

Compression Ratio How-to

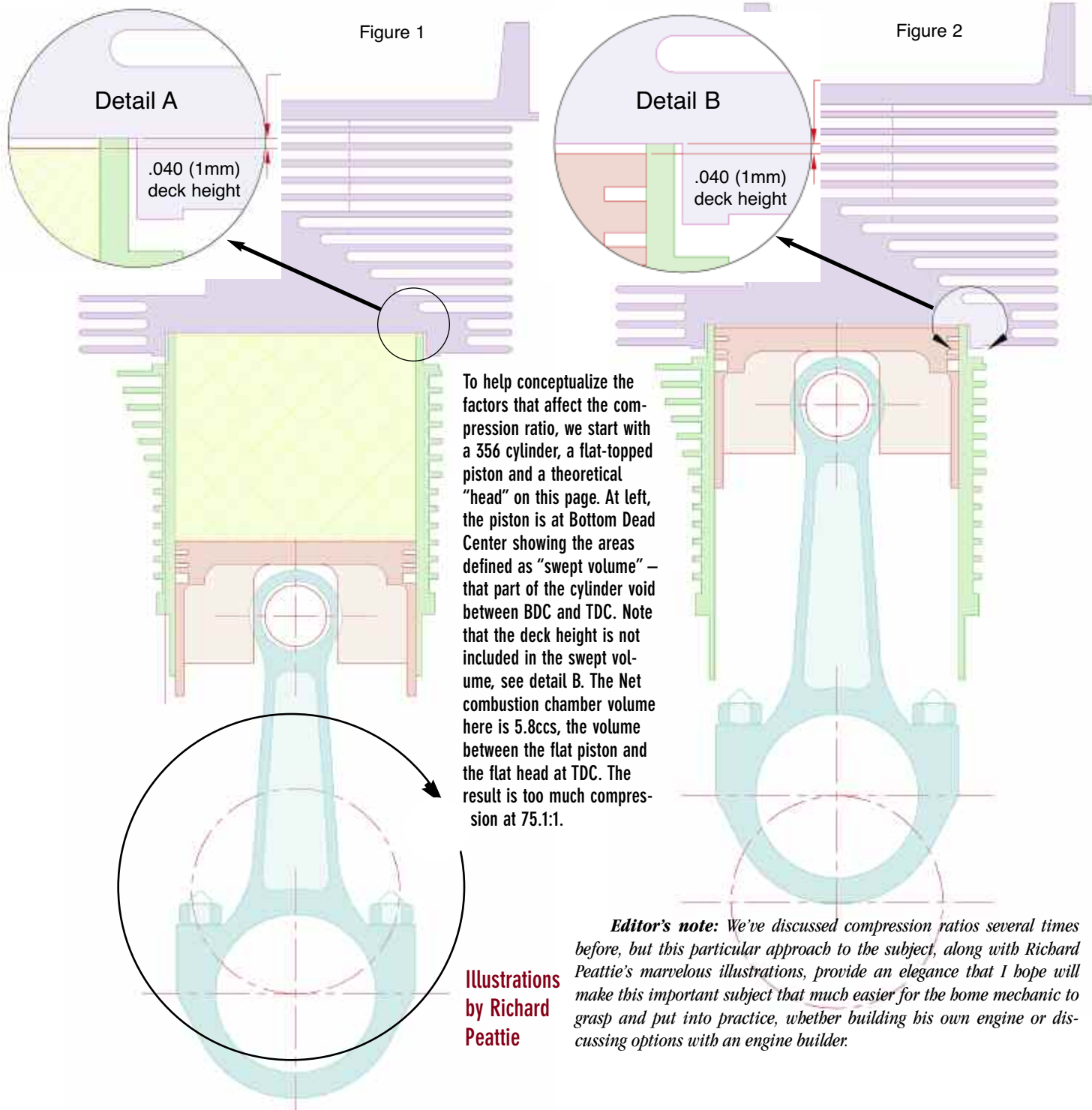
by Ron LaDow

Explanation

As detailed earlier, we already know that setting compression ratio is basic to building a good engine, and 356s can run quite high compression ratios to good effect. We also found that an engine produces power as if all cylinders are at the compression ratio of the lowest single cylinder. To achieve a certain compression ratio, and thereby balance all cylinders to the same value, we need understand how it is found and how it can be altered.

To find the compression ratio of any cylinder, we measure two values; the “net chamber volume” and the “swept volume”. Add both those numbers together and divide by “net chamber volume”. That’s the compression ratio of that cylinder. For example, one (the net chamber volume), plus nine (the swept volume), divided by one (the net chamber volume) equals 10:1 compression ratio or similar numbers. That’s all there is to the final sums. These two terms (“swept” and “net” chamber volume) are very important in understanding compression ratio. They’re not difficult to grasp and the terms will be used throughout the discussion. Other terms define portions of these values; they’ll be introduced as needed.

Finding the swept volume is a snap; there are few available for 356s and all are known to accuracies far beyond what’s required. They are all simply the bore area times the stroke.



