Mallock aforethought

Based on years of painstaking experience, Club racing's Godfather kicks off our brand new racing suspension development story. This month Arthur Mallock deals with corner weight jacking and spring rates . . . in terms that . . . er . . . some of us can understand

Corner weight jacking has been used in the USA almost since the dawn of motor racing, where Indy roadsters were fitted with cockpit adjusters to control balance during a race. In Europe, I suspect that Lotus were the first to master the technique. I picked it up from Mike Costin in 1960.

A four legged table in the Globe public house at Hanslope has one leg 1/8in. shorter than the rest. This leg and the diagonally opposite, carry almost no weight, giving an extreme case of weight jacking, where only two corners carry any significant load.

Drive one front wheel onto a 6in. block and the other front wheel will probably leave the ground. A gentle push on the body will cause the car to teeter, with most of the weight on the two diagonally opposite wheels. Exactly the same effect is created if the suspension on one corner is raised; e.g. by screwing up a spring abutment or fitting a thick spacer.

The facts above are well enough known. What is not so well understood is how significant these facts can be. There are very few cases where they can be ignored. In the 500cc Formula Three days, rear suspensions were often inter-connected left to right. Alf Francis started the trend on the Stirling Moss Kieft. This automatically adjusts the corner weights to neutral jacking. Likewise you do not need to worry overmuch if you use a vintage ladder chassis, which simply twists to accommodate any errors.

Beyond this you can say for certain: if you have not checked corner weights, they are almost certain to be wrong, and any other suspension tuning will not make sense. Even the wet string chassis of the late fifties were not immune.

For example, on a symmetrical single seater, one might expect the two front wheels to carry equal weights, and likewise the two rear. When we checked a Lotus 16 and a BRM P25, the front wheel weights varied by 50lbs. Our experience is that 5lbs is a reasonable tolerance and anything over 10lbs can be detected on the track, so that 50lbs is totally catastrophic. "Absolutely nothing I tried seemed to have any effect on the bovine understeer," was a typical comment. A Lister was next, with 130lb more on the offside front. Some of this was due to the two seater off-set weight distribution, but more than half was due to a jacking error. "Whoever heard of not being able to take Abbey flat," commented Gerry Marshall.

If this was important in the 50s, then today, where chassis are up to 20 times as rigid and the suspension rates are up to 10 times as stiff, corner weights become absolutely critical. Over the past few years two prominent formula car designers told me that they do not need to check corner weights on their chassis because their suspensions were built to such fine tolerances. On buying such a car, the error was found to be 60lbs. Correcting this defect, alone, improved times by 60 per cent of a grid length.

Some examples will illustrate the tolerances we are talking about. In 1962, the U2 Mk 2B had a chassis rigidity of 500lb ft/degree. Rear coil springs gave a static deflection of 3 1/8in. and the track-to-spring base ratio was about 1.41. Remembering that the lever arm has to be squared, the roll rate is half the suspension rate. A 3/8in. washer on top of the stem of the nearside suspension unit was enough to change uncontrollable understeer into a comfortable oversteer at Becketts.

