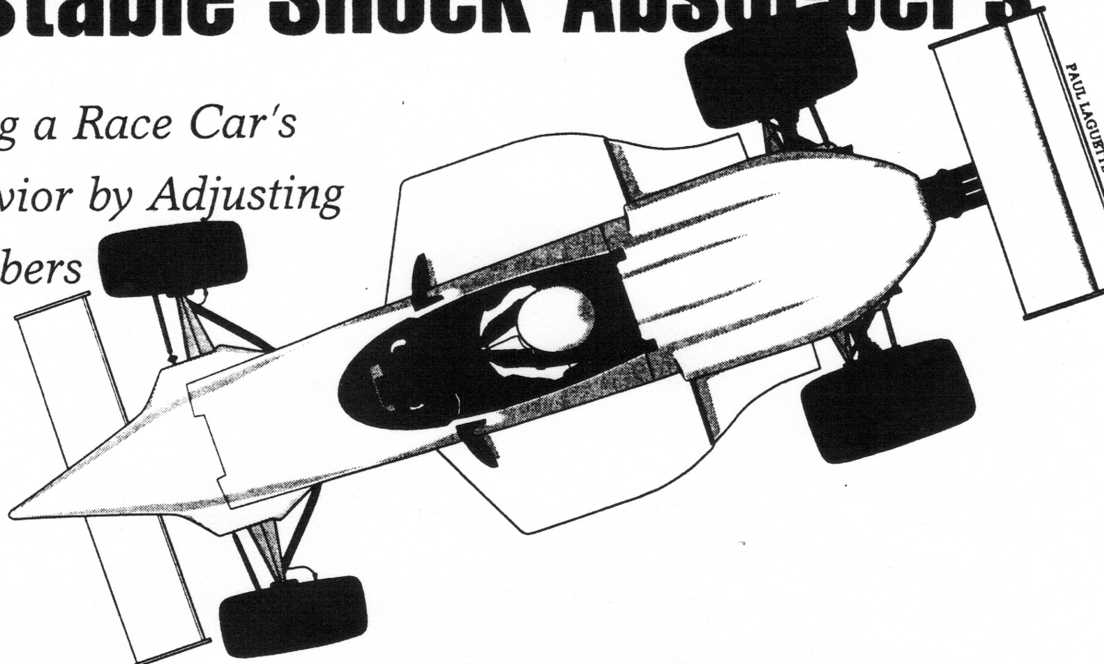
Damper Physics: The Black Art of Adjustable Shock Absorbers

Part 2: Changing a Race Car's Cornering Behavior by Adjusting Its Shock Absorbers

By Neil Roberts

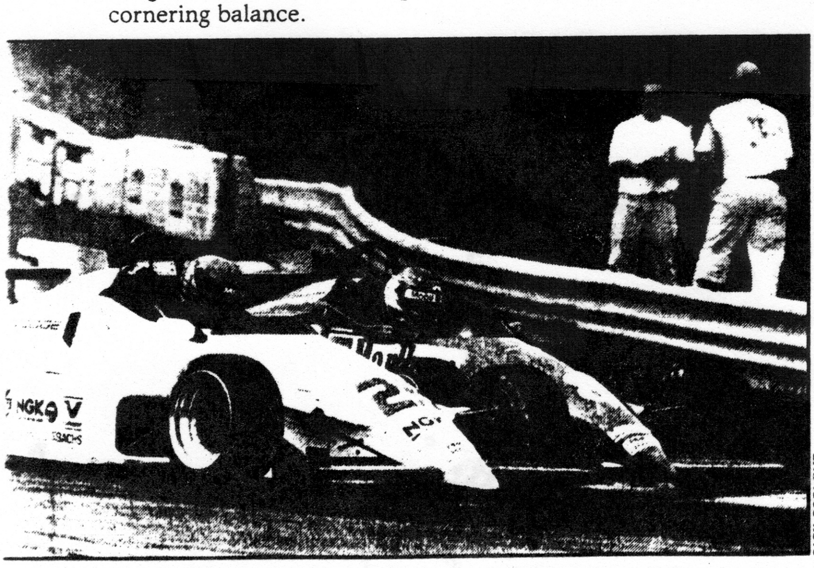


PAUL LAGUETTE ILLUSTRA

Last month, we looked inside a shock absorber to find out how it works. This time, we will discuss the damper adjustments which can be used to change the behavior of the car in each phase of a corner. We will begin by defining each phase of a corner and apply some sensible simplifications, then list the relative damper adjustments available to produce the desired handling change.

