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# Shocking Behavior

If you knew the extent of the effects that shocks have on handling, you'd be... well... shocked.

story by david s. wallens -- photos as credited

Given enough time, most enthusiasts can figure out how an anti-roll bar or a set of trick brake pads will increase their car's performance, but how many out there truly understand the benefits of a good set of shock absorbers? Probably too few, which is unfortunate. Properly selected and tuned, shocks can make or break a car's foundation.

If you're one of the masses who believe that a stiffer shock is always the right way to increase performance and decrease lap times, then read on.

"Perceived stiffness cannot be better by definition," explains Jay Morris, owner of the racing shock company Advance Design and parent company Ground Control. "Perceived stiffness would be a misconception compared to actual stiffness, which should benefit the race car.

"Why the distinction? Because there is such thing as a perceived stiffness that is not actually stiff. This is found in a shock that is a poor design with internal leakage preventing any real handling benefit, but which is very stiff over bumps in a misguided attempt to improve handling. The driver feels the bumps more, but the chassis is still uncontrolled. This is usually the very worst handling setup for any car."

### What Do Shock Absorbers Do?

Thanks to their common name, most people think that shock absorbers absorb the shocks and bumps experienced by the car as it travels down the road. Technically, this is not true. In reality, the springs carry the load of the car and regulate the suspension's reaction to any bumps or dips in the road. They're the ones that really absorb the shocks. The shock absorbers time the springs' reaction by changing kinetic energy (the spring moving up and down) into thermal energy (the heat built up as the shock's oil passes through the various pistons and valves).

"Springs hold the car," explains Lex Carson of JRZ Suspension Systems. "Shocks control the spring loading and unloading."

Since the shocks are damping the springs, technically shock absorbers should be called dampers. However, we'll stick with the name shocks or shock absorbers, out of a matter of habit. A strut is basically a shock that is also a load-bearing member, but once again we'll stick with the catch-all name of shocks.

To understand how a shock works, picture a car driving down a road that is perfectly flat except for one speed bump. If the car simply has springs but no shocks, once the car passes over the speed bump, the springs will continue to oscillate until they disperse all of the kinetic energy they gained by compressing. As a result, the car will pitch and buck as it drives away from the speed bump.

Now picture a car with both springs and shocks encountering the same speed bump. The springs would once again absorb the bump, but this time the shock absorbers would damp the spring's oscillations (by converting the kinetic energy into heat), allowing the car to calmly drive away from the bump.

Unfortunately, we all live in a world filled with more than one bump. Our cars are constantly encountering all sorts of bumps and dips. Throw in a few turns and place the car in a competitive or sporting environment, and you can see how your suspension is trying to do many things at once. This is why a good set of shocks can make the difference.

### Defining Our Terms

Like anything in life, there is a certain lingo used when talking about shocks-words like bump, compression, rebound and extension. These words describe the valving or action of the shock.

Bump (or compression) is when the shock rod is compressed into the shock body. Rebound (or extension) is when that rod is extended from the shock body.

Note that the same shock can have different bump and rebound characteristics. You can have a shock that has a slow bump (hard to compress) but a fast rebound (easy to extend). Matching the bump and rebound characteristics of a shock absorber to your car and venue is the trick. Hopefully, we can help you here.

### Who Needs Good Shocks?

"Good shocks are probably the second most significant handling change you can make to a stock car," says autocross and road racing national champion Jeff Altenburg, "tires with an alignment being the most significant.

"The only car I competed in without [upgraded] shocks was my 1989 Formula 350 Firebird," he continues. "I ran one event in it at Jacksonville on an undulating lot, and it was floating like crazy. I had a set of hydraulic Konis for the next event which was the Sebring Pro Solo 1991, and the difference was night and day. I won the event and the Challenge."

While some limited-production performance cars like the Miata Sport and Camaro 1LE come from the factory with high-quality shocks, most cars are sold with only commercial-grade pieces.

"The average enthusiast needs a good set of shocks because he is an enthusiast," explains Advance Design's Jay Morris. "A difference in handling and performance will neither be discovered or cared about by a non-enthusiast, so why spend the money? This is the attitude (and usually correctly so) of the car manufacturers, so the average stock or replacement shock is engineered to be adequate, safe and inexpensive as priorities over performance.

