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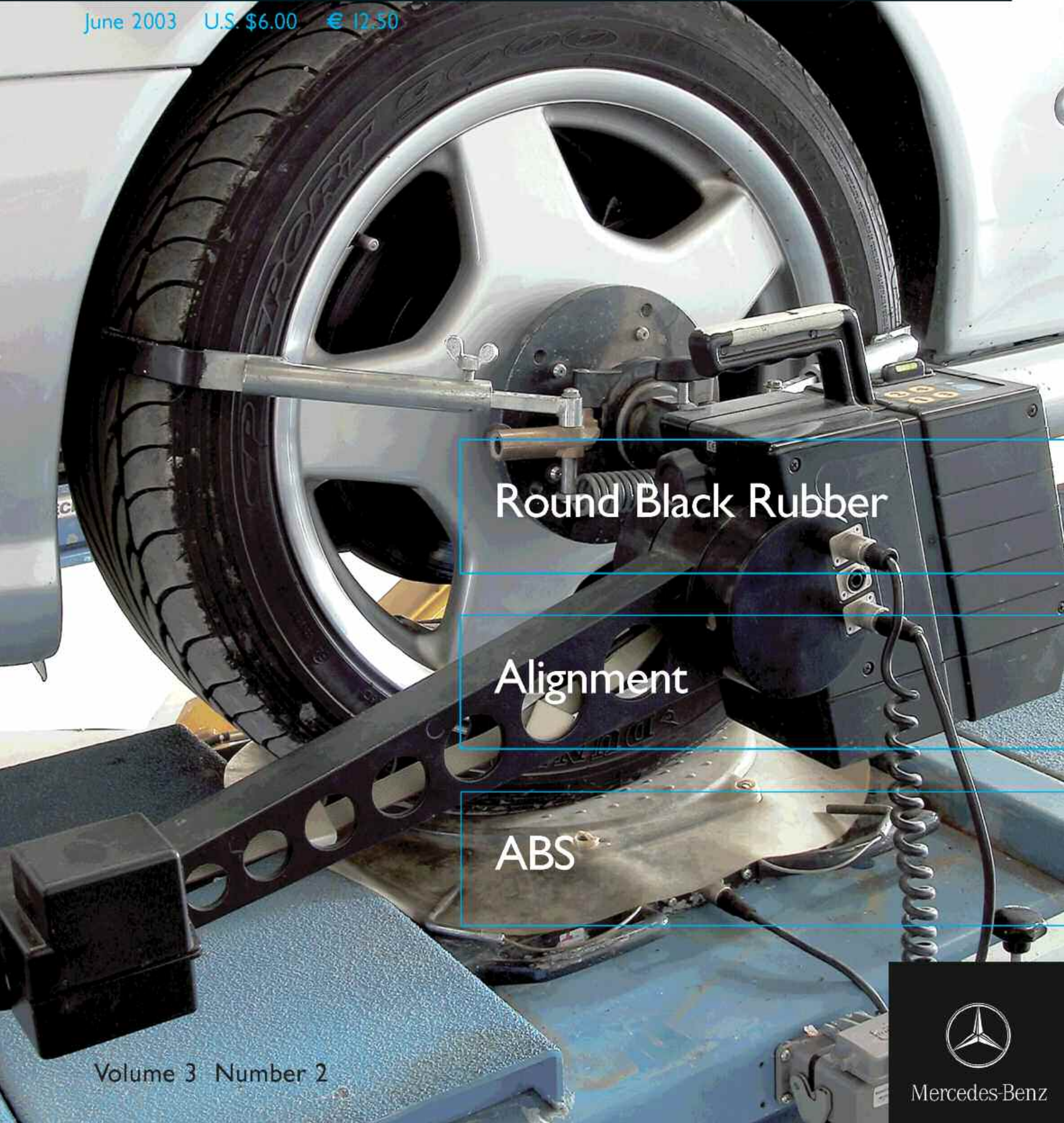

Round Black Rubber

Alignment

ABS

Volume 3 Number 2

Mercedes-Benz

To Our Readers:

Welcome to *StarTuned*, the magazine for independent service technicians working on Mercedes-Benz vehicles. Mercedes-Benz sponsors *StarTuned* and provides the information coming your way in each issue.

The worldwide carmaker wants to present what you need to know to diagnose and repair Mercedes-Benz cars accurately, quickly and the first time. Text, graphic, on-line and other information sources combine to make this possible.

Feature articles, derived from approved company information sources, focus on being useful and interesting. Our digest of service bulletins can help you solve unanticipated problems quickly and expertly. Our list of Mercedes-Benz dealers can help you find original, Genuine Mercedes-Benz Parts.

We want *StarTuned* to be both useful and interesting, so please let us know just what kinds of features and other information services you'd like to see in it. We'll continue to bring you selected service bulletins from Mercedes-Benz and articles covering the different systems on these vehicles.

Send your suggestions, questions or comments to us at:

StarTuned
Number One Mercedes Drive
Montvale, New Jersey 07645
Phone: 1 800 225 6262, ext. 2647
e-mail: BrzozowskiA@MBUSA.com

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Group Publisher
Christopher M. Ayers, Jr.
cayers@cmacomm.com

Editor
Joe Woods
jwoods@cmacomm.com

MBUSA Technical Content Advisor
John Heibler
heiblerj@mbusa.com

Project Director
Andrew Brzozowski
BrzozowskiA@mbusa.com

Art Director
Jef Sturm
jsturm@cmacomm.com

Production Manager
Joe Cristiano
jcristiano@cmacomm.com

Circulation Manager
Phillip A. Helon
phelon@cmacomm.com

List Consultant
NFocus

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Feature Articles

Departments

Mercedes Benz

ROUND BLACK RUBBER

Our two major features in this issue of *StarTuned* are about alignment and ABS, both of them affecting control of the car along the roadway. But round black rubber is the constant between everything on the car and the roadway, so let's talk tires first.

Remember how your mind slumped into a yawning torpor when your teacher droned, “Today, class, we’ll review... again.” No reviews here. We won’t bore you with tire lore you already know, like the difference between bias-ply and radial tires, what ‘aspect-ratio’ means applied to tires, how water-shedding tread patterns reduce aquaplaning or the difference between static and dynamic wheel balance. No nagging about the importance of checking tire pressure or measuring tread depth, rotating tires regularly or fitting tires of the correct size and type. If you don’t already know all those things, learn and practice them before you do tire work on somebody’s car. But we hope most of this tire information is new, information to illuminate your thinking and help your work on alignment and ABS.

How Does a Tire ‘Work’?

The question seems odd because it looks like we can already see how a tire works. Doesn’t it just smooth out small bumps and keep the wheel from getting bent? Besides, there aren’t any moving parts to a tire. How can it ‘work’ at all? What is it the tire does?

A tire ‘works’ by performing several tasks on a vehicle. It provides enough traction to reel in the paint stripe between the lanes and to shove the scenery deep into the rearview mirror. It achieves the grip to keep the road under the drivetrain and the car’s shiny side up. But that’s not the tire’s first job. If you just put a brand new set of tires on the wheels and bolt the wheels up to the hubs, the weight of the car will rest solidly on the ground. Tires don’t hold the car up; compressed air does.

Let’s start at the beginning, with the tire’s work hoisting the car’s weight and the tire’s most important component, that ring of compressed air. Almost everything in the car rests on some other component, the way the engine rests on the engine mounts, which in turn rest on the subframe and suspension. The driver rests on the seat, and the seat on the floor and frame channels. The car’s entire body and powertrain weight rests through the suspension on its four wheels. One thing stacks atop another from the roof down to the wheels.

But unless a tire is deflated flat and its wheel rests on the pavement through the folded tire rubber, the wheels don’t rest on anything. Instead, the wheels *hang* in the eight loops formed by the beads of the four tires, two apiece. These loops are, in almost every tire, multistrand steel cables. The beads are slings, loaded in suspension, not in compression. The weight of the car, supported on the wheels in the tire beads, *hangs* just like a suspension bridge from its cables. If the car weighs 4000 pounds, thus, each tire’s beads hold about 1000 pounds. The beads are actually much stronger than that to accommodate shock and stress loads occurring under severe impacts.

Pressure and

There’s an optimal pressure for a given load. Below that and the treadpatch squirms while the sidewall overheats from flexing. Above that and you don’t get a full footprint. Conditions can shift this slightly: higher pressure will resist aquaplaning by reducing the treadpatch and thus increasing the pressure per square inch.

Treadpatch area times pressure equals the load at that wheel, tossing in a little ‘fudge-factor’ for the stiffness of the rubber. Every variation in treadpatch area (from bumps and potholes) changes the pressure in the tire slightly, lifting the wheel if the pressure increases, lowering it if the pressure goes down.

Then what holds up the tire beads? The belts in and over the top half of the tire. We don’t ordinarily put an intact but deflated tire on a wheel, bolt that to an axle flange, lower the car to the ground and only then inflate the tire. But if we did, the pneumatic hoisting mechanism would be clearer. The increasing air pressure applies in all directions with equal force to every square inch on the inside of the tire and the wheelrim. The pressure around the wheelrim increases as the inflation goes up, but it does so equally all around its perimeter and all across its width. Since the inflation pressure on the wheel itself is equal all around, that can’t possibly contribute to lifting the weight of the car and so it doesn’t explain how the compressed air lifts the car.

NITROGEN INFLATION

Here's a bit of inflation lore you might have heard and something about how realistic it is. Car racing teams usually inflate their tires with nitrogen rather than with compressed air. About 80 percent of air is nitrogen, anyway, so this is not a particularly radical measure. The idea is to eliminate as much as possible any moisture in the inflation gas.

All inflation gas, including pure nitrogen, will lose or gain pressure with temperature, following Boyle's Gas Law, but gradually and predictably. Double the temperature while holding the volume constant, and you double the pressure. Reduce the temperature, and you reduce the pressure proportionate to the absolute temperature change.

