BRABHAM – HIS ROLE IN INDIANAPOLIS

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PORSCHE 1600 SUPER–
FULL TEST INSIDE

SPEED DAYS OF THE ROLLS ROYCE
HOW TO GET YOUR RACING LICENCE

WORK OUT YOUR REAR AXLE RATIO

...By PEDR DAVIS

TECHNICAL TEXTBOOK

USE YOUR MATHEMATICS TO GOOD USE AND DECIDE IF A CHANGE WILL GIVE GREATER SPEED OR MORE FUEL ECONOMY.

IN our article on differential units and their place in modern racing we promised to deal more fully with the question of rear axle ratio. We all know that by "dropping" the back axle ratio, we can knock a second or two off the standing quarter mile acceleration time. Conversely, if we want frugal fuel economy or a higher cruising speed, we "raise" the axle ratio.

The question of "dropping" and "raising" a ratio produces endless confusion, as some of our correspondents point out. They ask, quite rightly, is a 3.44 axle higher or lower than a 4.11 axle? The answer is HIGHER.

The reason is this: the rear axle is simply the relationship between the engine speed and the number of revolutions the rear wheels make per minute. This ratio is variable and in the conventional rear axle design is governed by the number of teeth in pinion and the corresponding teeth in the crown wheel.

A "high" axle ratio is one demanding relatively few engine revolutions for each revolution of the rear wheels. Such a ratio would have a low numerical value (say 2.91) and would give high overall gearing.

Conversely, a "low" rear axle ratio would have a high numerical number (say 4.38) because the engine has to make 4.38 revolutions for each complete turn of the rear wheels.

Summing up this rather confusing business, we "raise" an axle ratio by lowering its numerical number and we "lower" or "drop" the ratio by raising the numerical number.

Needless to say, you cannot increase the maximum speed of a car indefinitely merely by raising the axle ratio. Many cars have been built which will go faster in top gear than in third. Bugatti had a penchant for this sort of thing, his aim being to produce a high economical cruising speed by the use of what was virtually an overdrive top gear.

We ourselves have tested many cars fitted with electric overdrive units and in some cases it is definitely possible to reach a higher speed in fourth gear than in overdrive.

The reason can be seen by studying the nature of horsepower. At any given speed the brake horsepower of an engine is the product of its torque multiplied by its speed and divided by 5252 to bring the answer to foot lbs per second. (By definition, a horsepower is a unit of work and indicates that work is being done at the rate of 550 foot pounds per second.)

An engine is designed to develop its maximum torque at a certain speed. In a sedan, where flexibility is important, this may be as low as 2000 rpm. In a sports car, maximum torque may be reached at about 3600 rpm. In a racing engine, the figure may be as high as 5000 rpm. Anyway, the point is that the torque output drops off after the peak point has been reached. By studying a power graph of any engine, it can easily be seen that the point can be reached where the product of the engine speed and torque output is a diminishing factor. In other words, the power output drops the faster the engine goes.

Alternatively, although the engine may be spinning at say 4000 rpm, the product of the rpm and the torque may be a rising factor. In short, in all engines there comes a critical point where the horsepower is at its maximum.

The wind resistance and frictional losses within the transmission are proportional to the speed involved. It is thus possible for the gearing of a car at say 80 mph to be too high or too low for the engine to be turning over at the right speed to provide maximum power.

This is why an over-geared car may easily go faster in third gear than in top.

In motor sport, a driver may not necessarily be concerned with maximum speed. In drag racing, sprint work and some road racing circuits, maximum acceleration is far more important than sheer speed. Under such conditions, the gearing is lowered to provide maximum acceleration coupled with whatever maximum speed is required.

Even in sports car work, it is no exaggeration to say that the proper choice of rear axle ratio can make or break the ultimate performance of the vehicle.

So now we get round to the practical side of the axle ratio.

As we know, the axle ratio depends on the number of teeth on the crown wheel and pinion. So when gearing a car to give maximum acceleration, we must bear in mind three things. First, the available horsepower is directly proportional to the engine speed and the torque produced *at that speed.* It is therefore preferable to obtain a power curve for the engine, if available.

Secondly, the acceleration or hill climbing ability of the car is directly proportional to the excess horsepower available over and above the requirements of the car to maintain its present speed.

Thirdly, if we are gearing a car to accelerate on, say, a quarter mile strip, the ideal is to have the car reach its maximum speed at the end of the timed strip.

So, how does one calculate the ratio? There are many ways, from counting the number of teeth on the crown wheel and pinion, to jacking up the car and counting the number of engine revolutions required to turn the rear wheels 360 degrees.

How can the theoretically best axle ratio be calculated? This is best done by a formula which is given shortly, together with working examples. But getting back to the question of determining an existing ratio, the most accurate method is to count the number of teeth on the crown wheel and divide by the number of teeth on the pinion.

If you don't wish to pull the rear axle down, an alternative idea is to stand the car on a level floor, remove the spark plugs and turn the steering wheel until the front wheels are pointing straight ahead.