"This begs the question of why can't a performance shock also be cheap? It is not so obvious. The primary reason is that a performance shock is both stiffer and simultaneously accurately stiffer. With the increased stiffness comes a requirement for less internal leakage, or bypass. For the non-enthusiast, internal leakage is softer and preferred.

"In an inexpensive shock, the advantageous internal leakage inherent in using cheaper parts (o-rings instead of actual piston wipers, for instance) is utilized as part of the softer damping characteristics desired in the non-enthusiast shock. This puts the base cost below any performance shock, because of the lower quality of parts reducing the need for accurate tolerances. An economist could probably work out an inverse exponential function to describe this, but let's just say that it costs a lot less."

Shocktek's Michael G. O'Callaghan further explains the problems encountered by most street cars: "Typically, when the shocks are at the end of their life cycle, the rod seal will fail (hopefully slowly) and the shock absorber fluid will leak out. The damping characteristics of these aged shocks are not good: the overall damping forces are much lower, the damping curves have changed and there may be air in the shock which may act like a spring. Bottom line: wheel hop, uncontrolled porpoising, excessive body roll. Very dangerous in a collision avoidance maneuver.

"A lot of the readers of Grassroots Motorsports might be changing the mission of a car, such as modifying the car to be more competitive in a weekend autocross, or installing stiffer springs, sways and shocks to make the car corner better on the street," he continues.

"In this case, the idea of a 'good' shock is that it is very important to match the components carefully when modifying the suspension of a car.

"Not only does the shock have to control wheel motion and body sway," he further explains, "but it has an important influence in controlling the dive and squat of the car during braking and acceleration. And, of course, making sure that the shocks remain functional is an important preventative maintenance function that car owners should perform on a regular basis."

Enthusiasts who lower their cars-whether for looks or performance-also need to consider upgraded shocks. In most cases, the stock shocks will not properly operate when teamed with short, stiffer springs. "OEM equipment is not meant to be operated below stock height," explains Truechoice's Greg Calhoun. "Another thing to keep in mind is that when you lower a vehicle, travel is taken away from the unit. If there is not enough travel, the unit has the chance of bottoming out."

Those enthusiasts involved in competition also need to think about their vehicle's equipment and the effect those parts have on their lap times. "A vehicle's performance is directly related to the performance capabilities of its equipment," explains Jim Arentz, design engineer for Penske Racing Shocks. "When put to extreme conditions of a racing environment, typically the stock equipment does not provide the optimum handling package. Most road cars are equipped to handle everyday driving over a variety of road conditions.

"Racers need dampers that will outperform the stock parts in extreme driving conditions where comfort and ride aren't always a priority. The handling becomes paramount as the control of subtle variations in chassis platform movement and bump recovery can amount

to a large gain in lap speed."

Charles Cadieux of Dynamic Suspensions further explains. "A properly-sprung and damped vehicle has a better chance of maximizing the tire contact patch, therefore better grip, better turn in, braking, acceleration, etc."

### Are My Shocks Shot?

So, how do you know when it's time for new shocks? Even if your car came with better-than-average shocks, they may be at the end of their lifespan.

"Generally when your shocks are shot, you will feel a lack of control or crispness in the suspension," says JRZ's Lex Carson. "The car may begin to bounce or float when you go over bumps or uneven pavement changes."

"First, the car will feel different on the track or on the road," continues Michael O'Callahan. "It might be different steering characteristics, different behavior over bumps or any other anomaly. Next, visually check the shocks for leaks. And finally, if you're still stumped, you can always have the shocks dynoed."

Note that sometimes you may have a spring problem and not a shock problem. "Spring problems tend to be persistent and consistent, shock problems tend to usually occur only in transitions," explains Jay Morris. "Theoretically, if you have a problem in the middle of a corner (shocks in low-influence mode) it will be springs. Virtually any other time can be shocks or springs."