The humidity inside the tire does make a difference because it can mean the tire pressure fluctuates more with temperature than you'd like and at abrupt thresholds. Here's how it works: Humidity is a function of temperature – the higher the temperature of the air, the more water vapor it can hold in solution. As the air cools, it eventually reaches the "dewpoint," the combination of temperature and humidity when the water vapor reaches full saturation (100 percent humidity) and starts to precipitate out as liquid water. In volume, it takes a lot of vapor to make up a relatively small volume of liquid water. When you remove that water-vapor volume from the inflation gas, the pressure drops more than the temperature change alone would cause.

The practice derives presumably from aircraft tires, which have used almost pure nitrogen for a long time. When an airliner reaches cruising altitude, the temperature of the air in the wheelwells may be below zero. But if the tires had been inflated with very humid air, the moisture would have precipitated out of solution, liquefied and frozen in the tires. Since it's unlikely any ice in the tires will thaw and revaporize by touchdown, that could mean in the extreme case a dangerously reduced tire pressure at the very moment you want it to be perfect. Evidently water vapor dissolves more readily in oxygen than in nitrogen, so by excluding the oxygen you can avoid the moisture/change-of-phase problem.

What does this mean in your shop? Should you rush out and get nitrogen tanks? Probably not. It won't hurt to use nitrogen, but it's not going to do any measurable good, either. Car tires don't spend hours motionless at subzero temperatures and then suddenly sustain a smoking, full-load compression shock while spinning up beyond 150 mph at the same instant. Keep your compressor tank drained dry, and you won't have enough moisture in the inflation air that this will be a real-world problem. Your pneumatic tools will last longer, too.

If not pressure on the inside of the wheelrim, then it must be the pressure against the inside surface of the tire, because that's all that's left. The surfaces of the sidewalls hold about half a ton of pressure pushing outward each way, locking the beads against the rim, sealing in the air. But sidewall pressure pushes out, sideways, not up. That leaves only the pressure around the tread, inside the belts.

The pressure around the tread is equal, too, so how can it lift weight when the same pressure against different places inside the same wheel and tire could not? Pressure around the tread and along the sidewall also pulls the bead outward in all directions – but not *equally* in all directions. The difference around the tread is that the pressure on the bottom, the pressure just opposite the part of the tread currently touching the pavement, the treadpatch, encounters equal and opposite pressure upward from the road surface. The pavement, in fact, bends the naturally curved treadpatch flat, in an area corresponding directly to the load and the inflation pressure. Pressures above and below that roadpatch cancel out, and so the pressure under the belts at the top of the tire lifts the beads, wheels, car and all.

The air pressure around the circumference of the tire, just below the steel belts, also pulls the radial belts outward, thus pulling the beads outward. Of course the belts and beads are steel and don't stretch under tire inflation pressure. But that equal and opposite counterpressure from the pavement unloads the pavement/treadpatch section of the tire. The air pressing down and the pavement pushing up squeeze the rubber and that part of the steel belt, of course, but that sector's contribution disappears from the force applied through the radial belts to the lowest section of the beads. So the beads at the bottom pull down with less force than the beads at the top pull up, with in fact exactly the same force the treadpatch places on the road. The car's weight hangs by suspension from the tire beads, which rest by compression on the air at inflation pressure on the *top* section of the tire. The air, in turn, constrained in the ring-space within the tire, presses against the displaced section of the treadpatch directly in contact with the pavement.

Notice this is just like a suspension bridge, using the compressed air ring in place of the stone pillars. But the bridge isn't going anywhere, and the car is. Instead of a rigid stone column, the air in the tire forms an elastic, flexible torus. This is the first and most active part of the vehicle's suspension: The treadpatch follows the undulations of the pavement, but the undulations cause microvariations in the tire inflation pressure, pulses corresponding to the ripples in the pavement. The compressibility of the air and the elasticity of the rubber allow absorption and insulation of the quickest and smallest undulations of the pavement, movements that would otherwise make the vehicle ride intolerable. Ever ride on solid-rubber-tires?

So that's how the tire lifts the car. Here's how it cushions the ride: Very small road irregularities simply deflect the rubber surface at that point, with negligible effect on the ride. If the car encounters a bump up, first the tread deflects upward, reducing the volume of airspace in the tire and correspondingly increasing the momentary air pressure. The upward deflection also increases the area of treadpatch in contact with the pavement. Both of these effects increase the lift the upper part of the tire can exert to hoist the beads. The tire deflects upward, pulling up the wheel and the spindle. The spring compresses upward; the car rises at that corner. Just the opposite occurs when the car goes over a pothole or dip: the treadpatch loses area; the lift the upper part of the tire can exert on the beads drops correspondingly. The suspension extends, and the car dips.

Inflation pressure does push the sidewalls out, but that doesn't hold the car up. Tire sidewalls are never farther apart than when squashed out in a deflated tire. When you re-inflate the tire, pressure on those spread-out sidewalls constantly increases up to normal pressure, but at the same time they move back inward.

Inflation presses the sidewalls against the rim with a force of about 1000 pounds on each side. The resulting friction holding the tire to the rim is usually more than sufficient, well beyond the torque that could be put out by the engine or braking system or absorbed by the road surface. However there have been some nonoriginal wheels, brightly plated all over with smooth, shiny chrome, including on the mating surface between the wheel and the tire bead. Whatever be said about the 'lotsa-chrome' decorator touch, it doesn't belong between tire and wheelrim.

It's unlikely (absent the use of some sort of grease as a tire-mounting aid) the tire can turn much on a rim, even on such slick wheels, but it could move by an inch or so with hard braking or acceleration. And then another inch or so the next time. In an extreme case, that could throw off the wheel balance as well as any steps taken to minimize radial and lateral runout. You know, of course, about aftermarket wheels that block sufficient flow of air to keep the brakes cool under extreme circumstances. The advantage of sticking with a tire and wheel called out in Mercedes-Benz specifications is that you can have a high level of confidence there won't be any functional shortcoming masked as 'styling' that slipped past their testing.

High-Speed Distortion

One of the odder forms of tread behavior occurs at high speeds, when centrifugal force acting on the tire wants to make the tread circumference grow by centrifugal force. The steel belts are strong enough to prevent that from happening to any great extent, but there aren't steel belts in the sidewalls. That means the sidewalls can lift upwards and increase the wheel diameter just at the shoulder of the tire, in what are called 'pantographic effects.' You can see how this could have unexpected traction results, as the center of the treadpatch developed less and less pavement contact at higher speeds.

Modern high-speed-rated tires include auxiliary Kevlar- or Aramid-fiber belts right at the shoulder of the tire to constrain this kind of centrifugal-force growth.

Treadprint Squirm

We've discussed how the tire holds the car up because a similar mechanism controls the car underway, and understanding how it works clarifies ABS and alignment diagnosis and work. The belts, tensioned by the inflation pressure, conduct all the directional forces between the treadpatch and the wheel.

Let's look at five sets of remarkable treadprint photos provided to *StarTuned* by Goodyear, evidently taken under their glass-road test facility. These cover steady, straight-line driving, accelerating, braking, turning left and turning right. We can see what's going on at each of the four wheels in these circumstances. Please keep in mind these are tire graphics, not car photos. We have no way of telling what kind of vehicle was used for the tests or even whether the tires shown are specified for any Mercedes-Benz vehicle at all. There's every reason to suppose the treadprint variations are representative of all cars, however.

Straight ahead, steady speed. Assuming the inflation pressures are identical for all four tires, we see there is slightly more weight on the front tires than on the rears, typical for front-engined cars. There appears to be slightly negative camber on the front tires, as the inboard part of the treadprint shows a bit longer shoulder contact than the corresponding outboard section. I think this is so of the rear tires, too, but I'm less confident there. Slightly negative camber all around improves roadholding for most cars, as long as you stay within specs. The photos show no sideslip, and the water grooves are directly parallel to the direction of travel, represented by the edges of the photos. In these and all the other tireprint images, the tread bends flat abruptly just as it touches down and again as it lifts. At the same time and unseen here, the sidewalls flex at just the space of contact. This flexing as well as friction during turns, acceleration and braking, raises the temperature of the tire rubber.

Left turn, constant speed. This and the next set of pictures show hard, but not white-knuckled turns. Most of the weight has shifted to the right wheels by centrifugal force; there's almost no load on the inboard left shoulder. Each of the tires carries most of the weight on its right side, indicating that the force of the turn has forced the tire to roll away from the outboard sidewall. I would conjecture – but do not know – that Benz suspension geometry would show somewhat less of this 'camber' effect. We do see the beginnings of sideslip here, though. If the front wheel centerline points, let's say, 10 degrees left of the car's centerline, the tire treadpatch centerline will follow a line somewhat outboard of that, say 5 degrees. The tire twists under the wheel from the force of the turn. The centerline of the tread sets down close to the centerline of the tire, but as the car passes over it, leaning outward in the turn, the pavement progressively pulls the treadpatch back toward the center of the car.

Right turn, constant speed. We notice, in the opposite direction, all the things we saw in the left turn. We also notice (as with the left) that the sideslip of the rear wheel is less than the front wheel sideslip. Reasonable design requires this, not only to achieve predictable handling, but also to keep the rear wheels grabbing pavement beyond the point when the fronts have lost it. Disconcerting as understeer can be in an emergency, it's inherently far safer than the sudden spin of oversteer. With each of these sets of turning photos, you can also understand the consequences of braking and turning at the same time. In the absence of an ABS system, that combination could shift so much weight to the outside front wheel and remove so much from the inside rear, that a spin could become unacceptably likely.