Now engage top gear and make a vertical chalk mark at the point where one rear wheel touches the floor. It is then necessary to turn the engine's crank handle slowly and crank the car forward until the chalk mark is once again at the bottom of the wheel. At this point, the rear wheel has made one complete revolution and by counting the number of engine turns, you will know the rear axle ratio.

Suppose, for example, it took 4¼ crank handle turns to give one revolution of the rear wheel, then the rear axle ratio is approximately 4.25 to 1.

If no crank handle is fitted to the car in question, make a chalk mark on the crankshaft pulley and turn the engine, by pushing the car.

The above method also provides a rough and ready means of calculating the speed of the car at 1000 rpm. You measure along the ground to know how far the car has travelled for one turn of the rear wheels. Suppose this is 6½ feet and the rear axle ratio was found to be 4.25, then the car will move 6.5/4.25 feet for each engine revolution.

Therefore at 1000 rpm the car will move a total distance of

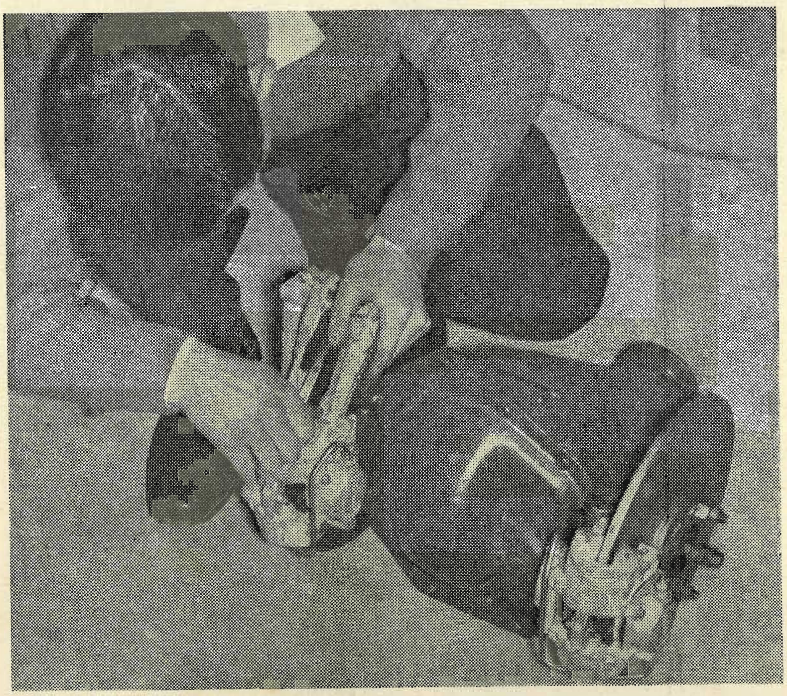
$$\frac{1000 \text{ by } 6.5}{4.25} \text{ feet.}$$

This means that the car is travelling at the rate of approximately 1500 ft per minute. Now 60 mph is equivalent to 88 ft per second or 5280 ft per minute. Thus we can easily calculate that the car is doing 17 mph at 1000 rpm engine speed.

If, however, you wish to calculate the best axle ratio for acceleration or maximum speed, the basic rule to remember is that the car should be geared to achieve its maximum speed with the engine turning over approximately 200-400 rpm above the speed where maximum brakehorsepower is achieved. When gearing for drag

Sexagenarian De Dion

A De Dion rear end designed and built by Sydney engineer Ray Alberry. The differential housing is Jaguar and the inboard disc brakes by Dunlop.



THE de Dion back axle, born at Puteaux, France, in 1894, celebrates its 67th birthday this year. It's generally accepted merits, *vis-a-vis* the live axle on the one hand and most forms of independent rear suspension (IRS) on the other, are well known. It drastically undercut the former's unsprung weight and, in its modern applications, using torsion bars or coils, relieves the springs of the subsidiary chore of axle location. Compared with the commonest type of IRS (viz, swing axles) de Dion carries only a slight unsprung weight penalty and it maintains the parallelism of the road wheels under cornering stresses. With its chassis-mounted final drive unit, either wedded to or divorced from the gearbox, it shares the IRS benefit of a potentially low drive line.

So how much longer, you may wonder, do we have to wait before the rank and file of the world's car makers get in the queue behind such arbiters of grand prix fashion as Ferrari, Maserati BRM and Vanwall and racing, you assume that the car will reach its maximum speed at the exact end of the quarter mile strip.

One popular formula used for determining the best axle ratio for acceleration or maximum speed is as follows:

$$\text{mph} = \frac{\text{engine speed (rpm) by Pi by tyre diameter}}{\text{1050 by rear axle ratio (A.R.)}}$$

How is the above formula applied? Let's suppose that you want to gear the car to reach a maximum speed of 100 mph, coupled with maximum acceleration. Suppose also that the engine develops its maximum speed at 4500 rpm. To this figure, we must add 400 rpm, giving a total of 4900 rpm.