Sometimes you'll need to take the shocks off the car and inspect them to determine if you have a problem. "A shock problem is easily detected usually by hand-compressing a damper off the car and comparing to another damper that seems to be working correctly," explains Penske's Jim Arentz. "The feel of the damper as it's compressed, the speed at which the shaft returns to an extended position, and the feel of the adjusters are easy hints at problem areas. For the best proof, a shock dynamometer usually can determine the source of a problem instantaneously, whether caused by system contamination, damaged parts, or an incorrectly-built damper."

Note that an on-track (or off-track) incident can also cause problems with your shocks. "If the car has been involved in an incident by hitting a wall, guardrail, or another car, then it is best to at least have the shocks looked at," explains Greg Calhoun of Truechoice. "Most times after a hit, the shock will need to be serviced depending on how heavy the hit was."

### You Get What You Pay For

The first tough decision you must face is deciding how much to spend. All of us have budgets, all of us hate to lose, and all of us have to balance the two. In all types of racing, you should buy the best shocks you can afford. Inevitably, you'll second-guess yourself many times and curse yourself for not going to the next level. Hopefully you'll be able to sell some of your first mistakes to your competition.

Shock absorbers come in many sizes and styles. They also vary in price from \$25 each to more than \$2500 apiece. "The \$100 shock doesn't have the technology or the sophistication that a \$1000 shock has," explains Lex Carson. "It's like the difference between an IT car and a WSC car."

Why the big difference in prices? The high-dollar shocks have bigger shock shafts, bigger pistons and bigger valve stacks. They are also built with more care to tighter tolerances. All of this costs more to manufacture. We're not saying everyone needs to spend 10 grand on shocks, but buying the best ones you can afford is usually the smart move.

"Excluding a few glaring examples of cheap shocks intentionally disguised as good shocks, you get what you pay for," explains Advance Design's Jay Morris. "Sometimes in performance, sometimes in additional features, or if you spend enough, both."

For example, Jay points out how a \$199 Bilstein Sport shock for a Camaro offers good valving and monotube quality, but no adjustment. That same \$199 will also buy one Tokico Illumina, which has softer but adjustable valving. However, a true race shock for that Camaro that offers qualities found in both shocks-rebuildable valving, monotube quality and adjustable compression and rebound-can start at \$399 each.

Where you buy the shocks and which company you use should also be a factor. Shock tuner Guy Ankeny of Pro Parts West says you should ask yourself the following questions: "Does the person you're purchasing shocks from know about the type of racing you do-or want to do-with the car? Does the shop have references for the types of shocks or shock work that they're trying to sell? Can the person selling you shocks give you any assistance in chassis setup?"

Shocktek's Michael G. O'Callaghan also notes that customer service should be strongly considered when buying shocks. "Can you get decent product support?" he asks. "Even the name-brand manufacturers can get you lost in a maze of phone tag to get even the simplest question answered."

Danny Criss from Leda Suspension also recommends looking at the quality of components and recommendations from other customers. "Serviceability and initial cost play a role as well," he explains. "Customers should be careful when comparing different manufacturers' shocks and struts to ensure that they are comparing apples with apples. A good question that customers should ask themselves is, 'What kind of performance do I want, and what is the budget?'"

Michael O'Callaghan also warns against purchasing low-quality shocks. "Bargain performance shocks can be very inconsistent in their damping characteristics which you'll be able to feel very easily," he says. "Brand name means nothing. Some of the poorest-quality shocks are made by the biggest brands, simply because their shocks are low priced. In fact, some of the very expensive shocks have pretty poor quality."

In response to the recent import performance boom, many new shock companies have sprung up on the scene. Some are truly geared towards the performance enthusiast, while others are better suited for common street use.

"When buying shocks, especially lately, reputation is more important than hype," explains Jay Morris. "Many companies have become aware of the demand for quality suspension components and have thrown their hats into the ring with hastily-developed shocks.

"Paradoxically, high-quality companies are left at the bus stop regarding new customer perception (Bilstein). Even then, there are so many inexperienced 'experts' in the Internet chat rooms that a lot of misinformation is being repeated as gospel. Try to get an opinion from someone who has owned more than one shock."

