Evolution of Typical Gasoline Piston Profiles

BY **Russ hayes**

It has been asked many times where to measure the true piston size when trying to determine true piston-to-wall clearances. Machine shops need to know this in order to be able to final hone to the clearances the engine builder desires. There have been many mistakes on how much actual clearance is truly needed and exactly how and where to measure the true sizes of pistons.

Piston manufacturers will usually design and develop their pistons from many factors such as application, type of usage, horsepower requirements, alloy desired, cast or forged, and while being able to design for their manufacturing capabilities. They can then determine the minimum clearance they would want to have their pistons ran. The type of design will determine how the skirt profile (top to bottom of skirt) and drop (contour around periphery of skirt) are to be defined. I will give examples of some basic profiles through the years for aluminum gasoline engines.

Many pistons were cam ground until the early 1980s. There were several cam profiles to choose from in order to find the desired contour wanted. The "C" (cloverleaf) design was needed in order to allow the area around the pin bosses not to be ground deeply as this would break down the grinding wheel at a fast rate. That would cause constant redressing of the wheel.

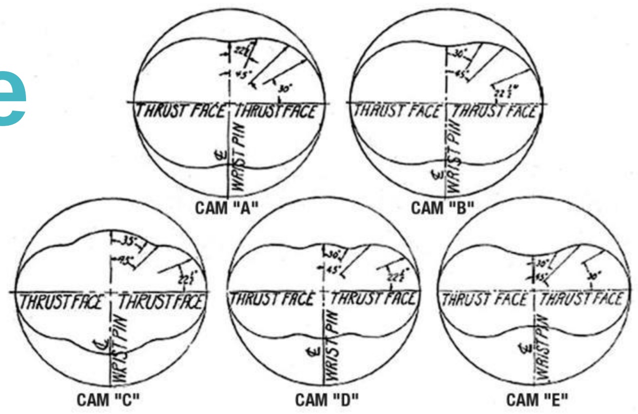


Figure 1. Various piston cam grinds since 1941.

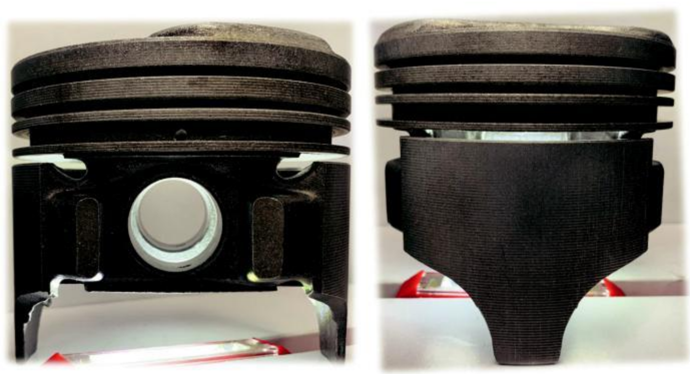
Many of the early style pistons were a full skirted such as the Model A & B (1928-34) as shown in Figures 2 and 3.

Notice the large open slot in the oil groove. This is there to allow oil return and to stop the heat from the piston crown going directly to the skirt. This "heat dam" as some used to say, allows the piston-to-wall clearance to be minimal. Most pistons with this design will have a "straight taper" profile which can be easily ground. This piston skirt is very flexible and does not need a deep cam grind.

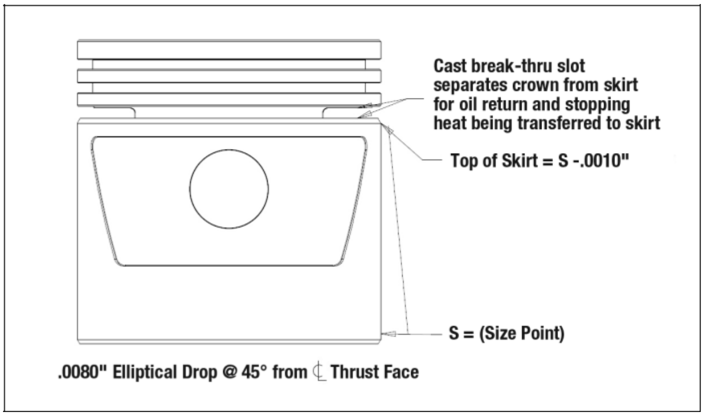
As engines evolved, the full-skirted design was not as prominent with V-engines with shorter deck heights. This is where the "semi-skirt" pistons were used a lot. The piston photos shown in Figure 4 are a stock 396 Chevy cam ground piston. Notice the large turned opening just under the oil groove. This heat dam operates to divorce the crown heat from the skirt and allows tight piston-to-bore clearances.