Straight ahead, braking. Again we see the weight-shift from a speed change. The front treadpatches have now grown larger than they were in steady cruise. We can also see the suspension of this car is sufficiently sophisticated that there is no detectable change of toe with the deceleration. In fact, we can't even guess whether the car uses antidive/antisquat suspension geometry, because you'd still have the same change of treadpatch area with acceleration and deceleration. That change of area, directly proportionate to the shift of weight and correspondingly to the traction available, vividly shows why every vehicle needs some sort of proportioning function to the rear-wheel brakes: Should the rear wheels lock up, there'd be nothing to control the vehicle's direction. Yaw change could be instantaneous and uncontrollable. Similarly, you'd never want enough front braking power and traction to bring about a 100 percent weight-shift, lifting the rears clear of the road. That would have the same effect. Braking also can cause the tire to wind more tightly on the wheel, effectively reducing the rolling diameter.

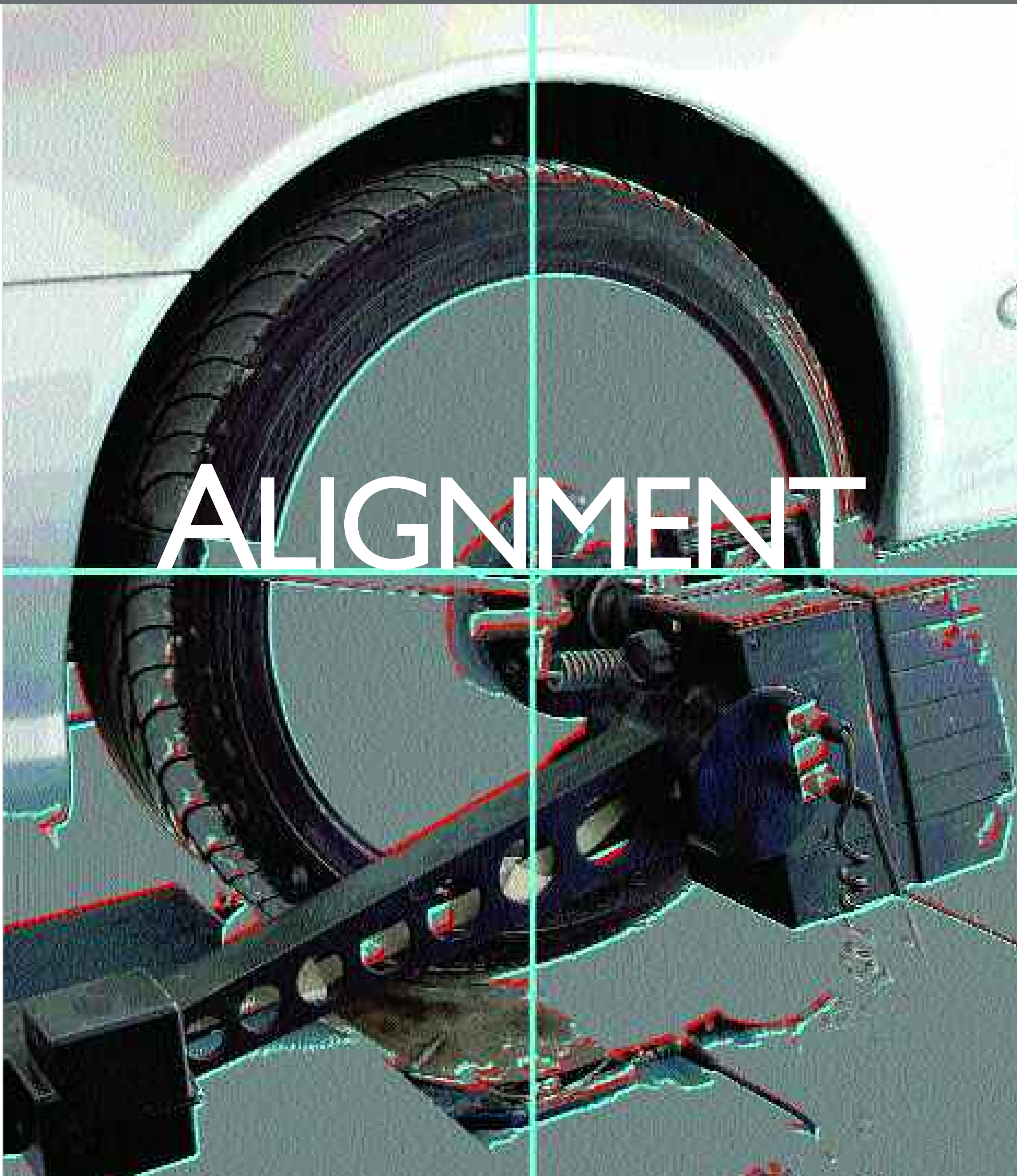
Straight ahead, accelerating. We immediately notice the weight-shift to the rear tires, evidenced from the increase in the relative size of the rear treadpatches. Since the total weight of the car doesn't change, however, the total area of all four treadpatches remains the same. This test did not involve accelerating enough to spin the rear drivewheels, but if it did, we'd see the separation of road and tire beginning at the back of the patch where there is the highest rubber stress. You've probably seen high-speed photographs of drag-racer tires as they wind tighter on the hub under power. The windup means the radial belts drive the wheel (and thus car) forward. It also means the wound-up belts lift the slipping, high-stress rear area of the treadpatch sooner than a normal, moderate acceleration would.

There's an interesting traction anomaly that occurs in a steep sideslip (we're only considering a car without any form of traction control here), interesting, that is, if you do alignments. Consider the extension of the caster axis to the point at which it intersects the pavement. Under most circumstances, this point is somewhat forward of the centerpoint of the treadpatch, and caster functions to pull the steering to the center. In a sideslip, however, the centerpoint of the treadpatch angles *outboard* of the wheel centerline, because the centrifugal side-load forces the tire to twist, just as we saw above. The stress on the treadpatch is greatest where the displacement is greatest, at the back edge. When a wheel starts to sideslip, most of the slip is at the back (as well as most of the tire wear).

Different tires are capable of different levels of slip, but 12 degrees is not unusual. The tire can continue to a higher angle of slip, as more and more of the treadpatch breaks loose from the pavement. But at a certain amount of slip, so much of the back of the treadpatch has broken loose that the caster angle axis now intersects the center and then the rear of the functional (i. e., non-slipping) contact patch. At that point, the steering is no longer self-correcting; there's no more 'caster' effect. The wheel instead of requiring the driver to positively turn in the direction he wants to go, suddenly falls neutral and then wants to go all the way into the turn, past the position the driver wants. But before the steering can slam against the stop, the tirepatch breaks completely loose from the pavement, steering goes neutral again, and there is effectively no traction at that wheel. The car has literally gone ballistic, and trajectory physics, not steering, determines where it goes and when it stops.

While that can happen with the last degree or so of steering wheel angle, once the tire slips that much, you can't recover traction by simply backing up that last errant degree. You have to countersteer hard, to bring the wheel centerline (and that of the tire) parallel to the direction of travel, perhaps 25 or 30 degrees toward the outside of the turn, away from the angle it held a fraction of a second before, away from the direction you want to go. Like driving an old car on black ice, not much of this is instinctual. You can understand why Mercedes-Benz went on to develop the ESP and other traction control systems we'll cover in future issues.

StarTuned *would like to thank Goodyear for some of the information in this article.*



Alignment

Surveying Directional Control

If the engine makes the car accelerate and the brakes make it slow, steering and alignment are what make it useful in the long, steady driving intervals between those more energetic events. A proper alignment makes the very best use of a vehicle's tires, for traction and for treadwear, a theme we've already begun in this issue, use to control exactly where the driver wants to put the car on the road.

Mercedes-Benz cars have used a progression of suspension geometries among cars you're likely to see in your shop, but you're never likely to see one with an especially simple suspension. These cars have used various multilink independent suspensions since 1937, so you can drop any quickie plans for 'set-the-toe-and-let-'em-go.' That's never a good idea on any car, and if you try it on an independent, multilink Benz, you may create problems that will take somebody a long time to solve, and if he corrects them, he'll probably keep your customer thereafter.

Let's start at the beginning. Why did the car owner think he or she needed alignment? Some people have their car's alignment angles checked regularly; others choose to do so when they notice erratic or disappointing tire wear. Still others have an alignment done because of a recommendation from a friend or from the shop service writer. If possible, find out why this car is in your alignment bay. Take the car for an initial roadtest: Perhaps you will know immediately from the way the car drives why it 'pulls left' or squeals on turns. If you know why the car is on your rack for an alignment, you have a running start on delivering what the owner wants solved when he or she gets the car back. But what the owner thought was something out of alignment, you may instantly realize is a dragging brake. Let's assume, however, we're working only on alignment problems this time.

Once the car is on the alignment rack, the first thing to do is to walk around the vehicle and look at the tires. They should all be the same kind of tire from the same tiremaker, with about the same level of treadwear. In fact, they should be one of the tires specified for that vehicle model by the carmaker, but in any case they should be the same tire all around. If they are different tires, or different size tires from the same tiremaker, just stop. You can't align that car properly until all the tires match. Don't try to 'come close' or 'make allowances.' Get the same tire at each corner.

Remove the encapsulation panels, keeping in mind that any road grit the car has collected is likely to be on the upper side of them. When you pull all the screws and release the panel, all that stuff could choose you as the best depository on its way to the floor, if you don't tilt it away. You need to remove the panels to adjust or replace many of the lower suspension components, but even absent the need to change parts, removing them allows you to check for impact damage. The panels are usually a composite material (some are sheetmetal) that absorbs small impacts but should 'record' the damage for later inspection. Although it is not specifically an alignment function, they also record leaked fluids and other such evidence for the need to perform engine compartment work.

Once they match, pull out your inflation gauge. Most cars will have the proper inflation specification on the sticker inside the doorframe, glovebox door, fuel filler door or in the owner's manual. The inflation specification, coupled with the tire specification, determines exactly the configuration of the wheel with respect to the ground. It is not possible to guess the inflation in a tire to a useful level of accuracy just by bopping the rubber with a wooden club or by eyeballing the sidewall. That bounce flex can vary considerably from one type of tire to another. Use your gauge and get the numbers right.