## Options and Choices

Besides quality and reputation, there are some nuts-and-bolts options to consider that are well-suited for the enthusiast. The ability to externally modify damping characteristics is a desirable feature. If you can easily tune your shocks to compensate for tire wear, poor surface adhesion and sometimes even poor driving, you'll be ahead of the game. Note that some shocks can only have their rebound adjusted (single-adjustable shocks), while some can have both rebound and compression adjusted (double-adjustable shocks).

"Double-adjustable shocks are geared to the serious enthusiast who requires specific ride/handling capability," explains Leda's Danny Criss. "The single-adjustable units are simple and easy to adjust and more than adequate for the average guy."

As a driver moves up the ladder, then maybe double-adjustable shocks should be considered. "At some point in a driver's career, independently double-adjustable shocks may be appropriate," says Michael O'Callaghan. "Certainly in purpose-built race cars at the higher levels, double- or even triple-adjustable shocks are appropriate. However, they are always more expensive and sometimes a lot more expensive.

"From my observations, the average guy at an SCCA event would not gain a significant advantage from independently double-adjustable shocks. Those who have them usually change the settings in the same direction at the same time. (When they stiffen the rebound, they also stiffen the compression.) This method of adjustment can be done much more cheaply by a single adjustment, double-acting shock or strut, in which the rebound and compression are changed by the same percentage by a single adjustment.

"Shocktek sells both single- and double-adjustable shocks and struts (based on Bilstein components), and the singles outsell the doubles by a wide margin."

Penske's Jim Arentz doesn't see double-adjustable shocks as so confusing, however:

"Double-adjustable shocks are easy enough to understand (basically one bump adjuster and one rebound) that the average enthusiast will be able to understand with some experience and track time."

When purchasing shocks, you should ask if they are serviceable. Shocks come in two basic flavors: sealed and rebuildable. The rebuildable ones can be repacked and tuned for your exact needs. The sealed ones can only be thrown away when they wear out, and have no potential of ever being upgraded. Of course, the rebuildable shocks have a higher initial cost.

"Konis are a very good off-the-shelf shock, but can be a great shock when rebuilt to autocross or road race specs," explains Guy Ankeny. During this rebuilding process, changes are made to the valving so the shock is better suited for its ultimate use.

"Off-the-shelf shocks are best for the average street enthusiast," says Truechoice's Greg Calhoun. "When doing custom-valved shocks, the customer is usually racing the vehicle in some form, whether it be track events, autocross, or drag racing. When the customer is in fact racing the vehicle, Truechoice will discuss with them exactly what is being performed with the vehicle and its setup to determine the proper valving for their application.

"Custom valving can also be performed to the standard street car, depending on its setup. If the vehicle is lowered in excess of 2 - 2 1/2 inches, it may be a case where the shocks will need to be revalved and shortened. This is necessary to allow for the increased spring rates

and sufficient suspension travel."

"Custom valved shocks are for the discriminating enthusiast," says Advance Design's Jay Morris. "When someone is experienced enough to tell the difference in performance and/or lap times, they should consider cost vs. benefit of custom valving; often the price is worthwhile. Some shocks are exclusively custom made, and although they cost extra initially, there is no custom charge to be paid.

"Please note that there are two types of revalving: the limited revalving used to try to use a street shock on a race car, and true revalving of a purpose-built racing shock which optimizes compression and rebound levels, rates of change and limits."

Also note that several companies can successfully convert a street shock to full-race specs, installing the appropriate guts into a street shock shell for production-based race cars.

All of these better race shocks can be rebuilt or revalved at factory-authorized facilities.

Depending upon the brand of shock and work performed, rebuilding and revalving can cost \$20 to \$135.

Rebuildable shocks can also be freshened to like-new condition at the end of the racing season or before a major event. "Shocks should be rebuilt at least every other year to keep them tip-top," says Guy Ankeny. "Fresh oil does make a difference."

Even if the high-dollar shocks totally shatter your piggybank, you can still shop wisely.

"The very least anyone can expect to pay is to find a mass-produced street shock that by coincidence or substitution has sufficient damping for racing," Jay Morris explains. "These shocks usually don't last as long, and racing voids the warranty, but the cost/benefit ratio is very favorable."

### Damper Designs

There are three basic designs of shock absorbers: twin-tube hydraulic, twin-tube low-pressure gas, and monotube high-pressure gas. Each of the three has its own abilities and functions, and you will find all three in street or street-derived racing applications.