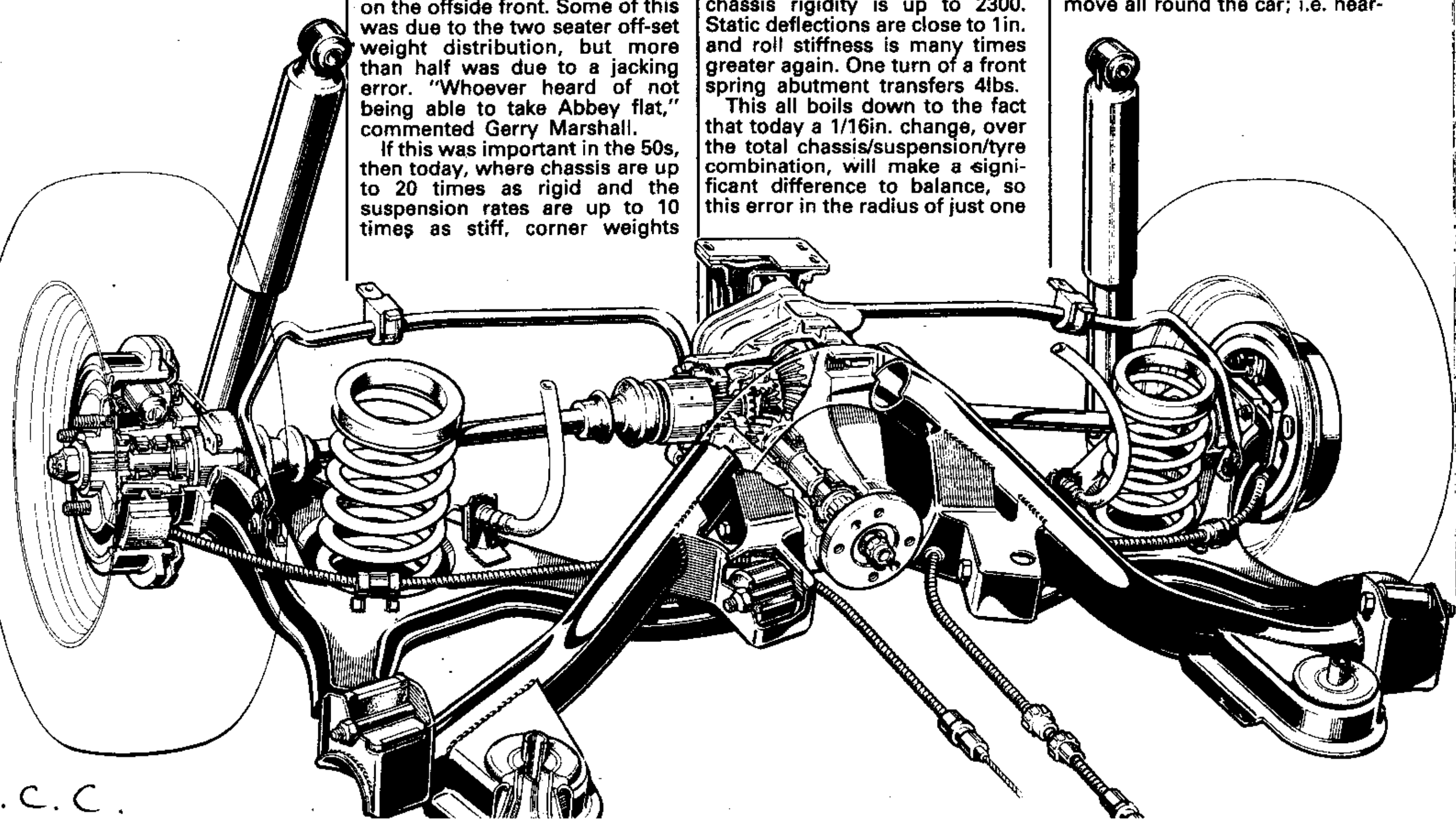
Eight years later, the Mk 7 chassis was twice as rigid and roll bars had doubled the roll stiffness. In this case, a 1/8in. 'C' shaped washer could be popped in during a practice pit stop to balance nicely a severe understeer at Gerrards.

Today, on the Mk 24, bare chassis rigidity is up to 2300. Static deflections are close to 1in. and roll stiffness is many times greater again. One turn of a front spring abutment transfers 4lbs.

This all boils down to the fact that today a 1/16in. change, over the total chassis/suspension/tyre combination, will make a significant difference to balance, so this error in the radius of just one tyre can upset the system. In our early karting days, this amount of wear could take place in one practice session and the king pin had to be washered-up to compensate. In those days, weight jacking was about the *only* method of balancing a kart.

The big teams set up their chassis on solid slave wheels and match tyres accurately. The rest must be content to check corner weights whenever tyres change.

So far, we have talked mostly of correction errors. That is, taking all jacking out of the suspension so that wheel weights relate exactly to centre of gravity position. This helps to get the suspension to work as the designer intended, but the exciting bit comes when we can deliberately introduce jacking to aid performance, especially where regulations prohibit major changes (as in Group One). Watching at Shaws exit, you can see that many rear wheel drive Group One saloons almost come to rest with their inside rear wheels spinning hopelessly in mid-air. Just fit a slightly longer spring to the offside rear and you transfer 40lbs or more to that wheel to reduce spin. Now jacking cannot move the C of G, so this 40lbs will move all round the car; i.e. near-



C.C.C.

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side rear and offside front will be 40lbs lighter and nearside front will be 40lbs heavier. On a symmetrical single seater, such a tweak will vary the balance between left and right hand bends; a situation which is not necessarily bad. On many circuits it could actually help. But with a live axle, torque reaction tends to lift the offside wheel, so that jacking it down will actually help to equalise left to right turn symmetry.

But what of braking? Your Group One Capri probably already has 40lbs more on the offside front due to driver offset, and if you accept that your front discs are doing most of the work, jacking some of this 40lbs to the nearside can actually help.