Right after checking that the car has the right tires and that they are inflated properly, you check vehicle ride height. You usually measure rear ride height from the axle shaft. If you do enough Mercedes-Benz alignments, get one of the more technically sophisticated suspension height measurement devices. This directly and immediately measures the angle of a specific suspension arm against a level. You don't have to use such a tool, but it can save time on a repeated job – important if you do repeat the work often enough.

Next, check the ride height. Begin by checking the trunk and the back seat to make sure there's nothing heavy to throw the vehicle height off, but make sure the tank is full of gasoline. Then do the technical measurements. Exactly where and how to perform this test varies by vehicle and should be described in your alignment machine's literature or in Mercedes-Benz technical documentation in your shop. Technically sophisticated alignment equipment can measure suspension height remotely and immediately, but even if you are using something older than the latest equipment, you can still find where to measure and confirm that the springs have not sagged and the geometry is suitable for further testing and any adjustment necessary. A suspension-height measurement does not test how far the car's bellypan is from the pavement, except indirectly; it determines instead that all the suspension members are at the proper angle with respect to one another and to the vehicle unibody. Absent that determination, all the measurements and adjustments you make would be incorrect. A vehicle that fails a suspension height test, of course, has one or more sagged springs. For newer air and hydraulic suspensions, consult your technical manuals. Replace springs in axle pairs, or the ride will be uneven after the swap. If you're replacing springs, check the shock absorber, too.

On most models, rear alignment adjustments are made with eccentric bolts through the brackets and bushings. For particular applications, there are select-fit special purpose bolt kits that go in different orientations, so you need not only the information from the alignment machine but you also need to know what kinds of alignment parts are available.

Before doing any angle measurements or adjustments, go over the suspension components very carefully, making a visual inspection to detect any damage to one or another part. Some kinds of damage, for example a bent front spindle, may only become detectable when you determine the non-adjustable SAI angle is out of specification. If there is impact damage to some part or another, you have to replace that part before you can do an accurate alignment. Keep in mind that impact damage can and often does include damage to wheelrims and other parts caused by driving over an unexpectedly rough railroad crossing or a pothole that pits the road even more deeply than usual. Most alignment equipment can factor out some damage to a wheel, but the car will still not drive correctly with such damage.

Now set up the alignment machine heads and do the rear alignment tests and any needed adjustments. Why start at the back? Because you align the fronts to the thrust line, which is the average toe of the backs referenced to the vehicle centerline. If you adjust the rear suspension correctly, that should dial in a perfect, zero-degree thrust angle. Do things in the right sequence, and you have fewer things to do!

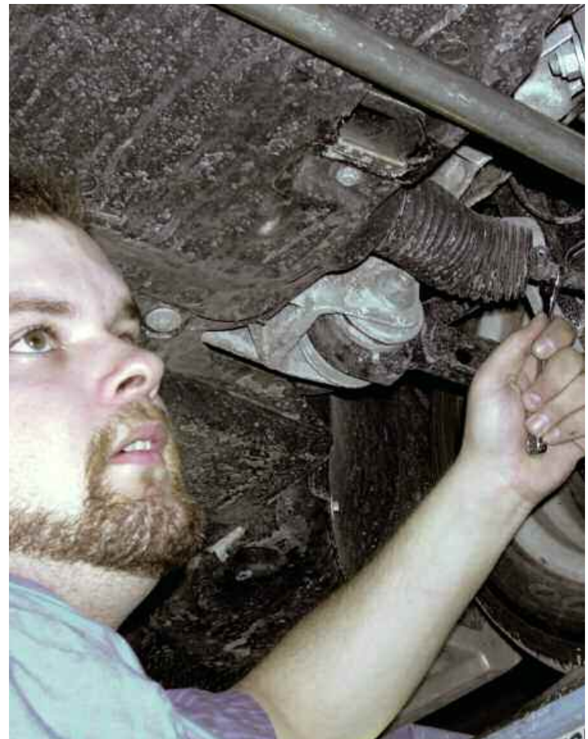
Rear alignments on most cars involve checking camber and toe, but keep in mind that the eccentric adjustments may change both at the same time. When you reset an eccentric bolt to change the position of a suspension strut in the back, keep in mind exactly what combination of dimensions you're modifying. Recall also that on each of the eccentric adjustments involving a rubber bushing that you must have the full weight of the car sitting level on its wheels before you snug the fastener to its final position. Otherwise the bushing will twist with the load and have a reduced useful life. Bushings tend to last a long time on these cars unless they have been soaked with oil.

Some of the later versions of eccentric bolts don't adjust by turning the eccentric, but by replacing the bolt with another, keyed to the slots on one side or the other of the bracket. The only economical way to do such alignments is to have a complete set of the adjustment eccentric bolts on hand, since it is unlikely you can predict in advance which you'll need. Having the inventory on hand is a much better time economy than measuring the car's angles, ordering the component, and then bringing the vehicle back when the parts are on hand.

If the vehicle uses one of the active suspension systems, be aware of how that works before you pull bolts out of suspension brackets, whether front or rear. These suspensions are active for a minute or so even when the engine is off and the key pulled out, so you'll have to consult your technical literature to determine how to disable the active suspension while conducting repairs. On some of them, you will not be able to reinstall a bolt through a bushing if you have not observed these steps.

Mercedes-Benz carries a tool, called a press-toe bar, that looks like a spring-loaded steel shower curtain rod, that correctly pre-loads the front wheels with a force corresponding to the forces acting during normal driving, simulating toe-out. By employing this tool or its equivalent, you can eliminate any looseness from the adjustment points when you set the toe.

Mercedes-Benz offers a special steering wheel holding tool, unique in that it steadies the wheel not against the seat cushion (which is none too steady an anchor) but against the headliner and roof. It is critical when using the tool, of course, to toggle off the convenience feature that lifts the steering wheel when the door is opened to make entry and egress easier. Failure to observe this step could allow the rising steering wheel to pop out the windshield, which might be an unwelcome surprise to a customer who dropped off a car for wheel alignment.



Alignment work takes a special kind of concentration and builds a familiarity with the characteristic difficulties of each model car. To become good at correctly aligning cars, you have to focus on getting the angle numbers correct exclusively. If you're working on a vehicle that is new to you and try to rush through it, it will probably take longer to complete than expected, and the job will not be done right. Take your time and learn the cars, the equipment and the special parts and tools. Then you can start cranking them out faster.

Centering the steering wheel often seems like an almost cosmetic step. After all, the car will run about as well with the wheel off by a couple of degrees, won't it? Well, actually, no it won't. For one thing, the layout of the driver's position was carefully planned by ergonomic designers to insure that the important gauges were all visible through the top of the steering wheel when the car is driving in a straight line. If the steering wheel is off center, that will no longer be so. Second, various traction control systems use a steering wheel position sensor to determine, for instance, how much variation in rolling velocity to allow to the wheels before adopting traction-retaining countermeasures. In a turn, for instance, ABS will allow more variation if the steering wheel is away from center than dead ahead. Third, the steering geometry assumes a specific position, i.e., centered, for straight-ahead driving. That is the only position in which the geometry will afford the correct toe-in specification. Of course, you can change the toe to achieve the right numbers with the wheel offcenter, but that turns out to be even worse. In that case, the tie rods will have the steering toed in too much at every other position. That would cost both steering control and useful life of the tires.

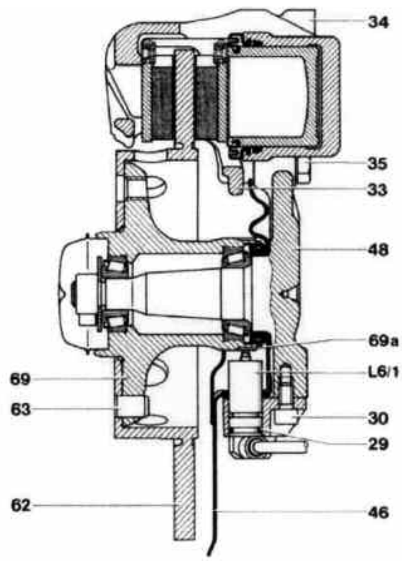
FACTORY SERVICE BULLETINS

These suggestions and solutions for technical problems come from service bulletins and other technical sources at Mercedes-Benz. They are selected and rewritten for independent repair shops. Your Genuine Mercedes-Benz Parts source can obtain any item designated by a part number.

Wheelspeed Sensor Replacements All Models with ABS

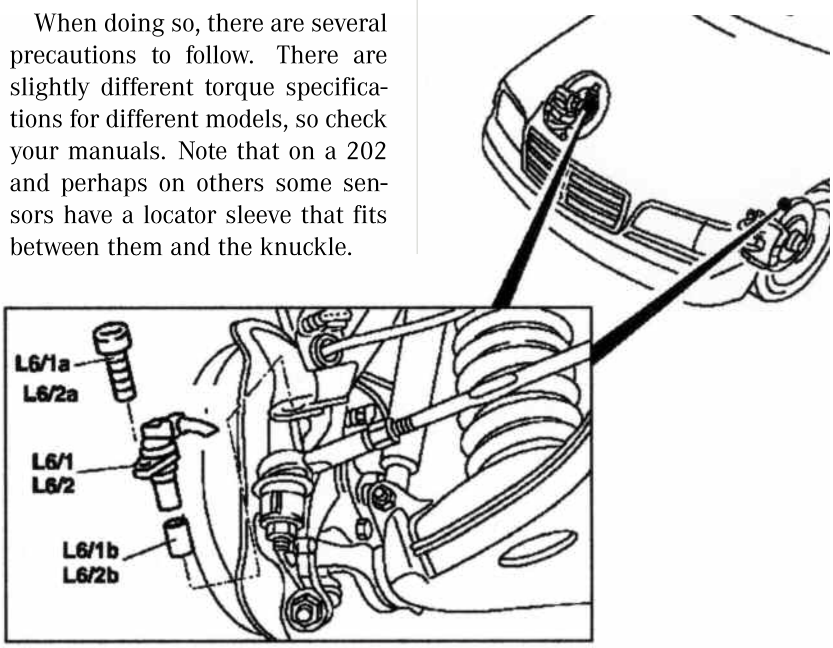
The most common ABS problem is likely physical damage to a wheelspeed sensor caused by impact damage with road debris. Most often such damage affects the harness, and certain kinds of harness damage can be repaired by splicing the harness itself. In other cases, you have to remove the old sensor and install a new one.