Finding the net chamber volume is where the fun begins. For reasons that are inherent in internal-combustion engine design, the head chamber (that's the part of the chamber that's in the head) and the piston dome (that's the lump on the piston tops) are irregular volumes and cannot be calculated. They must somehow be measured. To illustrate, we'll start with a chamber which is made of 'regular' forms that are easily summed; a flat head surface and a flat-top piston as in figures 1 and 2.

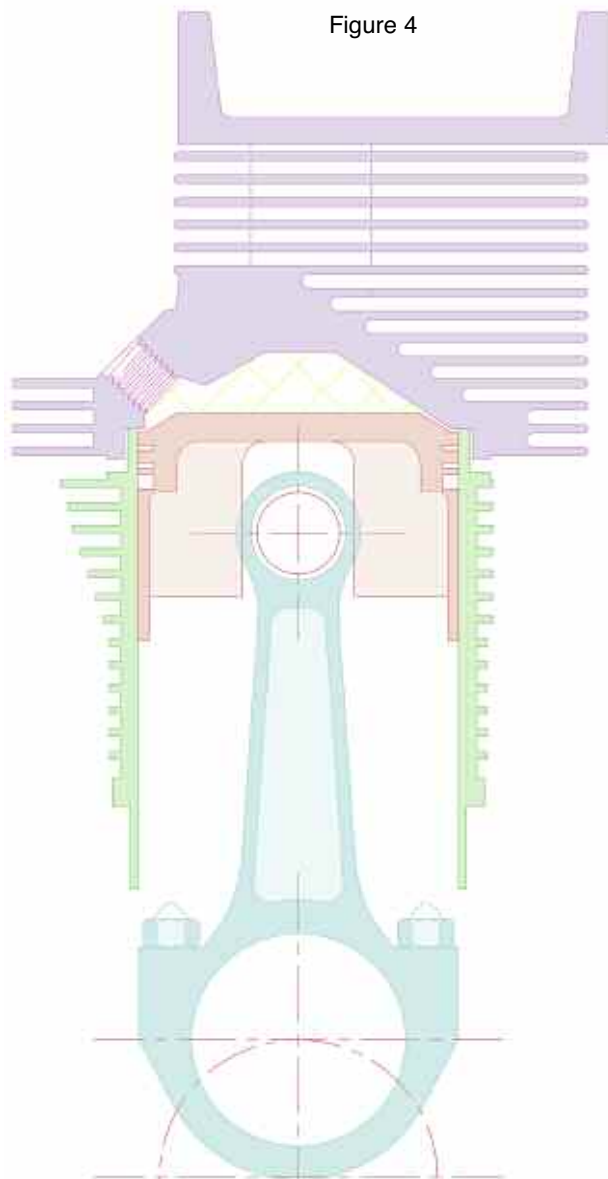
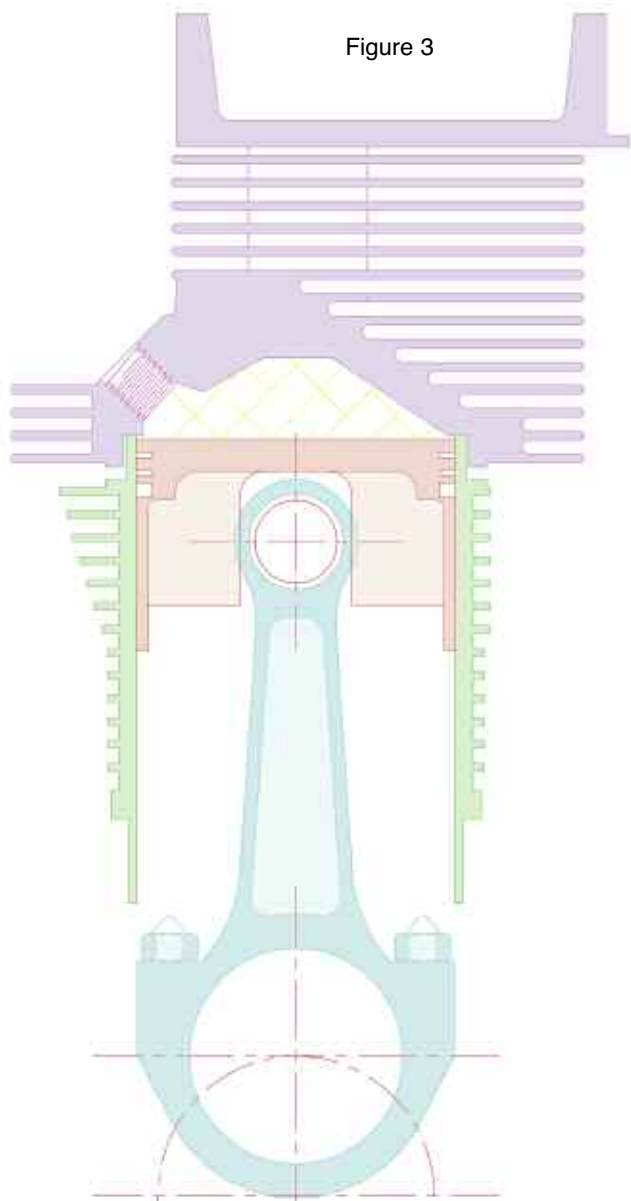
Fig. #1 shows the swept volume as the cross-hatched area in this simplified example. It is always easy to find; 'big-bore' (86mm) cylinders and a standard 74mm stroke yields 429.85ccs in swept volume. Note that the swept volume does not include the volume remaining above the piston at TDC (see details A and B).

