fast figures

By KEN KINCAID

Getting acquainted with your car and its performance is really quite simple. Here are 15 ways to find out just what the new set of wheels will do.

An important part of SCI's new policy is to satisfy the mental appetite of fans whose interest in sports cars goes beyond their good looks and nimble performance. We will describe the world's most exciting cars *in depth,* not just telling what they're like and what they do, but how, why and how well they do it. Furthermore, we'll put in your hands as many tools and techniques for evaluation and comparison as we can.

Here we offer 15 fundamental automotive calculations. Some of them will enable you to pre-test modifications you may be considering for your car. Others will give you a sound basis for armchair road-testing. Still others will provide techniques for actual full-scale road-testing. All of them will be of permanent reference value to the experienced fan, and for novice-class readers they will be an introduction to some of the most important subtleties of sports-car literature.

displacement

This specification is also known as piston displacement and swept volume by the pistons in their up-down course. It's easy to calculate, but ordinarily you don't need to — bore, stroke and displacement are part of any car's vital statistics and even a car salesman is likely to know them. But the picture changes when you get a rebore.

Let's say you have a Triumph TR2 and that the time has come for a bore job, in the course of which fifty-thousandths (.050) of an inch is cut from the cylinder walls. The original bore was 3.27 inches, the stroke 3.62 inches, and the displacement 121.5 cubic inches, or 1,991 cc. It's useful, particularly when displacement-class competition is involved, to know exactly how much difference the fifty-thousandths makes.

The displacement formula is "bore times bore times stroke times .7854 (¼pi) times the number of cylinders." Our TR2's bore has been increased to 3.32 inches. Therefore,

3.32 x 3.32 x 3.62 x .7854 x 4 = 125.4 cubic inches.

The new displacement translates to 2,055 cc in metric terms, enough to put you well out of two-liter competition. Of course the increase in displacement brought about by a rebore is even more striking when more cylinders are involved.

compression ratio

This figure is invariably given in factory specs, but it changes when you get a rebore or have the cylinder head milled. Let's see how it works.

Compression ratio is the proportion of swept volume of a single cylinder to the vacant combustion space — the space that remains when the piston hits the top of the stroke. When the compression ratio is 8.5 to one, the volume of the cylinder is 8.5 times as great as that of the combustion space.

To calculate the new compression ratio after a rebore you first need to know the volume of the combustion space. First, calculate the swept volume of the stock cylinder, before the bore job. To do this you simply divide the stock displacement by the number of the engine's cylinders. For the TR2: $\frac{121.5}{4}$ = 30.4 cu. ins. Now, divide this one-cylinder displacement by the original compression ratio, 8.5: $\frac{30.4}{8.5}$ = 3.58 cu. ins.

This is the volume of the combustion space, and with this figure you can now work out the new compression ratio. First find the displacement of the rebored cylinder:

3.32 x 3.32 x 3.62 x .7854 = 31.33 cu. ins.

Divide this figure by the combustion chamber volume:

$$\frac{31.33}{3.58} = 8.76$$

The new compression ratio is 8.76 to one.

Now suppose you want to get still more compression, and you're wondering what would happen if you had .050 of an inch shaved off the cylinder head. This would lop a thin, cylindrical-shaped slice from the combustion space. The volume of this slice can be computed in the same way that we've computed cylinder displacement, using the depth of the slice instead of the stroke:

3.32 x 3.32 x .050 x .7854 = .43 cu. in.

Now subtract this from the combustion space:

$$\begin{array}{r} 3.58 \\ -\ .43 \\ \hline 3.15 \end{array}$$

As before, to calculate the new compression ratio, divide the cylinder displacement by the combustion space:

$\frac{31.33}{3.15}$ = 10.0 to one.

Using these calculations you can eliminate much guesswork from the pleasurable pastime of engine souping.

piston speed

Because the rate at which the pistons charge up and down the cylinders tends to determine the point at which an engine coughs its innards, this is an extremely important figure. Quality of materials and workmanship can offset its not-entirely inexorable toll. But manufacturers of passenger cars like to stay below 2,500 feet per minute and those who build racing cars shrink from the 4,000 fpm figure. At this point the pistons' friction losses allegedly begin to match the engine's power output. But whatever the controversial facts may be, fast piston speed and fast engine wear undeniably go hand in hand. When judging engines and modifying them it's well to watch piston speed closely. You calculate it simply, by multiplying the stroke (in feet) times 2, times rpm.