When doing so, there are several precautions to follow. There are slightly different torque specifications for different models, so check your manuals. Note that on a 202 and perhaps on others some sensors have a locator sleeve that fits between them and the knuckle.

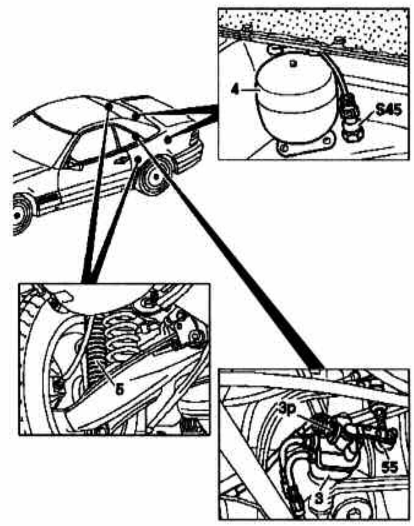


Before you install the new sensor, take the opportunity to rotate the wheel slowly while you inspect the teeth on the rotor very carefully using a flashlight. Remove any particles between the teeth; replace the rotor if you find broken teeth.

WIS



Swaying SL Suspension 129 with ADS



If you find an ADS-equipped SL with a ride that makes you wonder whether there are any shock absorbers in the car at all or even whether the road is attached securely to the planet, don't immediately start unbolting the shocks. If you don't see visible hydraulic leaks in the dampers or along the lines, it is possible there is one or more defective accumulator on the system.

There are accumulators and height sensors for each wheel. The suspension units work height sensors as the wheel goes through jounce and rebound. The control unit then routes or vents pressure as needed. The accumulators for the rear axle are in the trunk and simple enough to replace. Those for the front are inboard of the towers and not notably harder to access.

WIS

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The quality, reliability and value of the Genuine Mercedes-Benz Remanufactured A/C Compressor wasn't meant to be taken lightly. The A/C Compressor is not only an exact replacement for the original unit, it's also re-manufactured and tested to meet the same strict specifications as the original, so it performs just as well. And like all remanufactured parts, it's covered by the Mercedes-Benz limited parts warranty.* In fact, the only detectable difference you'll find between a Genuine Remanufactured A/C Compressor and a new one, is the price. Which we're sure you'll find quite refreshing.

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- Performs like new parts
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Cleaned, inspected, gauged, and honed to OEM specifications or replaced with new components as needed.

Discharge Reed Valve
Cleaned, polished, and inspected. Replaced with new components as needed.

Steel Gasket
Replaced 100% with new components.

Oil
Replaced 100% with R134a-compatible oil.

O-Rings & Seals
Replaced 100% with O-Rings compatible with both R12 & R134a refrigerant.

Pistons
Cleaned and inspected. Replaced with new, if the treated surface is scratched.

Shaft & Swash Plate
Cleaned, polished, and inspected. Replaced with new components as needed.

Shaft Keys
Replaced 100% with new components.

Shoes
Sized, cleaned, polished, & inspected. Replaced with new components as needed.

Snap Rings
Replaced 100% with new components.

Suction Reed Valve
Cleaned, polished, and inspected. Replaced with new components as needed.

Thrust Bearing
Cleaned, polished, and inspected. Replaced with new components as needed.

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Cleaned, polished, and inspected. Replaced with new components as needed.

*See your Mercedes-Benz dealer for details and a copy of the Mercedes-Benz Spare Parts Limited Warranty

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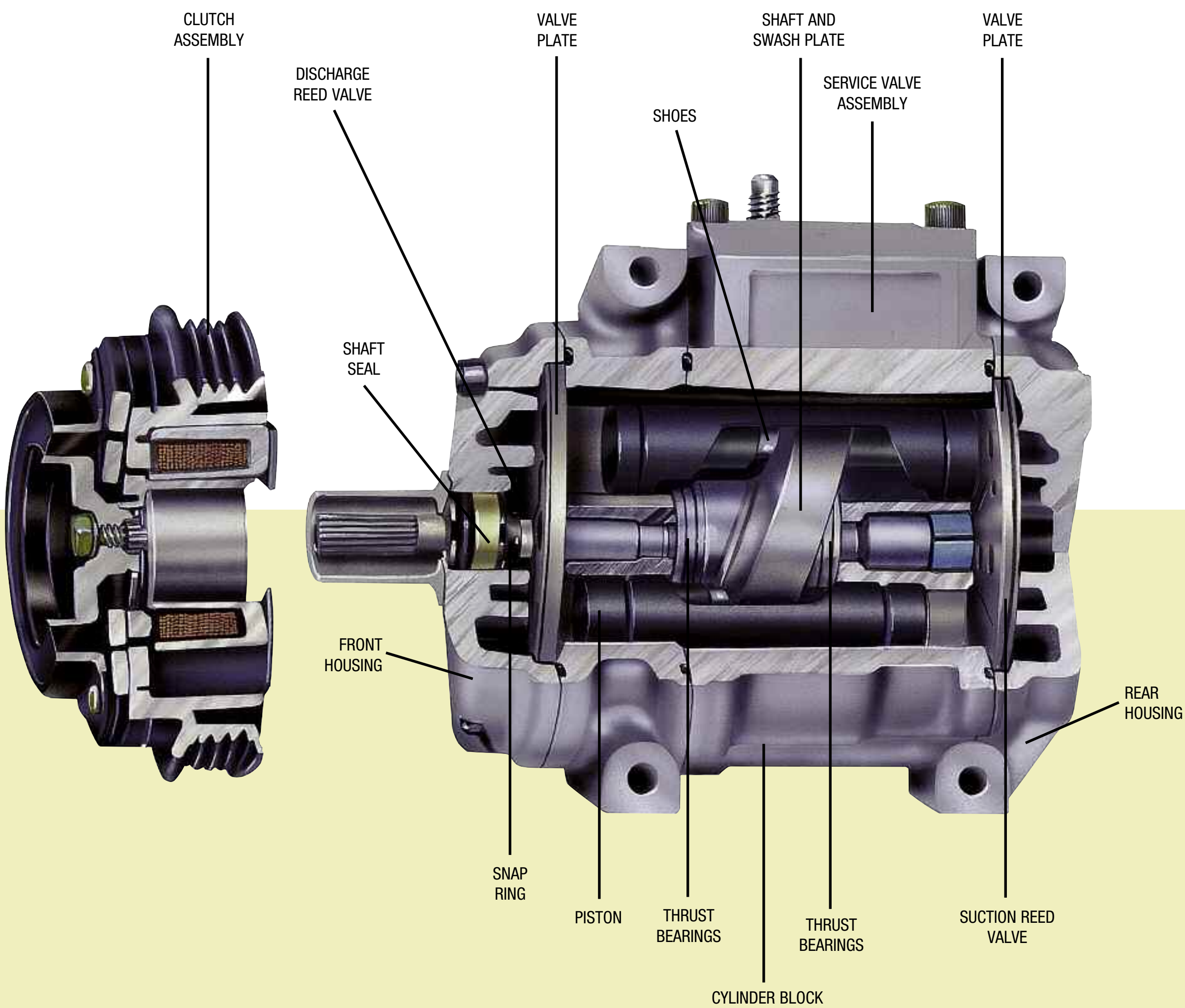

For more information about Genuine Mercedes-Benz Remanufactured A/C Compressors, contact your Mercedes-Benz dealer.

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PARTS NEWS

SPLINED HUBS

Certain parts, like the front hub with the precisely machined splines to generate a wheelspeed signal in combination with the sensor pickup bolted just adjacent to it, are obviously something you'd only want to get from the original manufacturer. The critical fit and function of the part are transparent, and nobody would be inclined to risk using something less than equivalent to the original Genuine Mercedes-Benz Part. The precision and criticality of other parts such as the eccentric bolts for adjusting alignment members is not so obvious, but think about that for a moment.

The hub and bearings, with the splined ABS sensor rotor, fit over the front steering spindle and carry not only half the front weight of the vehicle but also control the direction of the steering. What's more, the brake rotor and the wheel bolt directly to the flange. You can hardly imagine parts on a car that, besides carrying a lot of weight and stress, carry a lot of responsibility as well, responsibility for the manufacturer and for the shop that chose to install that part rather than others the market might proffer.