One of the most common misconceptions is that a gas shock is filled entirely with gas and no oil. In fact, all three designs use hydraulic oil—they just may have a nitrogen gas charge pressurizing the oil in the shock.

The twin-tube hydraulic, as the name implies, has two cylinders (or chambers) and no nitrogen. The inner cylinder is where the rod and piston live and work, and the outer chamber is a reservoir for oil and air. As the rod travels in and out of the inner cylinder during stroking action, it displaces oil from the inner to the outer cylinder, then draws it back inside. Although this is the oldest of the three designs, it still maintains certain benefits and has a place in performance damping.

The twin-tube low-pressure gas shock is much the same as the hydraulic, except that it has a low-pressure nitrogen charge (usually 5-15 bar/70-210 psi) in the outer chamber, instead of an air pocket. Some manufacturers seal the nitrogen in a plastic bag, while others will allow the nitrogen in solution with the oil.

The original theory behind placing the nitrogen inside was that it would put the oil reservoir under pressure and therefore raise the oil's boiling point, reducing the tendency for heat-related fading or foaming as it passed through the valves. That really isn't much of

a concern today as the quality of oil has increased in performance dampers. Plus, modern performance shock design has moved away from needle valves and o-ring seals that are affected by heat and viscosity changes, and most street cars and many race cars simply will not generate enough heat to challenge the oil in a proper performance shock.

However, when the nitrogen gas is in solution with the oil, it can give the added effect of damping really minute harmonics and motions that otherwise would not be big enough to make the damper's piston move.

The final design is the monotube high-pressure gas shock. The monotube's entire body serves as the chamber; this allows for a larger piston area, and therefore it has the ability to transfer more damping information over a smaller stroke area. Displacement of oil by the incoming rod is handled by a chamber at the bottom of the unit that contains a high-pressure nitrogen charge (20+ bar/ 300+ psi) and is separated from the oil by a floating piston.

Each design offers certain advantages and disadvantages, so the best choice will depend upon the intended application.

A twin-tube design, when compared to a monotube, has a longer stroke capability and greater oil volume in a similarly-sized unit. Therefore, the twin-tube will tend to give a smoother or more forgiving ride characteristic and still supply the firmness for proper handling control in vehicles that see average or long suspension stroke length.

The larger piston area of the monotube will give more control over much shorter stroke lengths or at the lowest piston speeds, but also tends to ride more harshly for exactly the same reasons. In racing applications where heat generation is more likely to be a factor, a monotube can cool itself more quickly because the shock body is the wall of the working cylinder.

You are likely to find monotubes on non-production-based race cars (formula cars and such), where control over very short strokes is mandatory and ride quality is not an issue, or on production-based race cars where once again control is more important than ride quality. Most of the rebuildable, high-end race shocks will use a monotube design.

Note that gas pressure in the shock can extend the oil's heat tolerances, but can also affect ride height because the greater pressure can act as a slight booster to the spring rate. Cars that run lower spring rates don't want the boost, so they usually use hydraulic shocks or must be willing to compensate for the gas pressure.

Monotubes can also operate while mounted on their side or at any angle, so they are more conducive to racing pushrod suspensions, while twin tubes must operate from upright to no more than 45 degrees from upright (which is still fine for most production-based suspensions).

### Before You Call

So let's say you have decided what vendor to go with and you have credit card in hand; now what do you do? Before calling, Danny Criss from Leda recommends you have at a minimum the following info on hand: vehicle year, model and use (street, road race, rally, autocross, etc.).

If the shocks are for a competition car, he also recommends being aware of any limitations

set forth for that particular series. While the general trend in racing has been a loosening of the limits set on shocks, you're still better off knowing what you can and cannot run before making any financial commitments.

Retailers need to know the true use of the car, stresses Jay Morris. "No Walter Mittys allowed except for the Walter Mitty Challenge. No retailer likes to field complaints from customers who said they were going to go through drivers school and never did." Morris adds one more caution for prospective customers who may still be coming to grips with reality: "We also need to know how much room you have left on your credit cards."