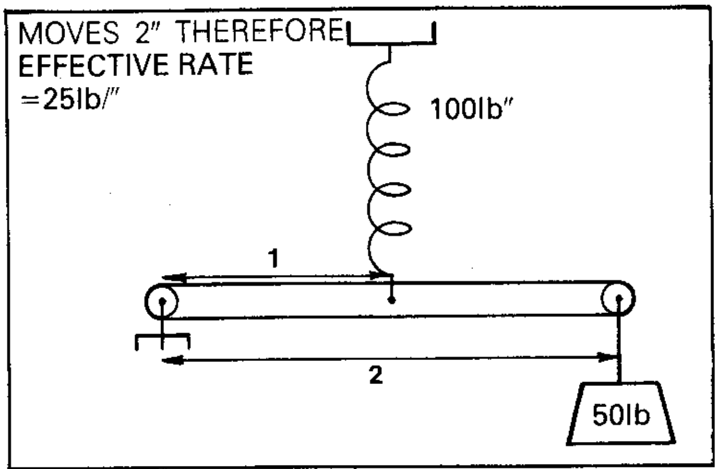
Apart from traction, jacking obviously affects the understeer/oversteer balance, so this can provide a simple, legal, inexpensive balancing act, especially where regulations do not allow suspension changes.

Now we come to the hardest part, which is the measurement. First of all, we need a flat patch where 1/16in. in 60 is a large error. It does not need to be flat; fore and aft and transverse errors can be neglected if they are the same front and rear. Care with a straight edge, spirit level and shims should do the trick.

If you are only looking to remove twist, then loading is not too important, but if the driver's seat is not on the centre line, then it should be occupied or ballasted.

The biggest enemy to constant readings is friction in the suspension. Obviously, shock absorbers are slacked right off, or, if practical, disconnected, and bolts clamping nylon bushes can be slackened. If this is not practical, the only substitute is a great deal of patience, taking dozens of readings and trying to guess the mean. If any change does not show as moving right around the car, then your readings are not reliable; i.e. an increase of 10lbs on one wheel should show as an increase of 10lbs on the diagonally opposite, and a decrease of 10lbs on the other two. Or, put another way, the weight on any axle cannot change, nor can the weight on any side.

And finally we come to the choice of weighing equipment.



The big teams used to use large platform scales, set in the ground, carefully levelled and accurate to half a pound. They were tedious to operate with sliding weight bars, but they're still fetching around £1,000 a corner secondhand, yet are incapable of sensible readings if there is friction in the suspension. The top teams now use electronic digital units at £10,000+ per set. ADA and Pace market an hydraulic

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lever device at under £80. This machine lifts the top of the wheel rim and records the load on an hydraulic pressure gauge. Its weakness is that the calibrations cannot be read much closer than 5lbs, and to work at all, the wheel must be lifted clear of the ground and hence must disturb the suspension. In most cases, however, it can locate large errors and get you in the ballpark, which you almost certainly will *not* be if no check has been made.

In 1962 the ideal tool was a paid of Salter type 206 bathroom scales. Today, alas, life is not so easy. The current wide tyres do not sit kindly and Salter simply don't make 'em like that any more. However, with very careful shaping and thick plywood bolted to the top to spread the load, strong bathroom scales are our current choice for front wheel measurement.

Calibration consists of loading to anticipate wheel weight, and if you can change left to right with-