ECCENTRIC BOLTS

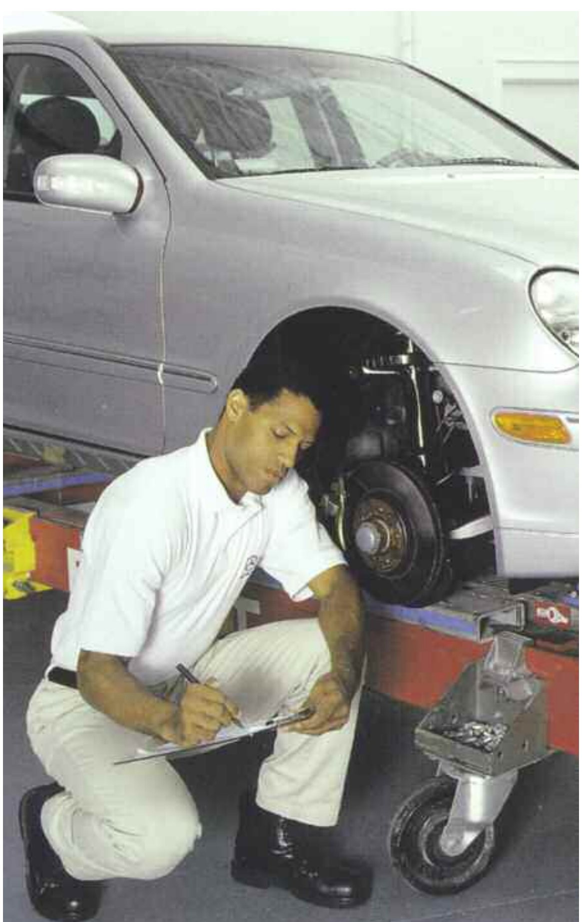
Now consider the alignment adjustment eccentric bolt. Obviously it has to be strong enough that it won't shear in the event of some hard stress still within the normal range of highway incident, but many manufacturers can make strong bolts. The factors that make the Genuine Mercedes-Benz Part unique are, besides the tensile strength, the precise shape and the sequence of special coatings and threadlockers. The German carmaker can and does make alignment specifications available to anyone who wants them to set the alignment of a car they built exactly right. But they don't broadcast the results of their painstaking testing and experimentation to determine exactly the right manufacturing technique and dimensions for such parts as these eccentric bolts, washers and locknuts.

Want the right parts? There's only one source for Genuine Mercedes-Benz Parts.

Collision Repair Facility Certification

Do you do body work and other collision repair on Mercedes-Benz vehicles at your shop? You might be interested in this. Mercedes-Benz has developed an official Collision Repair Facility Certification program, not only for body shops at Mercedes-Benz dealerships, but also for selected dealer-sponsored independent shops as well.

The object of the program is to distinguish those shops that meet the highest standards of work, of technician training, of equipment and of customer service. The benefit to participating shops is the opportunity for more work from customers who expect the highest standards of repair work on their vehicles. These are loyal, highly desirable customers. Does your shop measure up? Can you provide the prompt, professional, dependable service a Mercedes-Benz owner expects?



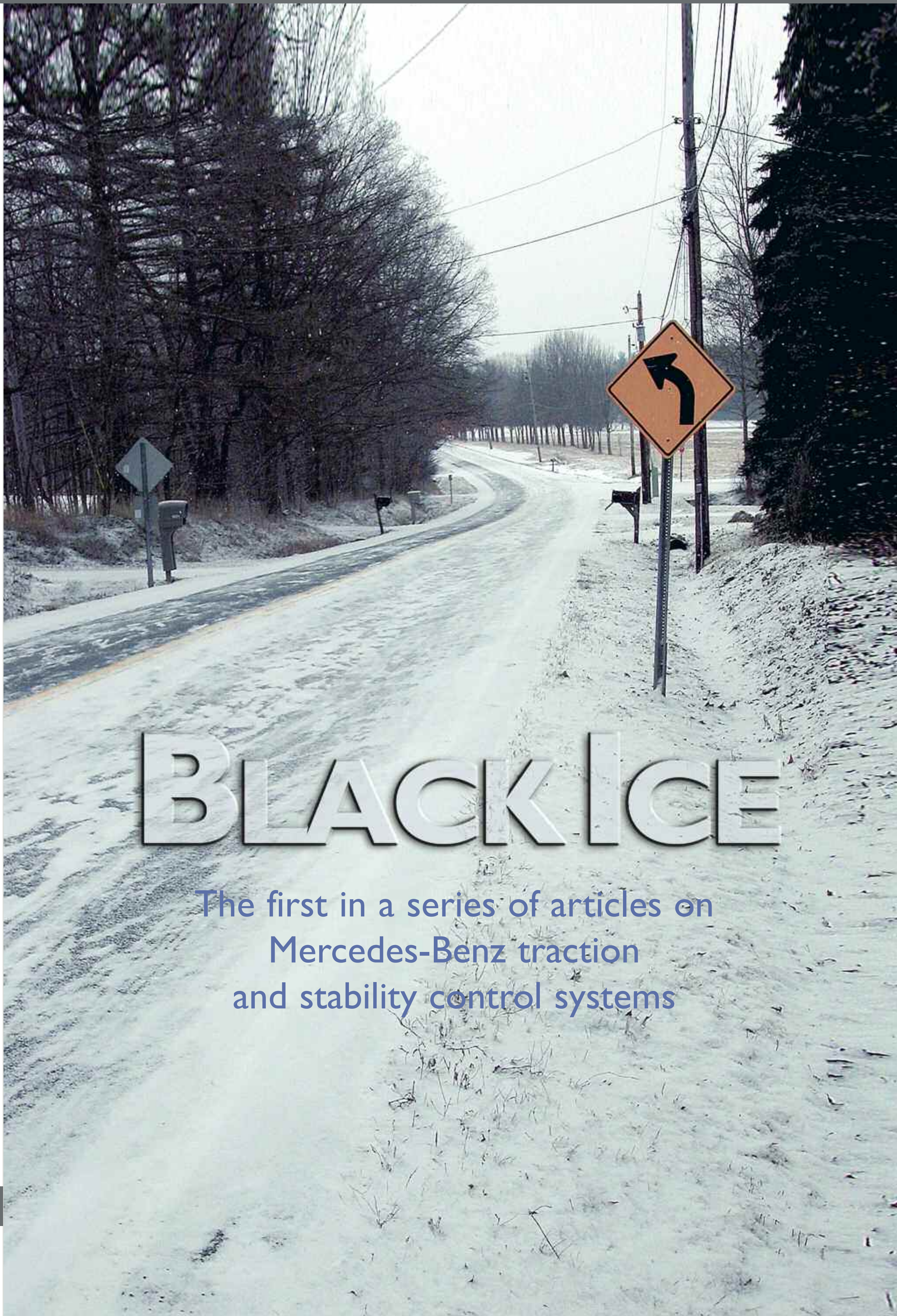
What Mercedes-Benz intends from this certification program are consistent customer and vehicle handling and care for an expanded range of needs, increased sales of Genuine Mercedes-Benz Parts, an increased contact with current customers to assure loyalty and a larger share of the luxury-car customer base. What the program offers your shop are new customers, additional business from existing customers, greater efficiency in your own business.

A collision repair facility included in the program should be able to meet the body repair needs of a growing customer base. It should be structured for business success in all details, from staffing to pricing to shop layout. Once included, the shop can promote its work as a "Certified Collision Facility" authorized by Mercedes-Benz USA, and Mercedes-Benz will include the shop on its list recommended to customers requesting assistance.

A dealer-affiliated and – sponsored independent facility certified in the program must provide repairs to published Mercedes-Benz standards, using the specified tools, equipment and Genuine Mercedes-Benz Parts. Certified facilities get access to repair resources, collision and new product training, tools and equipment discounts through the Standard Service Equipment Program, as well as the repair information in the Workshop Information System (WIS).

There are requirements for customer interface, for business standards, for the condition of the facility itself, for technician training and methods and for tools and equipment. Sponsorship for a shop in this program must be through an existing Mercedes-Benz dealer.

For more information about the Mercedes-Benz Collision Repair Facility Certification Program, contact StarTuned *by phone (1 800 225 6262, ext. 2647) or by e-mail (BrzozowskiA@MBUSA.com).*



BLACK ICE

The first in a series of articles on Mercedes-Benz traction and stability control systems

Techniques to maximize the available traction, to go, to turn, to stop, have been around for a long time. Four-wheel-drive vehicles go back to the late 1930's and probably earlier. Limited-slip and locking differentials, reducing the likelihood that the drivewheel with lower traction will spin loose, have long mechanical ancestry as well.

Some systems go back a very long way: Coal-fired Nineteenth-Century steam tractors sometimes used differential braking to grab back the traction when one of their iron-clawed wheels lost its grip in the dirt and started scrabbling down into the earth instead of dragging its plow along the furrow. The driver functioned at once as sensor, control unit and actuator; first dodging the flying rocks and clods, he heard the roaring steam and heaved to the corresponding brake lever with bicep power. Those three functions, electromechanical now and separate, remain the basis for current traction control systems, including our first:

Antilock Brakes

Why would you want an antilock brake system, anyway? Why not just stop all the wheels as fast as possible in an emergency and skid to a halt? Because of the difference between static and dynamic friction. Static friction is the force holding two separate but stationary objects together, dependent on factors like the character of the materials and their surface quality, the force pushing them together and the temperature. A boulder resting on the ground stays put against the force of the winds because of static friction. Dynamic friction is the force between two objects moving with respect to one another. A boat moving through the water, an airplane through the air and a hockey puck across the ice are examples of dynamic friction. So is a car spinning out of control, with all its wheels locked by the brakes. In each case, the dynamic friction will eventually bring them together, but static friction between the contact surfaces can stop movement much faster and under control.

Static friction increases with pressure up to the point when it breaks free and the objects slide. Static friction is always greater than dynamic friction between the same objects. Set a brick in the middle of a plank and lift one end. Static friction will hold it in place up to a certain angle, but once it starts to slide it can probably scoot to the other end before you can drop your end, because the dynamic friction between the sliding brick and the plank is much lower than the static was. A parking brake holds a vehicle at a standstill on a hill by static friction, but (assuming neutral rather than park or a gear) once it starts to roll, increasing speed shows how much lower the dynamic friction is.

At the hydraulic heart of the ABS system is the hydraulic unit. This component sits on the brake fluid circuits between the tandem master cylinder and each wheel cylinder. When there is no need for antilock countermeasures, it is an elaborate coupling between the pipes in and the pipes out. When the control unit senses initial wheel lockup, the hydraulic control unit is the center of wheelspeed controls, of the selective reduction of brake force to specific wheel cylinders as needed to slow them without lockup.