The tyre diameter is measured in inches and is normally taken when the tyre is inflated to correct pressure. In this example it is 25 inches. Pi is the normal mathematical constant of 3.12. Thus to gear the car to peak at 100 mph we have—

$$100 = \frac{\text{4900 by Pi by 25}}{\text{1050 by A.R.}}$$

$$\text{Thus Axle Ratio} = \frac{\text{4900 by Pi by 25}}{\text{1050 by 100}} \text{ or } 3.70$$

Suppose that on a trickier circuit you calculate that the maximum speed should be 80 mph, then the axle ratio required would be—

$$\text{Axle ratio} = \frac{4900 \text{ by Pi} \times 25}{1050 \times 80} = 4.55$$

As well you can see, the above formula will provide an approximate maximum speed for your car, provided you know the other factors take the Hillman Minx to test its accuracy. Here the mph is unknown, the engine speed is 4800 rpm, the tyre diameter 25.5 inches and the rear axle ratio 4.55.

$$\text{Thus max speed} = \frac{\text{4800 by Pi by 25.5}}{\text{1050 by 4.55}} = 79 \text{ mph}$$

How accurate is this? Our latest road test of the series 111A Minx showed a maximum speed of 80 mph. Thus the formula gives a close approximation to the real speed, for the rpm, tyre diameter and axle ratio quote in the example are correct for the Minx.

It is also possible to use this formula to calculate the maximum possible speed in each gear, provided that you know the gear ratio involved. Suppose, for example, that a gear ratio is listed as 1.392 to 1 then in the formula above it is necessary to multiply the axle ratio by 1.392 to provide the overall gearing.

If, for example, the axle ratio is 4.55 and the gear ratio is 1.392, then the "A.R." shown in the above formula is 6.33.

If you try out this formula experimentally against known results, you may easily find that although the theoretical and actual top speeds may be close, there may be four or five mph difference in theoretical and actual top speed in second or third gear.

The reason is simply that the formula is based on the assumption that "ideal" axle and gear ratios have been selected. In point of fact the manufacturer may easily decide to use a lower or high intermediate gear ratio to suit the driving habits of the buyer.

We have in previous articles discussed the question of quick change diff ratios. The formula above works well with such an axle and enables you to calculate the desired ratio for given conditions. The spur gears used in most quick change rear axles are provided by manufacturers who can also give a chart showing what combinations are required to give a certain ratio.

These charts are ideal companions to the above formula and even if they are not available, the data can be quickly worked out, bearing in mind that the gear ratio resulting from the use of two spur gears is calculated by dividing the number of teeth of one spur gear by the number of teeth in the other. #

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embrace this mechanical paragon? Certainly there's no legal impediment because the original patents expired almost 50 years ago.

For over a quarter of a century, technical savants have been prematurely writing the live axle's obit in at least four languages; and if, as seems likely, the bell does indeed toll for this anachronism within the next three or four years, the de Dion deal should stand a good chance of fulfilling the promise it's transiently shown at scattered periods throughout automotive history.

The first edition was before its time in the most literal sense. At a date when cars were no faster than the brisker horse-drawn traffic a few pounds of unsprung weight either way didn't mean a thing; nor did parallelism of the wheels, which anyway was fully maintained by the live axle that was the only contemporary alternative, or did the possibility of lowering the drive line, which would have been pointless as long as tonneaux remained high enough to make motoring a sort of mobile Summit conference.

In fact, de Dion and partners never even aimed at these objectives, their purpose being to relieve the wooden road wheels — a frequent cause of breakdown back then — of excessive strain. This, in the invention's earliest form, it succeeded in doing. The first vehicle to feature it, by the way, was a steam tractor.

But when, as time went by, wheel design improved it became harder to justify the expense of an admittedly rather complicated mechanism, and gradually de Dion cars swung over to the homely but cheap and serviceable live axle. After WW1, no de Dion had the "de Dion" back end — not that this term for it came into currency until many years later.

First copyist of the system was another French maker, Pilain, who flirted briefly with exposed and articulated halfshafts and the accompanying dead axle beam around 1910/11. Following de Dion's own abandonment of the idea it found no new adherents until 1924, when Harry Miller applied it to a front drive car he'd built for Jimmy Murphy to drive at Indianapolis. Murphy, killed while racing at Syracuse, NY, that year never had a chance to prove his theory that fwd was the right recipe for Indy success; but Millers with front drive in conjunction with four quarter-elliptic springs and a de Dion beam did subsequently score impressively in the 500, placing second at their first try (1925) and later winning outright. Then, when Miller had second thoughts about the advantages of fwd, he adapted his version of de Dion to the back axle instead.

The gook's European renaissance is often mistakenly credited to Daimler-Benz, due to the fact it was featured in 1937 on Mercedes-Benz grand prix cars, one year ahead of the rival Auto Union racing camp. But what is sometimes forgotten or overlooked is that Horch, a member of the Auto Union group, used de Dion axles on their big passenger cars in '36.—MARTIN DENIS #