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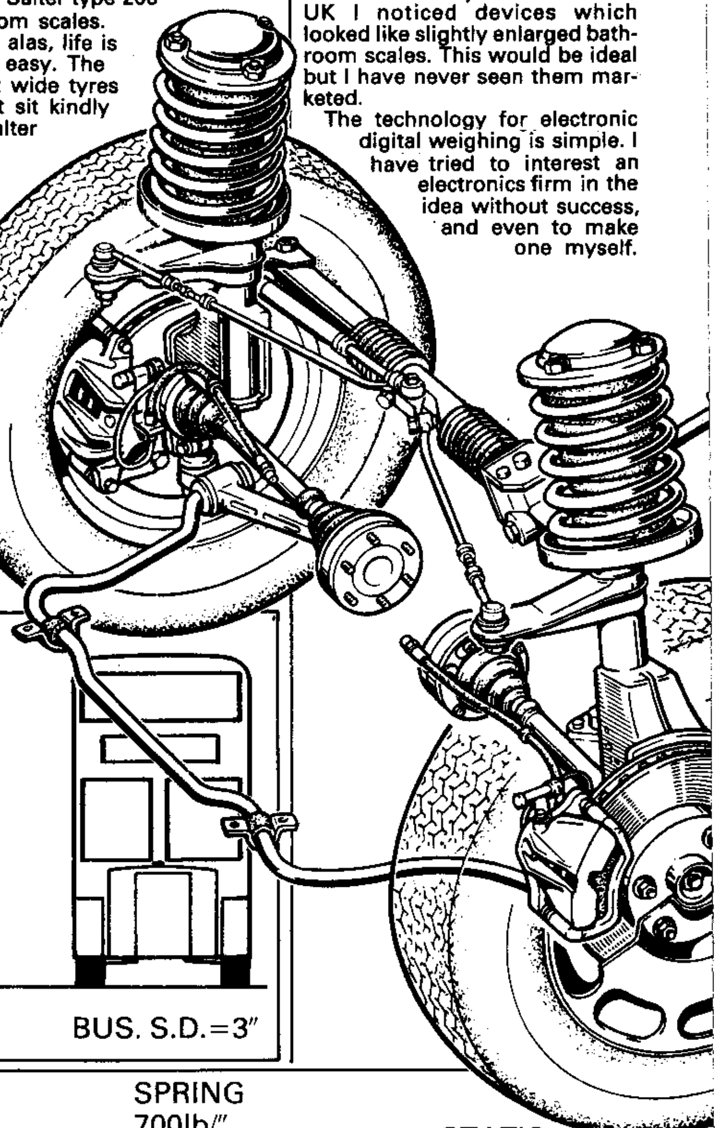
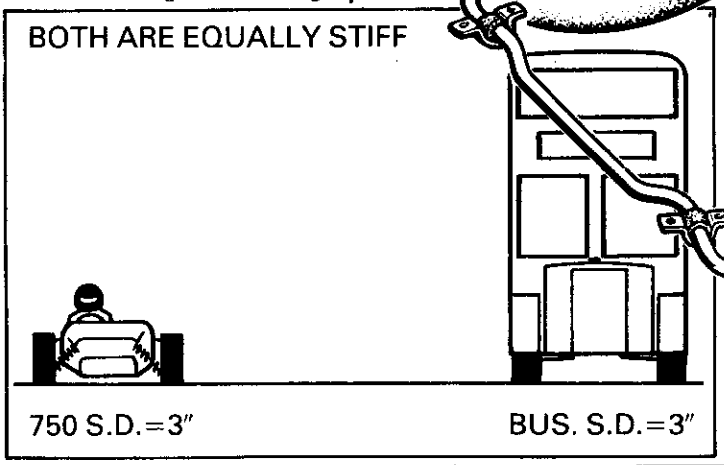
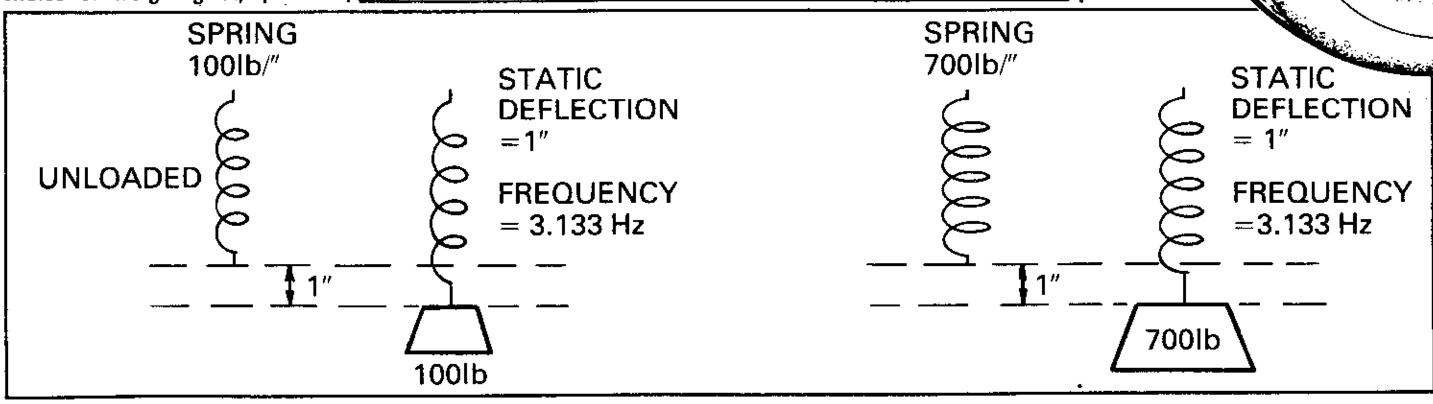
out altering the reading, you have an accurate system. We tried using four scales for the rear, with planks between, without much success, so the lever is the only choice for the rear, which is also useful for heavy cars, where a change of gauge allows readings of up to 1000lbs to be taken.