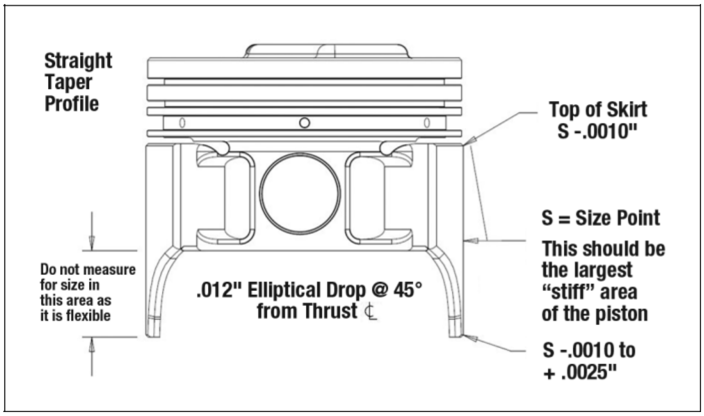
(continued)

Figures 2 & 3. Straight Taper Profile – Model A



Figures 4 & 5. Straight Taper Semi-Skirt Piston – 396 Chevy





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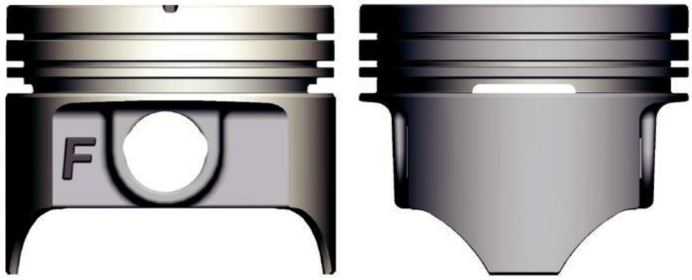
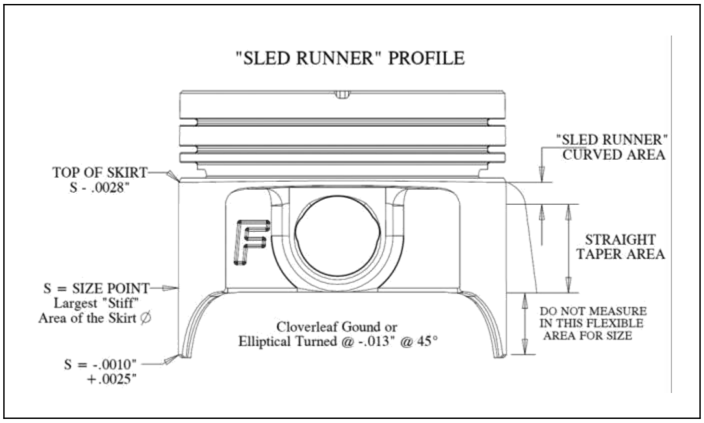
This has the same type of straight-taper profile, but it is of utmost importance not to derive the size measurement below the stiff areas because the skirt “tails” are extremely flexible.

Another type of profile that was used in the 1980s was the “sled-runner” profile. This 300 Ford piston started life as a “C” ground straight taper piston, but through the years developed into a slightly different profile shown below. Hard-cam turning machines were being used more often and could now follow a ground master cam for improved profiles.

Many times, the oil slots were being reduced for added strength and therefore had more heat transferred to the skirt. The sled-runner profile gave a deeper profile at the top of the skirt to offset the increased expansion. This was then followed by a straight taper.



Figures 6 & 7. Sled runner profile – 300 Ford L6



When compared to pre-1990’s engines, todays’ engines have much higher horsepower per cubic in³, smaller bores, longer connecting rods, reduced reciprocating mass and shorter piston compression heights. Many also have forced induction and have higher combustion pressures and temperatures.