Fig. #2 shows the net chamber in this simplified example; only the deck

add the irregular head chamber:

Fig. #3 is a rough representation of a 356 head chamber on the same big-bore, flat-top piston as shown above. The deck height volume remains the same as the earlier illustration, but we've added an unknown volume in the head chamber. The only way to establish that volume is to measure it with a calibrated amount of liquid. I do not trust any markings on the heads unless I personally know and trust who measured and marked them and that I can verify that they have not been altered; any factory markings are by now untrustworthy. The tooling to measure them is not an extravagance for the hobbyist; alternatively some shops offer the service, but one way or the other, they must be measured.

For this discussion, we'll say that this head chamber measures 62ccs, since it is a common enough 356 value. Add 62ccs to the deck volume (per



height volume. It is the volume represented by the deck height (the distance from the deck of the piston to the top of the cylinder) times the piston area. Since this example is based on 'big bore' pistons with a radius of 43mm, good, old Pi R squared times the 1mm deck height means a net chamber volume of 5.8cc.

Adding 5.8cc to 429.85 and dividing by 5.8cc says this cylinder has a 75.1:1 compression ratio. This is unrealistic, simply a result of the arbitrary design. As we get closer to real-world design, it'll change back and forth. Let's

above, 5.8cc) and we have the net chamber for this design: 67.8cc. Add 67.8 to 429.85 and divide by 67.8; a 7.34:1 compression ratio - good for kerosene. But most of our pistons have a dome as shown in Fig 4.

Now we've arrived at an archetype 356 net chamber. A piston dome rises above the deck of the piston and subtracts some volume from the net chamber and adds a bit more complication. The last example had a net chamber volume of 67.8; now we need to subtract the dome volume to find the new net chamber.

Ideally, you should measure the dome, but it takes some custom tooling to do so accurately. I do trust any and all of the cast big-bore pistons to have a dome between 17.1 and 18.0ccs but only because I continue to measure them. If that is close enough for your purposes, subtract 17.5cc (average dome) from a new net chamber of 50.3cc. Keeping the same 429.85 swept volume yields a compression ratio of, say, 9.6:1 (9.47:1 to 9.73:1)

As another example, two sets of Shasta forged pistons showed domes of 18.9cc, not a hint of change over the eight pistons. Subtracting 18.9cc (Shasta dome volume) from the earlier value yields a net chamber measuring 48.9cc and a compression ratio of 9.79:1 ($48.9 + 429.85 = 478.75 / 48.9 = 9.79:1$). This is approaching the limit of what can be used in a 356 on premium pump gasoline without going to twin ignition. With Shasta pistons you have data, with cast pistons you have some data and a choice. I have not yet measured the domes of pistons offered by others.

You can arbitrarily change either volume in this example. Do the arithmetic and see why we focus on the net chamber in changing compression ratios.

Review

To repeat, the swept volume is known and fixed while the net chamber is unknown, highly variable and more important. The above examples show there are several measurements required and they vary in importance and difficulty. Here's a review of the values with some tips on techniques.

There is only one method of measuring the deck height: Measure from the top of the cylinder to the deck of the piston. It is not possible to measure

it with clay or solder on the piston dome; see the illustrations and details below.

As you can see, the piston/head clearance can vary quite a bit while maintaining a constant deck height. Any clay or solder techniques will tell you piston/head clearance but will not yield any meaningful information about deck height. The 'trick' here (if there is one) is to measure above the ends of the piston pin (centerline in the illustrations below) to prevent funny data as the piston rocks in the bore. Good technique and a narrow tail on a dial caliper will tell the story.

The deck height is very important in establishing a compression ratio and is highly variable. It alone is determined by the consistency of at least five parts in each cylinder, any one of which may be out of specification. If you get funny measurements, they can be caused by errors in the compression height of the piston, the length of the connecting rod, cases which are no longer square, a crank which is not centered in the case or cylinders of varying heights. All of the parts can be checked by a competent shop, or tooling is available from Precision Matters and others. If your deck heights measure within .005", you're within .7cc in this particular volume; other volumes will vary also. .002" is not out of reach, but the choice (and the engine) is yours.

The 356 head chamber volume is important and not consistent. Head chambers have been accurately measured between 56.Xcc and 65.Xcc, a 9cc range, disregarding damaged heads. Measuring the chambers is not that difficult and the tools are available from Precision Matters and others. Alternatively, some shops will measure and record them for you. But visualization or caliper and rulers won't do it here; the volume must be measured.