In the case of the TR2, piston speed at maximum horsepower would be

.30 x 2 x 4800 (rpm) = 2880 fpm,

a very reasonable speed for a high-output engine.

bore-stroke ratio

Very likely you've heard, or will hear, plenty of talk about this subject. You may have noticed the recent trend toward the "square" ratio, one where the width of the bore and the length of the stroke are equal, and the "over-square" ratio, which means a bigger bore than stroke. The snowballing prevalence of the big-bore school of engine design is related to rpm, and to the fact the faster you rev an engine the more its piston speed and internal friction rise. Sports car engineers are not overly concerned with bearing speeds, which are seldom critical. But they are concerned with piston speeds. And long strokes increase piston speeds. The closer you approach "squareness" — the shorter the stroke — the more you can rev an engine without putting an unduly heavy load on its reciprocating or up-and-down parts.

To calculate bore-stroke ratio you simply divide the stroke by the bore. In the case of the TR2:

$\frac{3.62}{3.27}$ = 1.11 — very slightly under-square.

transmission ratio vs. overall ratio

British specifications generally express all gear ratios in "overall" terms. In other words, all the transmission ratios are expressed as multiples of the rear-axle ratio. In the U.S., on the other hand, transmission ratios are nearly always listed "pure" — without reference to the rear axle ratio.

To translate an overall ratio into a simple ratio you divide it by the final drive, the rear-axle ratio. For example, the TR2's third gear has an overall, British-type ratio of 4.90 to one. Divide this by the rear axle ratio of 3.70, for a simple, U.S.-type third-cog transmission ratio of 1.32. To convert a simple transmission ratio to an overall ratio, multiply the transmission ratio by the gearbox ratio. Since top cog almost always has a one-to-one ratio, overall "top" in the gearbox is usually exactly equal to the rear axle ratio.

Occasionally in overseas literature you'll come across gear ratios expressed, as, for example, "9/44." Here the 9 refers to the number of teeth on the small pinion gear, 44 to the number on the large ring gear. Dividing 44 by 9 gives the ratio — 4.9 to one.

tire revolutions per mile

This is a particularly useful figure if you want to work out top speeds available in various gears. The Tire & Rim Association has worked out a very neat formula for making this calculation:

$$\frac{10084}{\text{loaded radius in inches.}}$$

When the TR2 is standing on its tires the measurement from hub to pavement — its loaded radius — is 13.0 inches.

$\frac{10084}{13} = 776$, the number of times the wheels rotate in a mile.

speeds in the gears

Now that we've determined the tire revolution figure we can find out the speeds in the various gears at any engine rpm figure. Let's discover what top speed ought to be in the TR2's third gear. The formula is

$$\frac{\text{rpm x 60}}{\text{gear ratio x tire revs}}$$

The TR2's peak hp is developed at 4800 rpm, its overall third gear ratio is 4.9 to one. Therefore:

$\frac{4800 \times 60}{4.9 \times 776} = 75.8$ mph, top speed third gear.

In this way you can determine performance on each of the gears. This is particularly valuable to know when you're considering the installation of non-standard gears in the transmission or in the rear axle.

the quarter mile

A measured quarter mile is a handy tool for the performance-minded enthusiast. Arm yourself with a 100-foot steel tape and find a quiet, level section of road that is long enough to give you plenty of shut-off room at each end of the measured distance. The tenth-mile rotor on your car's odometer or mileage counter is useful for making rough preliminary surveys. Once you've picked your spot, measure off the 1,320 feet carefully, marking with chalk or lumber crayon each 100-foot "step." Mark each end of your test strip with some permanent marker. Stakes at each side of the road, spikes driven into the pavement, and paint marks on the pavement are all good. Before you run tests put up markers that can be seen from a distance of a few hundred feet. You can use flags, piles of rocks, or even stacks of the ubiquitous beer can.

bhp per cubic inch

This calculation is one way of relating power to unit of displacement, and it's very handy when you're comparing engines that are very similar in design. But you should use it with caution and remember that design differences can make it worthless as an index of a car's efficiency. For example, if a given engine's stroke is cut in half and its rpm is doubled, its power output will remain the same while the bhp per cubic inch figure will be doubled.