For the purposes of this discussion, we will assume the racing surface to be perfectly flat, smooth, and uniform. So, all damper velocities will be relatively low, assuming a smooth driving technique. We will assume a simple road course setup, with no asymmetric adjustments.

The damper velocities and travel directions resulting from each cornering phase affect the distribution of load among the four tires. This change in load distribution changes the cornering balance. We will focus primarily on the effects of diagonal weight transfer due to damper forces and the resultant change in cornering balance.



RICK CORWINE

As they approach the apex, the cars above are in Phase 2. Although the outside front tire is loaded, weight is being transferred to the outside rear as braking decreases.

Cornering Phase Definitions

PHASE 1: Increasing braking + increasing steering

This phase is the first part of a fast decreasing radius turn. This phase will not occur at all if maximum braking is achieved before turning in. Since weight is being transferred both forward and outboard, the outside front damper moves in the bump direction. Also, the inside rear damper moves in rebound. The other two dampers do not move as much or as rapidly, so their effects are minimal. For our purposes, we will consider the inside front and outside rear dampers to have a fixed position during Phase 1.

PHASE 2: Decreasing braking + increasing steering

This is the turn-in phase of a slow corner. This phase may or may not occur depending on the type of turn and driving technique. Weight is being transferred outboard and aft, so the outboard rear damper moves in bump and the inside front damper moves in rebound. The other two dampers are considered to be stationary.

PHASE 3-A: Increasing steering at constant throttle

This phase can be a course correction, a slalom turn-in, or a turn entry taken at full throttle. Weight is being transferred outboard, so both outside dampers travel in bump and both inside dampers travel in rebound.

PHASE 3-B: Decreasing steering at constant throttle

This is the opposite of Phase 3-A. During a slalom, this phase occurs while the steering is changing away from the current cornering direction. As soon as the lateral acceleration passes through zero, the car reverts to Phase 3-A. This is part of why so many spins occur in slaloms.

PHASE 4: Decreasing steering + increasing throttle (or decreasing braking)

This is the apex-to-exit phase. Weight is being transferred inboard and aft, so the outside front moves in rebound and the inside rear moves in bump. The other two dampers are considered stationary.