When the Indy cars visited the UK I noticed devices which looked like slightly enlarged bathroom scales. This would be ideal but I have never seen them marketed.

The technology for electronic digital weighing is simple. I have tried to interest an electronics firm in the idea without success, and even to make one myself.







Today, even mass production road cars are running roll stiffnesses of 2000lb/ft per degree, whereas many a Formula Ford spaceframe is struggling to achieve even half this figure, so that in spite of very soft springing, they are unable to inhibit rear axle weight transfer sufficiently to cure inherent oversteer and traction problems.

Absolute accuracy is of no importance, as only a different answer is needed. John Gibson Lifting Gear keep making noises, but nothing materialises. The first man to market such a device at under £100 will find the World beating a path to his door.

To close, take a run up Prescott: At Ettores, a right hand hairpin, you understeer onto the grass and exit very slowly. Next, you arrive at Pardon (a steeply climbing left hand hairpin). Here, the nearside rear wheel hovers above the ground, seeking grip in the air. At the Semi-Circle, you have to lift off again as camber and understeer suck you towards the bank.

Back in the paddock, you screw down the nearside front spring abutment by three turns and try again. Gone is the understeer at Ettore's and Semi-Circle. Gone is the wheelspin at Pardon. The result is the cheapest half-second improvement ever achieved!

And so, without more ado, let's get on to the subject of spring rates.

At Mallock Racing, we have checked over single and two seater racing cars of most categories, from Formula One to 750 Formula, and in almost every case, have found at least one and often several fundamental suspension errors including the problem of corner weights, as I have just intimated.

The purpose of what is being printed here is to cover points on suspension theory and practice which have seldom been covered either correctly or fully in print.

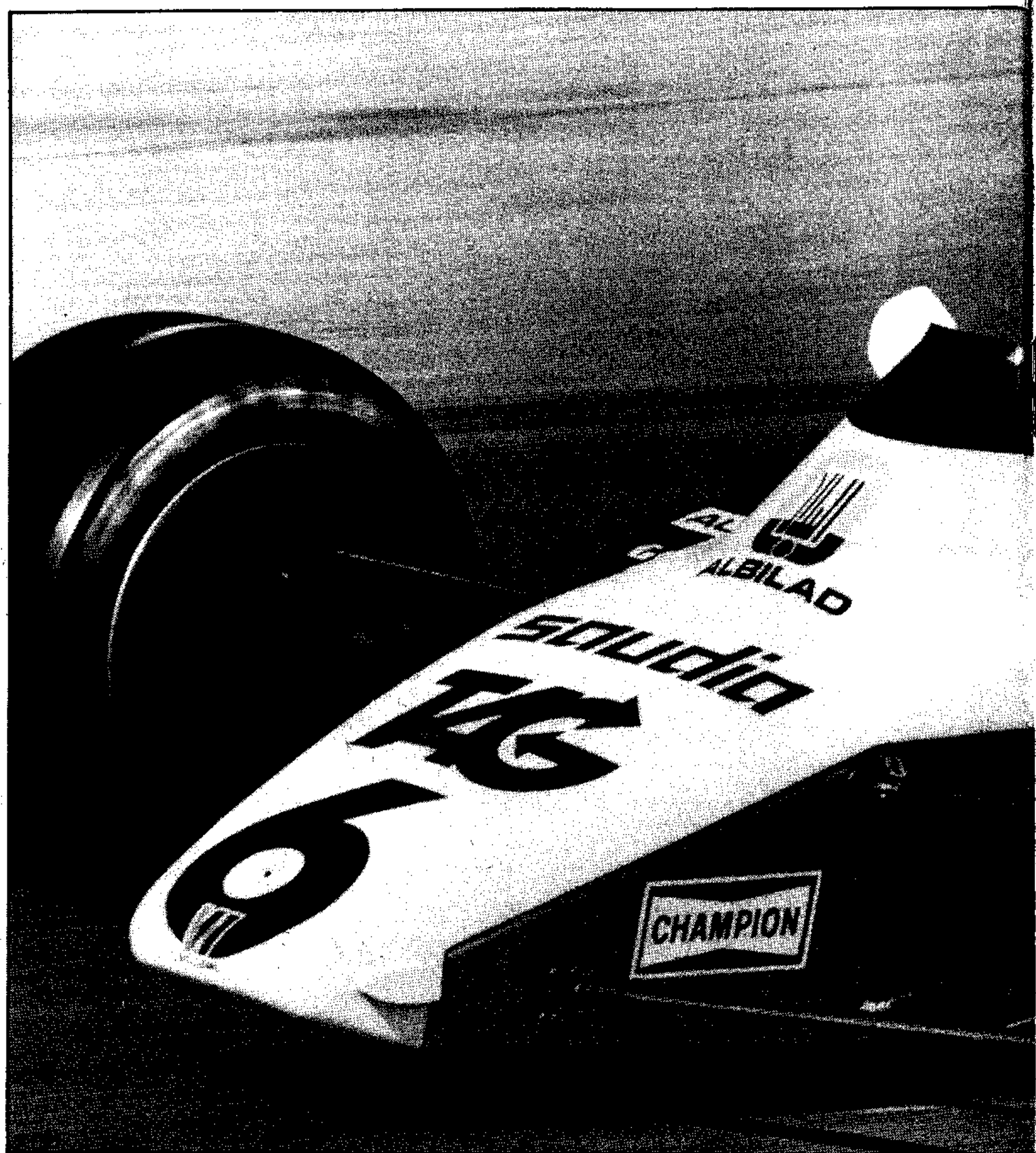
The most fundamental but seemingly least understood suspension property is that of its rate (i.e: how soft?). How is rate specified?

