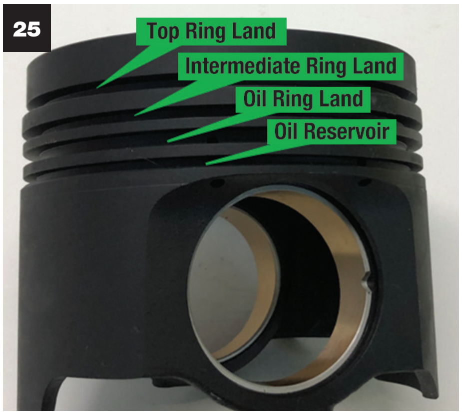
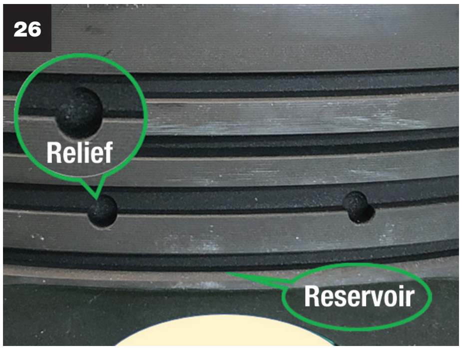
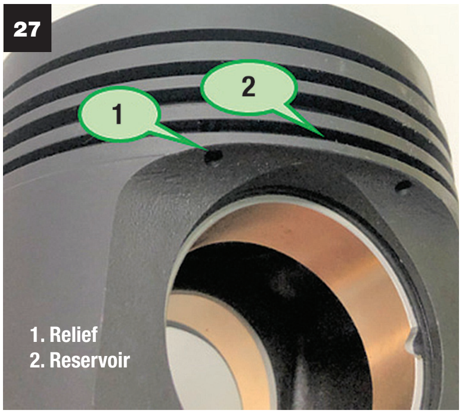
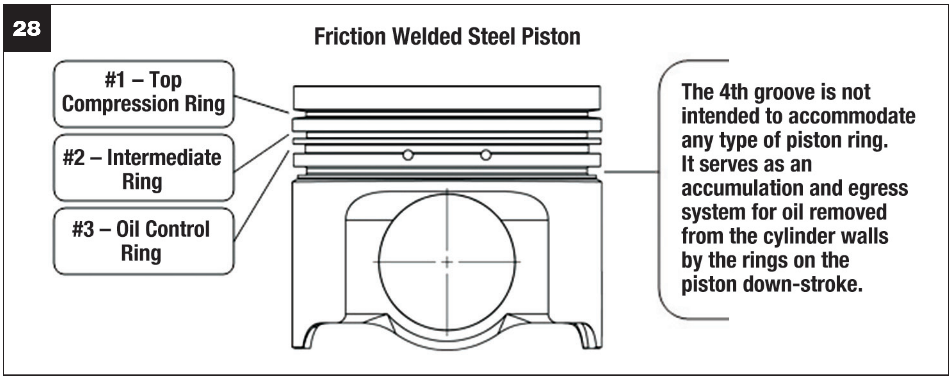






accumulate into this reservoir. Of course, how these reliefs are machined also varies. (Figures 25-28)

Two major difference in aluminum pistons are Single vs. Dual Ni-Inserts and if the piston is gallery cooled or not. The aluminum alloy in most industrial applications is not strong enough to support the rings, so a Ni-Insert is molded into the aluminum piston body. These inserts are easy to identify. A single Ni-Insert supports only the top compression



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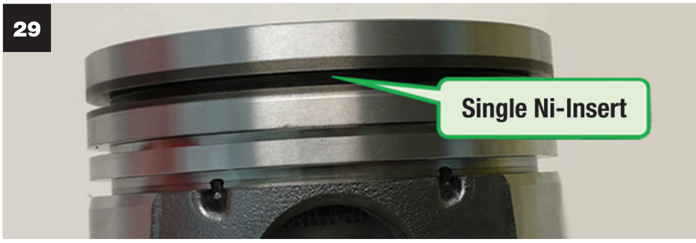

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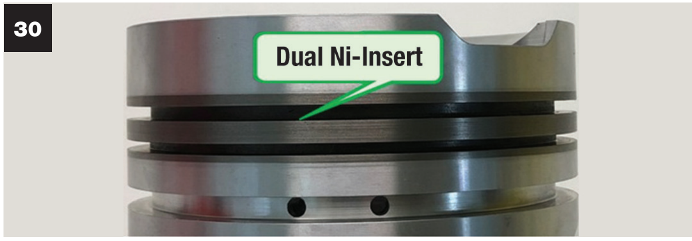

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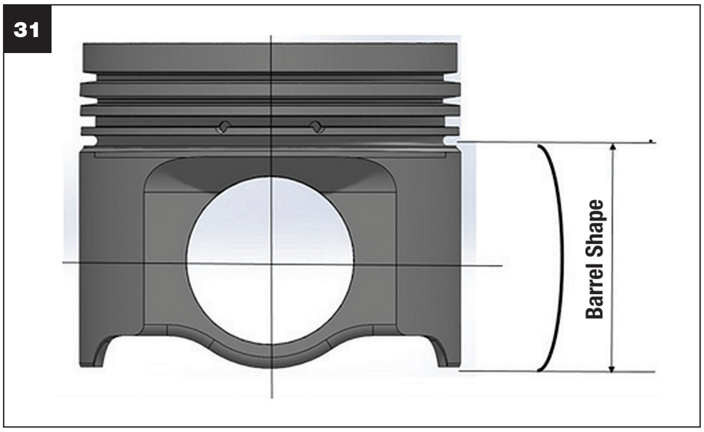