To determine bhp per cubic inch, divide the horsepower by the displacement in cubic inches. For the TR2:

$\frac{\text{90 bhp}}{\text{121.5 cu. ins.}} = .74$ bhp per cubic inch.

tire revolutions per mile

This is a particularly useful figure if you want to work out top speeds available in various gears. The Tire & Rim Association has worked out a very neat formula for making this calculation:

$$\frac{10084}{\text{loaded radius in inches.}}$$

When the TR2 is standing on its tires the measurement from hub to pavement — its loaded radius — is 13.0 inches.

$\frac{10084}{13} = 776$, the number of times the wheels rotate in a mile.

speedometer calibration

Few speedometers are even reasonably accurate. Their error is almost always optimistic and it grows with the speed. However, they are easily corrected if you have a measured quarter-mile available. All you need to do to convert elapsed time over the quarter-mile into mph is to divide the time in seconds into 900. Let's say you're running a check through the quarter with your speedometer held at a steady 60 mph, indicated. You start your stopwatch as you cross the first marker and stop it as you cross the final one. The elapsed time is, say, 15.50 seconds.

$$\frac{900}{15.50} = 58.06 \text{ mph, actual speed}$$

top speed standing quarter-mile

The measured quarter-mile is useful for top-speed tests, using the same basis for calculation. Let's say you take a generous running start in a TR2 and cover the quarter-mile timing strip in 9.35 seconds. Divide 900 by this number and you have a top speed of 96.25 mph.

You can also use the measured course as a private drag strip, recording elapsed times for the standing-start quarter mile. Such elapsed times (standard in all road tests) furnish an enlightening basis for comparison with the performance of other cars. You can get the most accurate results by averaging two-way runs.

determining unknown gear ratios

Usually there's no question about the gear ratios of the car you're driving. They're pinned down in the factory specs, or the owner's manual. But every now and then the time comes when you find yourself in a machine whose exact final drive ratio is unknown. If you have an honest-to-God clutch instead of some variety of hydraulic coupling, you can figure it out without the bother of dismantling the rear end.

This is the procedure. You jack up one rear wheel, clear off the ground. Remove the spark plugs, to ease the job of turning the engine over. Make a chalk mark on the crankshaft fan belt pulley or vibration damper and a matching mark on the engine block. Drop the gearbox into top cog and make a clear chalk mark on the ground-free rear tire, and a corresponding mark on the road. Now the setup is complete.

While a helper keeps his eye on the crankshaft fan belt pulley or vibration damper, turn the free rear wheel. In the case of the TR2, when the wheel has made a full round the pulley will have gone around 3.7 times — and that's the final drive ratio. Repeating the operation in the other, intermediate gear positions will give you the other overall ratios. To get the simple, unadulterated gearbox ratios, divide these by the final drive ratio. And then you'll know your gearbox.

speeds in the gears

Now that we've determined the tire revolution figure we can find out the speeds in the various gears at any engine rpm figure. Let's discover what top speed ought to be in the TR2's third gear. The formula is $\frac{\text{rpm} \times 60}{\text{gear ratio} \times \text{tire revs}}$ The TR2's peak hp is developed at 4800 rpm, its overall third gear ratio is 4.9 to one. Therefore:

$$\frac{4800 \times 60}{4.9 \times 776} = 75.8 \text{ mph, top speed third gear.}$$

In this way you can determine performance on each of the gears. This is particularly valuable to know when you're considering the installation of non-standard gears in the transmission or in the rear axle.

mph per 1,000 rpm

This is another, even simpler way to compute miles per hour for any engine speed in any gear. The formula is three times the loaded tire diameter divided by the overall gear ratio equals mph per 1000 rpm. To illustrate, let's find the TR2's speed in second gear at peak engine revs. Its overall second gear ratio is 7.40, its loaded tire diameter is twice its loaded tire radius, or 26. Thus:

$$\frac{3 \times 26}{7.4} = 10.54 \text{ mph per 1000 rpm.}$$

The car's peak power is developed at 4800 rpm, so multiplying 10.54 by 4.8 gives a top speed in second gear of 50.6 mph — a pretty accurate figure.

#