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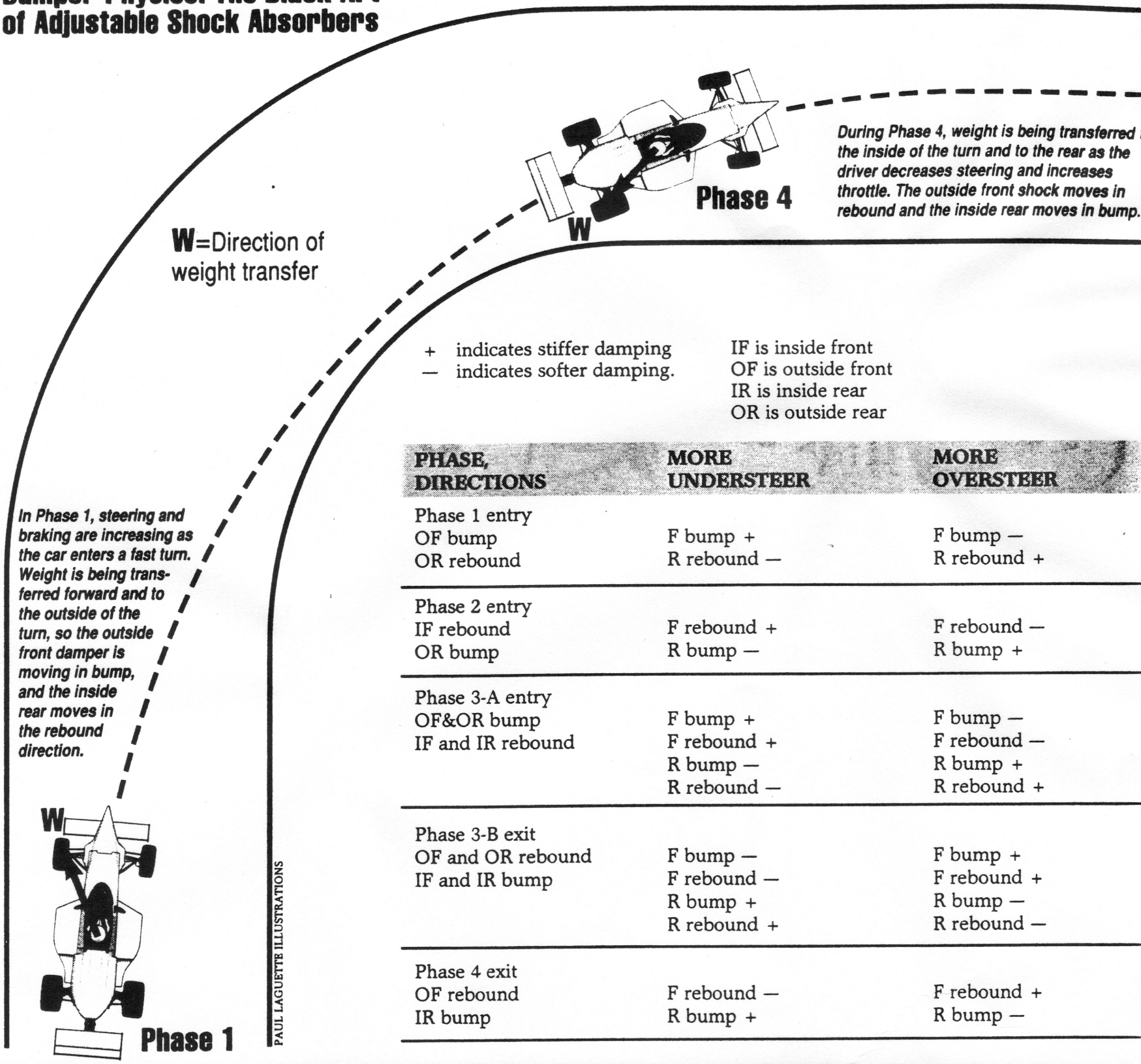


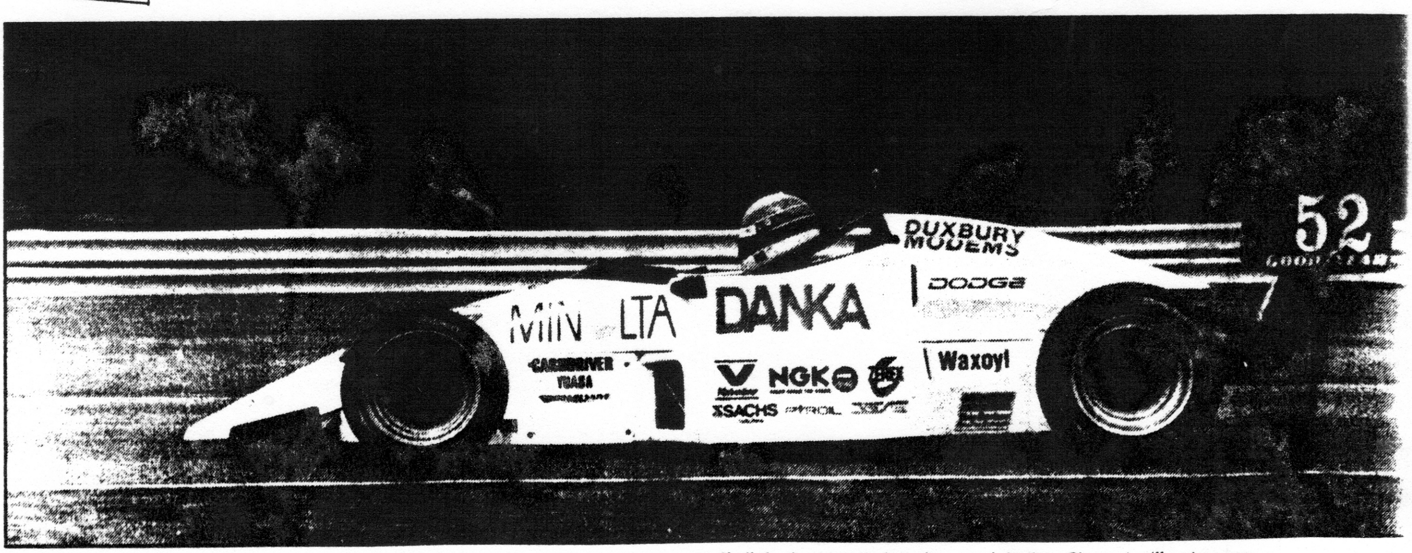
During Phase 4, weight is being transferred to the inside of the turn and to the rear as the driver decreases steering and increases throttle. The outside front shock moves in rebound and the inside rear moves in bump.