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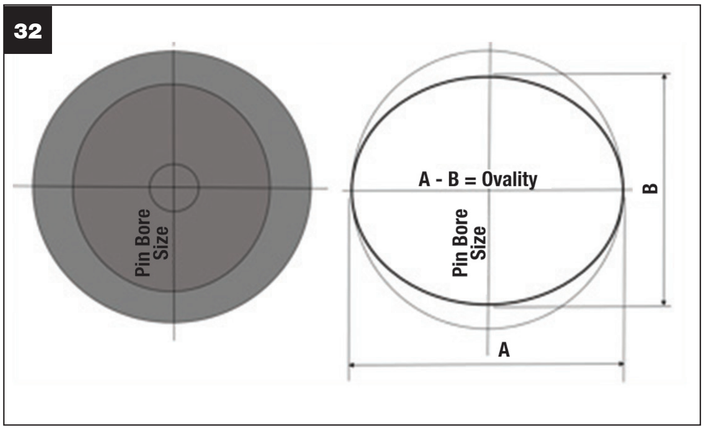

ring. A dual Ni-Insert supports the top and intermediate rings. (Figures 29-30)

Piston Skirt Features

What may appear to be a simple round machined surface is far more complex than it appears. Industrial piston skirts are often barrel shaped, and the surface finish helps hold the protective oil film. Most pistons are also elliptical. The OEM guidelines may list a few dimensional specifications for pistons, but those can also be confusing or misleading since they generally do not specify the exact locations to measure. For example, the outside diameter of the crown can be machined differently than the lands below it, and the lands between the rings may be machined at varying angles. Measuring in the wrong location may result in disqualifying a piston unnecessarily. (Figures 31-32)

Articulated Piston Design

Articulated pistons may seem a little odd. The crown of the piston and skirt are held together by the piston pin, but the skirt may not fit tightly against the bottom of the crown. The top of the skirt may have reservoirs or passages to retain oil to help cool the piston crown. Might be silly to mention, but the skirt may be directional (top/bottom). Honestly, I did not know it could happen, but I know of at least one instance where the skirt was installed upside down and it broke off the piston cooling jet (tube) and seized the piston. (Figures 33-34)

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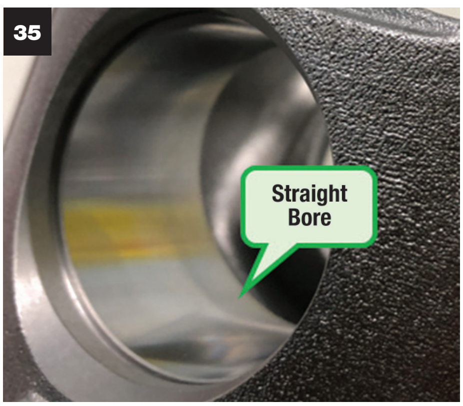

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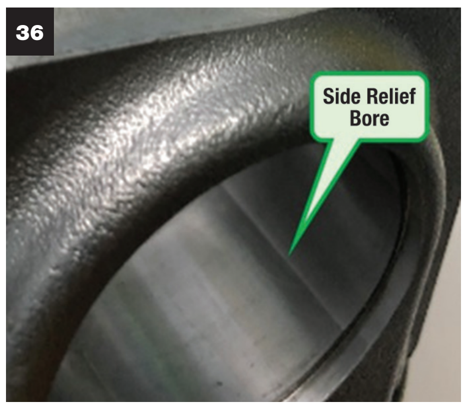

Piston Pin Bores

Over the years, the piston pin boss or bores have evolved as well. Again, this can vary from the simple straight bores, side relief cut bores, bores with non-replaceable bushings and to the most complicated-profiled bores in the steel pistons. (Figures 35-38)

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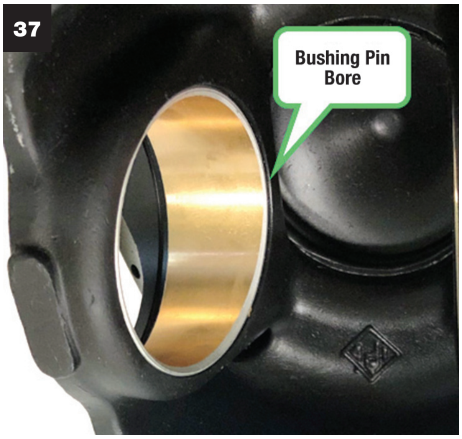

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The purpose of this article was to take a quick look and address some of the more common questions we hear. All the features shown are in current production pistons today, but this is just an overview. The design details of each could likely be separate articles, but you would likely be as bored trying to read them as I would be writing them. The demand to improve efficiencies, reduce emissions, and extend service life are contributors to some of these changes, but there is not a one design fits all answer. Differences between a used piston and a new replacement does not necessarily mean the new is wrong. The old and new features may or may not be interchangeable or compatible. It is better to ask than take a chance changing designs on your own. Pistons are at the heart of the horsepower, and that is not good place to have a problem.