From the tire footprint tests we looked at earlier, you can see the problem of achieving optimal braking even under ideal circumstances. A traditional hydraulic-mechanical brake system can only deliver two different hydraulic pressures to the calipers, one pressure for the front, a lower but directly proportional one for the rear (front-wheel-drive cars use dual-diagonal plumbing, instead, but the point is the same).

If a driver were such an accomplished master of the pedal he could hold the front brakes with just the application pressure to achieve the ideal amount of slip, say five percent, the system has him locked into a specific pressure for the rears, a pressure determined by the proportioning valve, suspension height sensor or whatever mechanism is used. That may be just the right pressure for some set of conditions, but not for others if the pavement changed or temperature went up or down or if it rained or snowed. Toss in any side-to-side variation in pavement quality, and the best our accomplished master driver could do would be to optimize braking for whichever of the four wheels had the least traction! Add to the mix even the slightest turn, and you need four different application pressures, all to come from one foot on one pedal at one master cylinder. Ain't gwine happen, Huckleberry!

All the control you have over a moving car comes from those four grooved rubber parts not moving at all, those four sections of the tiretread in momentary contact, in static friction, with the pavement. While those contact patches constantly change, they are stationary with respect to the pavement as long as you have the car under control. As long as the brake pads don't 'lock' to the turning rotors but the rolling tire treadpatch stays 'locked' to its pavement track, you're still driving. Antilock brakes serve to prevent the first lockup and maintain the second.

The earliest of the traction systems is ABS, Antilock Brakes. Beginning on Mercedes-Benz cars in 1978 following research and development dating back over 20 years earlier for railroad and aircraft landing brakes, these systems have achieved a reduction in the number of accidents caused by loss of traction during braking and a reduction in the severity of such accidents as did occur. Thousands of people worldwide may be alive who would not be had their cars not included ABS. Your work keeping the systems functional is just as important. If a day comes when a customer walks into your shop and says, "Your ABS repair worked and just in time. All of us walked away from an accident that didn't happen thanks to what you did," you'll remember that day and that customer as long as you own a wrench.

The engineering problems were actually simpler for trains and planes. Train wheels share their common axle, and locomotives corner... well, on rails or not at all. Airplanes usually make a single dead-straight stop from high speed and then stand on the tarmac until the brakes cool to ambient temperature long before the next sustained application. But cars do many other things on the road than trains or planes, so the much more complex objectives of antilock brakes have always been the following:

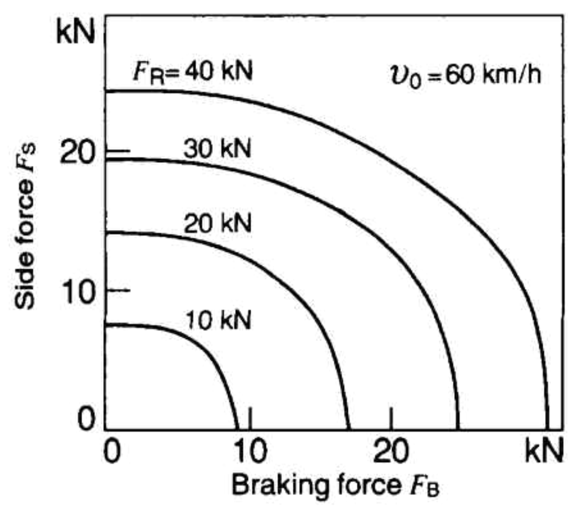
1. Directional stability (rear wheel traction),
2. Steering control (front wheel traction),
3. Braking effectiveness (all wheels).

You can't maximize each of these different objectives simultaneously. Perfect directional stability would mean you'd have to stop the car, lift one end with a floor jack and re-aim to the course you wanted to travel next. Perfect steering control might preclude brakes at the very time you want them most, and the shortest possible braking distance might leave the car wrapped sideways around a tree.

Sorting out exactly what the system would do under what circumstances – prior to designing a mechanism to do it – took a long time and sustained imagination and effort. The engineers had to think of every possible '*what-if..?*' and then translate the whole set into machined steel and microprocessor functions and hydraulics. Notice the first objectives have to do with direction and steering control; braking improvement comes only once those conditions are met.

Lateral force vs. braking force

Maximum achievable adhesion at constant wheel load.



You often hear of the 'circle-of-forces' story for a tire's traction. According to it, any given tire has a certain amount of traction, which we can quantify as the amount of force necessary to break it loose from the pavement and then visualize that force as the radius of a conceptual circle. You can, the circle-of-forces story goes, load that wheel with any combina-

tion of braking and turning forces so long as the combination of them does not add up to more than the radius of the circle of forces. This theory is a reasonably good, rough-and-ready explanation for a driver. Actually, however, a tire can conduct maximum acceleration and braking forces about 15 to 25 percent greater than the maximum cornering forces, because the treadpatch doesn't squirm of twist as much stressed parallel to the vehicle's centerline. The circle of forces is more of an ellipse, with the long axis in the direction of travel. The shape of the 'ellipse of forces' also depends on the tire's aspect ratio and the sidewall stiffness.

Let's consider a single braked wheel. For the moment, we'll pay no attention to the rest of the vehicle or the other wheels and brakes, just our one specimen wheel and brake. How can a system prevent that wheel from locking up? For a given wheel and tire and a given pavement, there is a maximum static friction corresponding to the weight. It's not a one-to-one relation, but it is close to linear. The best estimates are that an ideal rubber-tread tire against an ideal concrete pavement can yield a maximum of about 1.6-G's deceleration force. No car can actually stop with that power and control, though some can come close. A car that could really achieve and hold that maximum grip on all its wheels simultaneously could, in theory, stop from a speed of 60 mph in about 1.7 seconds and just under 80 feet. That's a juddering, hard deceleration: You might need a wire hook to fish your sunglasses out of the defroster duct.

But you can't just extend the same system to all four brakes, because the interworking of the brakes can have adverse effects on directional and steering control. If under extreme braking force one wheel slipped even a little, its tirepatch would lose all the static friction, and the car would spin out of control. In principle, the brakes could stop a wheel much faster than that 1.6-G rate because of their enormous overcapacity to turn the vehicle's kinetic energy into the random kinetic energy of heat, dissipated rapidly into the air.

The limitation on the vehicle's stopping capacity is not the gripping power of the brake pads against the rotors, but the friction between the tire tread and the pavement. If the vehicle were rigidly connected to the road, as if on a cogwheel railroad, it could stop much more quickly than 1.6 G's, perhaps drilling your sunglasses through the windshield. But at least on cars, there are no such rigid connections from tire to road, so we want variable sliding ('dynamic') friction between the brake rotors and pads but static friction between the treadpatch and the pavement. Then we can vary braking with brake pedal force, as much as is compatible with the available tire-to-road friction.

So you can encode in the antilock control unit information about the maximum speed at which the wheel can slow, translated into changes in wheelspeed sensor pulses per millisecond over a (very short) time. The control unit has an internal clock to detect the interval increase between the sensor pulses, as well as read-only (hardwired) data corresponding to the maximum possible deceleration. The control unit monitors the time of the interval between wheelspeed sensor pulses. It checks against its memory for the maximum allowable increase; if that internal change occurs or is exceeded, the wheel is locking up, so the control unit adopts countermeasures. If that interval change between wheelspeed sensor signals is exceeded, the wheel must have lost its traction against the pavement. Maximum braking force occurs when there is about a 5 percent slip relative to the pavement. Notice this does not mean that all of the treadpatch is slipping by 5 percent, but that 5 percent of the patch is slipping – quite a different thing.

Even then, there are sometimes reasons to reduce the available brake pressure below the maximum possible and to focus more on directional stability and steering control. If you're driving on black ice with the right wheels and dry pavement under the left, you don't want the left front brake to apply with so much decelerative force that the car pivots and spins left, sliding sideways into more black ice. We'll see later how the early ABS systems were devised in such a way that the rear wheels sustained only such braking as was compatible with retaining traction on the wheel with less grip on the road.

ABS Functional Strategies

If the wheelspeed sensor signal indicates incipient wheel lockup, the control unit first triggers the hydraulic unit to close the valve to that caliper, retaining the existing pressure but not allowing the increasing pressure from the master cylinder to increase the pressure to that specific circuit. The other brake circuits can still accept higher pressure, but not the one threatening lockup. If that measure corrects the lockup, no further steps occur, and the system shortly thereafter allows pressure to increase with the others, sensor signals allowing.

If holding steady pressure doesn't correct lockup, the control unit switches the valve in the control unit and reduces hydraulic pressure. Once wheelspeed resumes, the control unit then opens the valve and returns pressure from the accumulator to the master cylinder. The electric pump maintains pressure in the accumulator independently of any brake actuation.

In early ABS-only systems, pressure to a caliper can never exceed pressure in the master cylinder. The entire process repeats rapidly to coordinate the driver's braking intentions (as evidenced by pedal use) and the deceleration possible under the available traction circumstances. If problems are evident, there are separate relays (besides the overvoltage protection relay) for the hydraulic unit's solenoids and for its pressure pump.

All ABS systems have separate wheelspeed sensors for each of the front wheels, mounted in the steering knuckles. You can follow the harnesses back along the suspension members and up toward the control unit.

Early ABS-only systems used a single wheelspeed sensor in the differential case, directly measuring the pinion shaft speed rather than that of the wheels. The control unit's programming correlated the signal ratios together. Since the rear brakes are pressure-modulated together, there was only need for the one speed sensor. This means, of course, that braking force is limited to the traction available at the wheel with less traction. Whichever one started to lock up, the system reduced hydraulic pressure to both until both turned at the same speed.

This initially seems odd, since that implies the system sacrifices some braking force. In fact, that's exactly what it does. Recall that minimizing braking distance is the third of three objectives for ABS. Retention of directional stability is the first. You keep directional stability by retaining antisideslip traction at both rear wheels, whatever the other conditions. The system is working as planned when it cycles the rear brakes together.