In Phase 1, steering and braking are increasing as the car enters a fast turn. Weight is being transferred forward and to the outside of the turn, so the outside front damper is moving in bump, and the inside rear moves in the rebound direction.

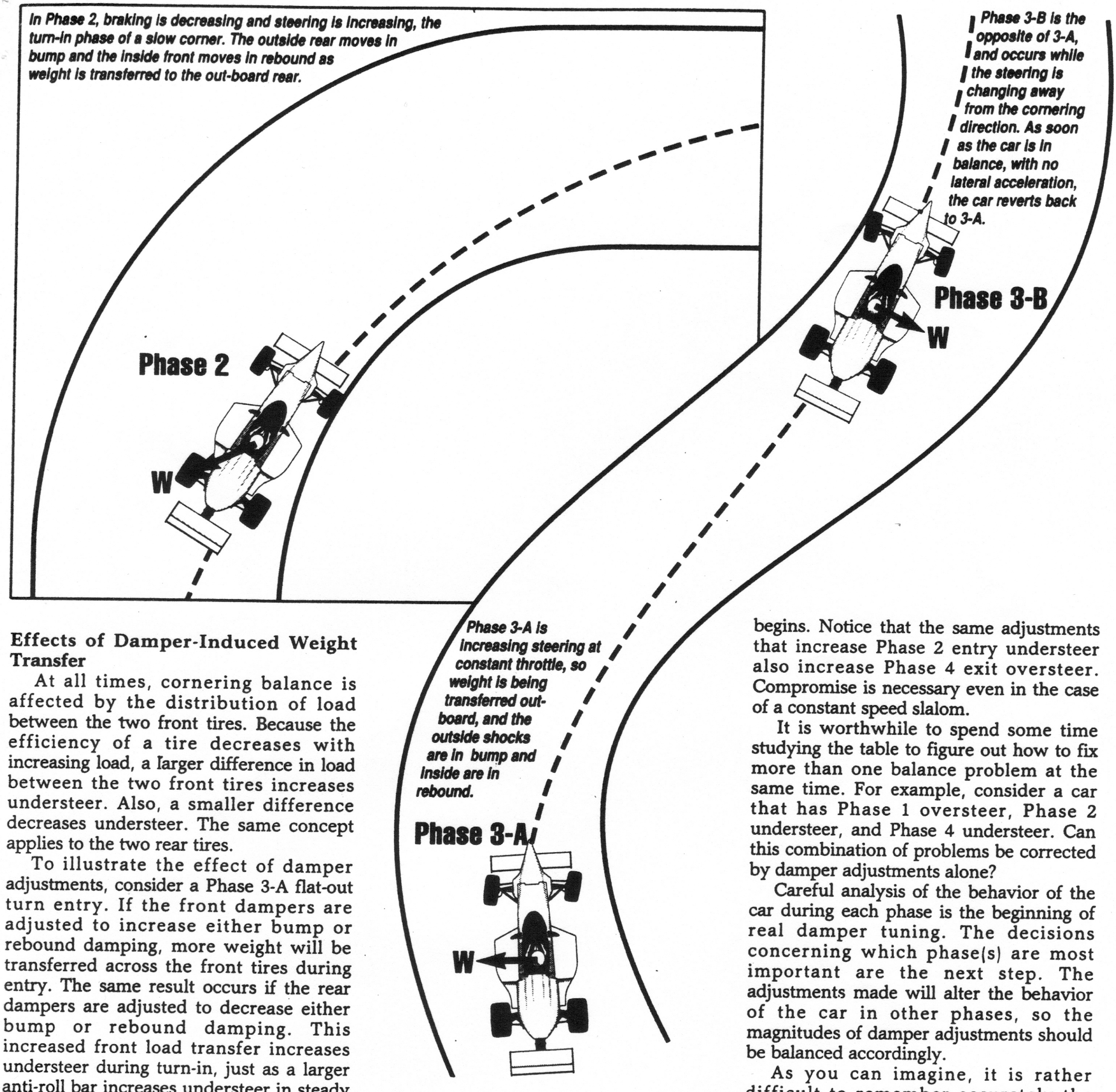
\+ indicates stiffer damping
— indicates softer damping.