Stand in the corner that man who said "by spring rate"!

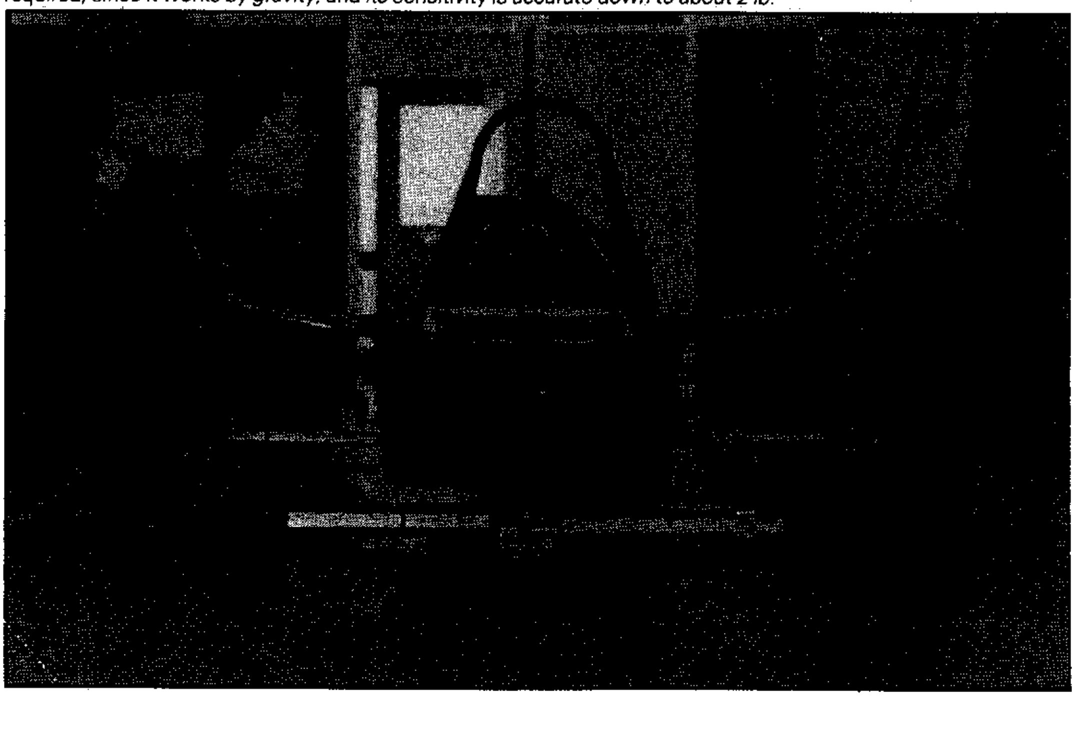
Without any reference to the load being carried, spring rate tells us absolutely nothing about suspension stiffness; 1000lb/in. springs on a double decker bus would be *very* soft indeed, but on a 750 Formula racer they would be almost solid. Likewise, lever arms have to be considered. From memory, I recall that the Lotus 6 used 55lb/in. rear springs and 160lb/in. fronts. Which is the stiffer of the two?