If the car is a purpose-built car (vs. a production-based race car), there is some other info the shock builder will need, points out Penske's Jim Arentz: "Make and year of car, type of racing, inner spring diameter, spring length, needed bump travel, fully extended length of existing damper on car, number of adjustments desired, and type of chassis mounts."

From the info you provide, the shock company should be able to hook you up with the right shock. "The tuner should be able to calculate natural frequencies (or recommend spring rates) and a good guess at the damping characteristics, while on the phone," explains Shocktek's Michael O'Callahan. "Note that this information should not be a guess out of the blue, or from 'experience,' but should be based on the physics of automotive suspensions."

### Rebuilding What You Have

Many of us can't afford to buy new shocks, but we would still like to improve our chances of winning. Upgrading your present shocks may be an economical way to vastly improve your car's transient handling characteristics and bump control.

For instance, if you bought off-the-shelf Konis or Bilsteins, you can have the internal valving modified so that it reacts more quickly or offers more resistance in bump or rebound. Koni shocks that initially came with only adjustable rebound can be upgraded to double-adjustable specs (both adjustable rebound and bump). Likewise, Shocktek can convert non-adjustable Bilsteins to either single- or double-adjustable specs.

This can be done at a substantial savings when compared to purchasing new shocks. At the time of the upgrade, you could also have the valving modified to suit your specific type of racing. Autocross shocks would be valved differently than road race or drag shocks.

Having your shocks upgraded is good, but just as in purchasing, be cautious. This work should be done by factory-trained personnel (who have access to a shock dyno), and hopefully by someone who also understands the type of racing you do. Look for references and look for the reputation the company has within your racing circles.

### SOURCES

Advance Design  
(530) 677-8600  
[www.ground-control.com](http://www.ground-control.com)

Bilstein Corporation  
8845 Rehco Road

San Diego, CA 92121  
(619) 453-7723

Boge  
3658 Atlanta Industrial Blvd. NW  
Atlanta, GA 30331  
(404) 699-1131

Carrera Racing Shocks  
5412 New Peachtree Road  
Atlanta, GA 30341  
(770) 451-8811  
[www.carrerashocks.com](http://www.carrerashocks.com)

Dynamic Suspensions  
85 Valleywood Drive  
Markham, ON L3R 5E5  
(905) 470-8778

GAB  
48511 Warm Springs Blvd. #210  
Fremont, CA 94539  
(510) 490-7078

H&R  
3815 Bakerview Spur #7  
Bellingham, WA 98226  
(888) 827-8881

Koni North America  
1961A International Way  
Hebron, KY 41048  
(606) 586-4100  
[www.koni-na.com](http://www.koni-na.com)

Leda Suspension  
13705 West 11 Mile Rd.  
Oak Park, MI 48237  
(248) 542-2370  
[www.leda.com](http://www.leda.com)

Neuspeed  
3300 Corte Malpaso  
Camarillo, CA 93012  
(800) 423-3623  
[www.neuspeed.com](http://www.neuspeed.com)

Overseas Dustributing

210 East Fourth Avenue  
Vancouver, BC V5T 1G5  
(800) 665-5031  
[www.overseas-auto.com](http://www.overseas-auto.com)

Penske Racing Shocks  
PO Box 1056  
Reading, PA 19603  
(610) 375-6180  
[www.penskeshocks.com](http://www.penskeshocks.com)

Progress Group  
250 Viking Avenue  
Brea, CA 92821  
(714) 257-0644  
[www.progressauto.com](http://www.progressauto.com)

Pro Parts West  
21417 Ingomar Street #7  
Canoga Park, CA 91304  
(818) 888-8904

RD Enterprises  
1300 Hill Street  
El Cajon, CA 92020  
(800) 683-2890  
[www.shox.com](http://www.shox.com)

Shocktek  
227 Hathaway St., East  
Girard, PA 16417  
(814) 774-8808  
[shocktek@ibm.net](mailto:shocktek@ibm.net)

Truechoice  
4677 Northwest Pkwy.  
Hilliard, OH 43026  
(800) 388-8783  
[www.truechoice.com](http://www.truechoice.com)

Tokico  
1330 Storm Parkway  
Torrance, CA 90501  
(310) 534-4934