IF is inside front
OF is outside front
IR is inside rear
OR is outside rear

PHASE, DIRECTIONS	MORE UNDERSTEER	MORE OVERSTEER
Phase 1 entry OF bump OR rebound	F bump + R rebound —	F bump — R rebound +
Phase 2 entry IF rebound OR bump	F rebound + R bump —	F rebound — R bump +
Phase 3-A entry OF&OR bump IF and IR rebound	F bump + F rebound + R bump — R rebound —	F bump — F rebound — R bump + R rebound +
Phase 3-B exit OF and OR rebound IF and IR bump	F bump — F rebound — R bump + R rebound +	F bump + F rebound + R bump — R rebound —
Phase 4 exit OF rebound IR bump	F rebound — R bump +	F rebound + R bump —



This photo of Jaki Scheckter braking shows the weight transfer to the front of the car. If all the braking is done in a straight line, Phase 1 will not occur.



Effects of Damper-Induced Weight Transfer

At all times, cornering balance is affected by the distribution of load between the two front tires. Because the efficiency of a tire decreases with increasing load, a larger difference in load between the two front tires increases understeer. Also, a smaller difference decreases understeer. The same concept applies to the two rear tires.

To illustrate the effect of damper adjustments, consider a Phase 3-A flat-out turn entry. If the front dampers are adjusted to increase either bump or rebound damping, more weight will be transferred across the front tires during entry. The same result occurs if the rear dampers are adjusted to decrease either bump or rebound damping. This increased front load transfer increases understeer during turn-in, just as a larger anti-roll bar increases understeer in steady state cornering.

The same increase in understeer results from diagonal weight transfer from the inside rear to the outside front. The fact that the two diagonally opposite dampers move in opposite directions allows us to modify cornering balance with damper adjustments.

Note that we are only considering longitudinal weight transfer if accompanied by steering change. Longitudinal weight transfer without steering change moves both front and both rear dampers in the same direction at the same speed, so damper adjustments cannot change the diagonal weight distribution. Obviously, longitudinal weight transfer affects cornering balance; but, since the dampers cannot affect balance unless accompanied by roll, we will ignore this effect for damper tuning.

The table shows the damper adjustments available to modify the cornering balance in each phase. Each entry lists the phase, the damper travel directions, the desired change, and the damper adjustments available to produce that change.

As you can see, none of the available adjustments affect only one cornering phase. This is where the balancing act begins. Notice that the same adjustments that increase Phase 2 entry understeer also increase Phase 4 exit oversteer. Compromise is necessary even in the case of a constant speed slalom.

It is worthwhile to spend some time studying the table to figure out how to fix more than one balance problem at the same time. For example, consider a car that has Phase 1 oversteer, Phase 2 understeer, and Phase 4 understeer. Can this combination of problems be corrected by damper adjustments alone?

Careful analysis of the behavior of the car during each phase is the beginning of real damper tuning. The decisions concerning which phase(s) are most important are the next step. The adjustments made will alter the behavior of the car in other phases, so the magnitudes of damper adjustments should be balanced accordingly.

As you can imagine, it is rather difficult to remember accurately the balance of the car in each cornering phase for each corner of the track. This process can be assisted considerably by an in-car video camera and/or a data acquisition system.

The restriction to symmetric damper adjustments is the source of many of the required compromises. If you have followed the discussion to this point, you can work out for yourself the amazing cornucopia of damper adjustments available to oval track tuners. If a particular road course features all or most of the important corners in the same direction, asymmetric adjustments can be used to fine tune the setup to that track. ■