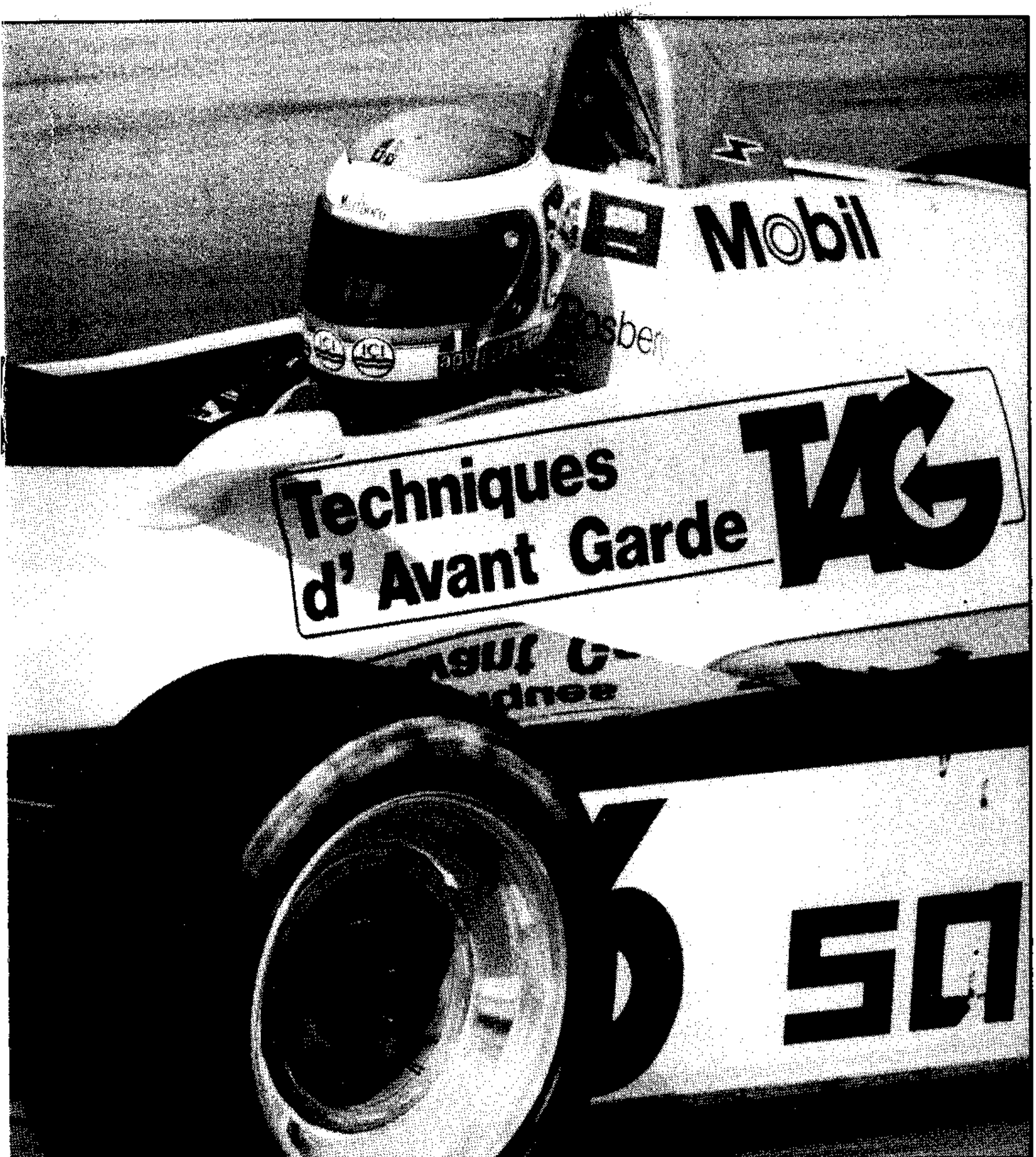
Stay in the corner that man! The answer is almost certainly the rear.

Text books often refer to "natural frequency". This is the frequency at which the axles jump up and down, when a car is dropped on the ground, as, for instance, in that well known VAG television commercial. Natural frequency is a useful tool for the



The Miles Mumford balance beam is very effective for sorting out corner weighing quickly. A flat floor is not required, since it works by gravity, and its sensitivity is accurate down to about 2 lb.





road car designer, as there is a mass of medical-style data available relating frequency with passenger comfort. For the performance enthusiast it is, however, almost meaningless.