All this newer technology necessitates much stronger pistons and very complex profiles and ellipses in order to keep the pistons and rings stable.

This is where the “barreled-profiles” must be used. While you can still run a hard-cam lathes and run off mastered cams, the advent of CNC machining is preferred by many. These CNC’s allow profiles and contours to be changed precisely and quickly.

In the J60GM piston drawing in Figure 8, you can see where the entire piston from the ring lands to the skirt have specific profiles.

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With the reduction or elimination of any large slotted oil grooves, much more heat from the piston crown is transferred to the skirt. This necessitates deeper piston skirt profiles immediately under the oil groove. The contour can be changing ellipses from top to open end.

The idea is to have profile wear patterns as indicated by Figures 9 and 10.

You do not want to have a wear pattern under normal heavy loading as seen on the piston in Figure 11.

Figure 8.
Barrel piston skirt profile

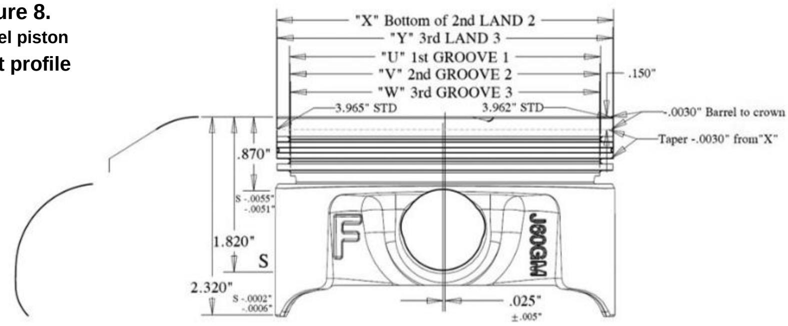

Figure 9.
Barrel piston thrust face wear.

Figure 10.
Barrel profile under heavy loading under normal operation.

Figure 11.
Full face wear under abnormal operation.
*** Note: Will score at corners as skirt cannot deform at these stiff areas.**

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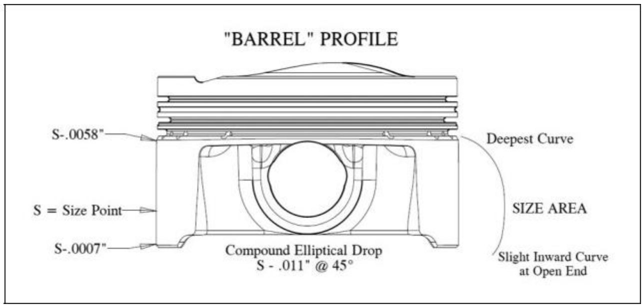

Figures 12 & 13. Barrel profile – Forged 3.5L Ford EcoBoost

Improved piston design for aftermarket use is essential for increased strength, higher boost pressures, and longevity. An example is shown in Figure 12 for Jasper's new forged 3.5L EcoBoost piston. This application has the profiles and contours defined enough to allow just .0010" of piston-to-cylinder wall oil clearance (not including the skirt coating thickness). To obtain a good piston ring seal with minimal blow-by, it is critical to have tight clearances that will live.

Pistons must continue to evolve in order to meet the increasing demands placed on today's engines. The race for better fuel mileage, ever-tightening emissions, and increased power output has made piston design much more complex. The lighter weight, shorter compression heights, and thinner ring packs needed require very tight tolerances in order to perform as desired. The future will have options to evaluate such as: thermal barrier coatings, friction reducing coatings, ever evolving rings, higher strength aluminum alloys, possibly steel, diesel type inserts, forgings, pin steel alloys and design with DLC coatings just to name a few.n

Russ Hayes is the Product Design Engineering Group Leader at Jasper Engines & Transmissions. He has over 30 years of piston design experience including manufacturing, tooling, cost analysis, R&D, patents, complete dyno testing and in-field testing. 500+ piston applications from redesigns to clean-sheet developments using cast and forged, including automotive replacement, strip/street performance, oval track, marine, OEM crate performance engines, 2-stroke, motorcycle, OEM automotive, small engine and light/medium duty diesel. For more information, email Russ.Hayes@jasperengines.com.