The parameter I favour is known as static deflection. This is quite simply the distance that the suspension moves when spring load is varied from normal to nothing On modern Formula cars it can easily be measured simply by jacking up each axle in turn and noting the difference in ride height between normal ride and the point at which the springs are just not trapped. If the springs are pre-loaded at full droop, measurement is not quite so simple, but with knowledge of the amount of pre-load and the lever arm ratio, it can be calculated.

Static deflection is an absolute measurement of suspension softness, e.g: if the aforementioned bus and a 750 Formula car both have static deflections of three inches, then they have the same rate, so that wheeled vehicles of any size or configuration can be directly compared.

If your mind is tuned to think in terms of natural frequency, then the formulae below relate the two:

$$\text{F in Hz} = \frac{3.133}{\text{S.D.}}$$

or conversely:

$$\text{S.D. in inches} = \left(\frac{3.133}{\text{F}}\right)^2$$

Table 1 gives an instant comparison.

S.D. at wheel	Frequency (Hz)
1"	3.133
2"	2.216
4"	1.566
8"	.783

My preference then for measuring rate in static deflection rather than frequency is:

1. S.D. is easily measured. Frequency is almost impossible to measure directly.
2. S.D. gives a good mental picture of what is going on. A deflection of say two or three inches can be clearly visualised. A frequency of 2.216Hz simply does not register. (Dead right, Arthur! Ed)
3. If you double the spring rate, you will halve the static deflection, i.e: there is a linear relationship. By adopting the frequency to spring rate route, you have to involve square roots.

I should perhaps emphasise that the static deflection we are talking about is as measured at the wheel. It will differ from the spring deflection if there is a lever in between.

Having decided how to specify and measure suspension rate, some guidelines or likely values may be helpful. The Boulevard ride of the Rolls Royce or the ship-at-sea waywardness of the older Yank tanks indicate a static deflection of seven inches or more.

On the super-soft competition cars pioneered by Colin Chapman in the mid-fifties, up to 5½ inches of S.D. was not uncommon, but as you really need a wheel movement of about twice the static deflection, running out of suspension travel made itself obvious as a serious fault, and by the end of the decade, values had settled to a more practical 3½ to 4½ inches.

By the late Sixties, 'cotton reel' concave moulded tyres had appeared, which were very sensitive to camber change. These innovations were followed shortly by the 'discovery' of downforce, which called for a drop to 1¾ to 2½ inches of S.D.

A decade later and we had ground effect, with downforce in excess of vehicle weight being generated along with extreme sensitivity to attitude change, all of which necessitated a static deflection around one solitary inch.

I cannot claim to have technical mastery of the 1981 Grand Prix scene, but you can be sure that those hydro-pneumatic systems were down to small fractions of an inch on the start line, yet could be more than doubled at speed due to the downforce generated.

For best control of vehicle pitch, the rear suspension should be slightly stiffer than the front, and all-round independent systems are usually set-up in this way.

With live, or De Dion rear axles, the inherently high roll centre makes it difficult to arrange a frontal weight transfer that is greater than the rear – essential for good traction – and this may mean the need to compromise by running the front end stiffer than the rear.

Weight transfer calculations are based on the assumption of an infinitely stiff chassis, and clearly, roll stiffness tuning cannot be effective if the chassis is weaker than the suspension. This is a factor that many designers, right up to Grand Prix level, still don't seem to have grasped fully.

Today, even mass production road cars are running roll stiffnesses of 2000lb/ft per degree, whereas many a Formula Ford spaceframe is struggling to achieve even half this figure, so that in spite of very soft springing, they are unable to inhibit rear axle weight transfer sufficiently to cure inherent oversteer and traction problems.

To summarise: if you are using modern tyres but are not utilising ground effect, then about two to three inches of S.D. is a good starting point. With Historic, or Formula Ford tyres, you can go softer than this, but once over four inches, be *very* careful with suspension travel. If springs have any significant pre-load, then it is all too easy for rebound travel to bottom-out, which results in sudden (indeed instantaneous) weight transfer. I suspect that the expression, "it suddenly swapped ends for no apparent reason", was first coined to describe this dramatic situation.

Lever arm ratios keep cropping up and sometimes cause confusion.

Fig. 1 shows a 100lb/in. spring moved by a 2-to-1 ratio lever. Thus, 50lbs applied at the end obviously gives 100lb at the spring, so that at first sight, the effective rate at the lever end might appear to be halved to 50lb/in.

On second thoughts, however, 50lbs has moved the lever two inches, so the new rate is 25lbs/in. The effective rate then is spring rate divided by lever ratio squared.

In the next article, I hope to cover another much misunderstood, subject, the effect of roll centre height on weight transfer.■