Later systems (ASR, ASD and ESP) use separate rear wheelspeed sensors because they also control engine output and/or actuate differential locks or individual brakes to retain traction and directional control.

The complications in an automotive application arise from the complications of driving on real-world roads: variable quality of pavement, curves, bumps, variability of tire inflation. That's not all. If someone has put different tires on one axle, perhaps snow tires, or a low-inflation spare anywhere, you can lose ABS altogether as the control unit toggles it off. Different tires, with different rolling diameters that is, can mean the control unit will calculate from the different wheelspeed signals that something is amiss and toggles the ABS system off.

Got a problem with an otherwise insoluble ABS-light problem? Check that the car has the same tires on each axle. Snow tires on the drivewheels can make enough of a diameter-difference to trigger a wheelspeed sensor fault when there's nothing wrong with the sensor. Check for correct and consistent inflation pressure at all tires, too. Any significant variation can produce enough of a difference in wheelspeed sensor signals that the control unit turns the light on and the system off. If you find an electrical problem on an ABS system, but resistance is within specs and the signal looks normal, check the relays connected to the circuit, not only the overvoltage protection relay, but also the pump and solenoid relays on the hydraulic unit. If you do enough Benz work, it is probably an economy to get a code-reader that can access the ABS data. This is not, in general, part of OBD II.

The wheelspeed sensors are electromagnetic pickups, just like ignition pickups at a flywheel or in a distributor. But unlike ignition pickups, they operate in much harsher surroundings, not so much from heat as from dirt, grit, water and sudden temperature changes (water splash, for instance). Electricity and magnetism, of course, are immune from these distractions, but the devices that generate and conduct them are not.

The most frequent problems with ABS systems result from damage to the wheelspeed sensor or its harness, not surprising considering their location. You can check for continuity through the sensor by tracing the harness up to the first connector and measuring back from that point. A sensor with an intact inductive coil, however, could still have a

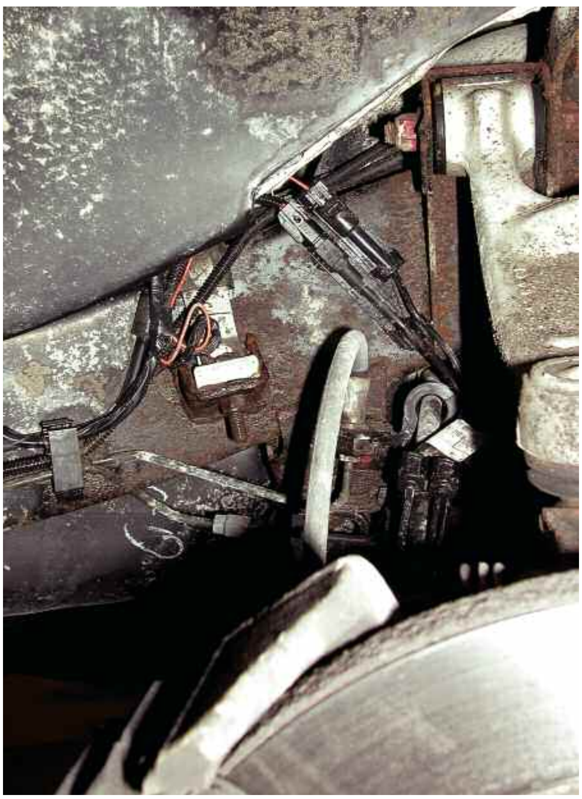
cracked magnet or a damaged toothed wheel, so the most reliable test is an a/c voltage measurement with the wheel spun by hand. This works on differential-mounted sensors, too, if you put the transmission in neutral and turn the driveshaft.

Some differential sensors come in pairs on the output side. In such arrangements, naturally, you should test each sensor separately. All the static and dynamic tests in the world are irrelevant, of course, if the signal doesn't get all the way back to the control unit or if the control unit can't recognize it as the genuine item.

Sensor Signal Troubles

Among road-dirt particles are many ferrous metallic chunks, some of products of earlier brake applications, from this car or from one that passed along the road earlier, some of them just miscellaneous circumambient industrial microrubble. These magnetic particles, if they find their way to the tips of the sensor magnet or get jammed between the teeth of the sensor ('tone') wheel, can even falsify the signal. Suppose, for instance, there is a relatively large iron chunk bridging the gap between two sensor wheel teeth. The sensor will report the fluctuating magnetic field as voltage oscillations in accordance with that, and the control unit will construe the signal as a very rapid deceleration of that wheel. After all, there was double the period between its peaks and the previous/subsequent signals. Depending on the system and the circumstances, this may trigger either antilock countermeasures, or trigger a failure code and toggle the system back to normal non-ABS hydraulic brakes. While this is hardly catastrophic, neither is it desirable. If it happens under conditions of reduced traction like rain, snow or black ice, it could be dangerous.

Wheelspeed sensors in the differential housing are not immune from this, although they have a calmer time of it kinetically. It is possible for metal particles to flake off gears, bearings or castings and slosh around in the differential oil. Better they stick to the wheelspeed sensor magnet, triggering the ABS light and summoning repair, than float around the differential finding something worse to lodge in.



An interesting puzzle comes with the development of the 'tone wheel,' originally the toothed wheel or signal rotor on the brake disk hub/differential pinion or output shafts that, with the magnetic pickup sensor provided the wheelspeed data, the basic information used by the various component control units for ABS, ASD, ASR and so on. On early systems, these sensor components were on the hubs or shafts. Some of the later versions, I'm told (though haven't seen), use wires embedded in the hub's grease seal! Of course, all you need to trigger the sensor signal is a continuous alternation of fluctuations to oscillate the magnetic field around the sensor as the wheel or shaft rotates beneath it, and a continuous waved steel wire can do that. I wonder how long it would take someone to realize the reason the ABS light is on after his wheelbearing work was the 'bargain' grease seal (with no internal wheelspeed sensor signal sender wire) he got to save the cost of the 'expensive' Mercedes-Benz version!

You'll commonly find small particles of metal clinging pointlike to the inboard surface of the wheelspeed sensors. This occurs because they surround a magnet and operate in an environment that tosses a lot of road grit and debris their way, including some of these ferrous pieces. They are both harmless and unavoidable on the insulation side of the sensor.

Iron particles at the inside of the sensor, the pickup points, or particles stuck between the teeth of the toothed rotor are a different story. At the sensor tip, such a particle can distort the magnetic field so the sensor can't generate a recognizable signal. Between the teeth, a ferrous particle could make those two teeth look like a single one, just what you'd see during wheel lockup, fooling the control unit into adopting ABS countermeasures or toggling the system off and lighting the ABS lamp.

It used to be easier to inspect the toothed rotors than it is now. The reason it's harder now is that it was also easier for such particles to find their way between the teeth. Burying the rotor out of easy sight also buries it out of easy metallic contamination.

The signal from the toothed wheel need not be exactly the same as that of every other wheel. After all, under many driving conditions each wheel turns at a different speed. The question is only whether the wheels move at different speeds compatible with the turn the car is in. Later systems employ information from a steering wheel position sensor to calculate the intended radius of the turn and thus the range of allowable wheelspeed difference. But as mentioned earlier, different diameter tires can flag a false sensor fault.

Bleeding techniques are the same for a vehicle with ABS as without, though the importance of flushing the brake fluid with new regularly is more important when there are components as expensive as the hydraulic unit in the circuit. If air gets into the system, it may be necessary to flush the system repeatedly or even operate the vehicle under conditions that will trigger the ABS to clear all the air out of the system.

The overvoltage protection relay can prevent the ABS system from working if it has failed itself. Similarly, if the charging system can't reach a threshold voltage (about 11 volts), the ABS system won't turn on. It would be very frustrating to spend very much time doing electrical diagnosis of the ABS system before discovering the alternator wasn't putting out enough power.

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Crown Automobile
205-985-4200

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Regal Auto Plaza
256-837-5752

Mobile
McConnell Automotive
251-472-3187

Montgomery
Jack Ingram Motors
334-277-5700

Tuscaloosa
Leigh Automotive
205-556-1111

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Mercedes-Benz of Anchorage
907-277-3383

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A & B Auto
907-459-7070

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Chandler
Mercedes-Benz of Chandler
480-403-3444

Phoenix
Phoenix Motor
602-264-4791

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Schumacher European
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Tucson
Mercedes-Benz of Tucson
520-886-1311

Arkansas

Fayetteville
Jones Motorcars
479-521-7281

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Riverside Motors
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Caliber Motors
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Rusnak/Arcadia
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Autobahn Motors
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House of Imports
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Calabasas Motorcars
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Carlsbad
Hoehn Motors
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Chico
Courtesy Motors Auto Center
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Encino
Auto Stiegler
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Escondido
Mercedes-Benz of Escondido
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Fremont
Claridge's
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Mercedes-Benz of Fresno
559-438-0300

Glendale
Calstar Motors
818-246-1800

Laguna Niguel
Mercedes-Benz of Laguna Niguel
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La Jolla
Heinz Gietz Autohaus
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Long Beach
Mercedes-Benz of Long Beach
562-988-8300

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Downtown L.A. Motors
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Modesto
Modesto European
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Mercedes-Benz of Monterey
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Fletcher Jones Motor Cars
949-718-3000

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Mercedes-Benz of Palm Springs
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Park Avenue Motors
650-494-0311

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Rusnak Pasadena
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Mercedes-Benz of Pleasanton
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Walter's
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Mercedes-Benz of Sacramento
916-924-8000

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415-673-2000

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San Jose
Smythe European
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San Rafael
R.A.B. Motors
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Cutter Motors
805-682-2000

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Smothers European
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Berberian European Motors
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Silver Star A.G.
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Colorado Springs
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Mercedes-Benz of Fairfield
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Carriage House of New London
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Bill Ussery Motors
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Coggin Motor Mall
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Prestige Motors
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Precision Cars of AtlanticCity
877-5MB-PARTS

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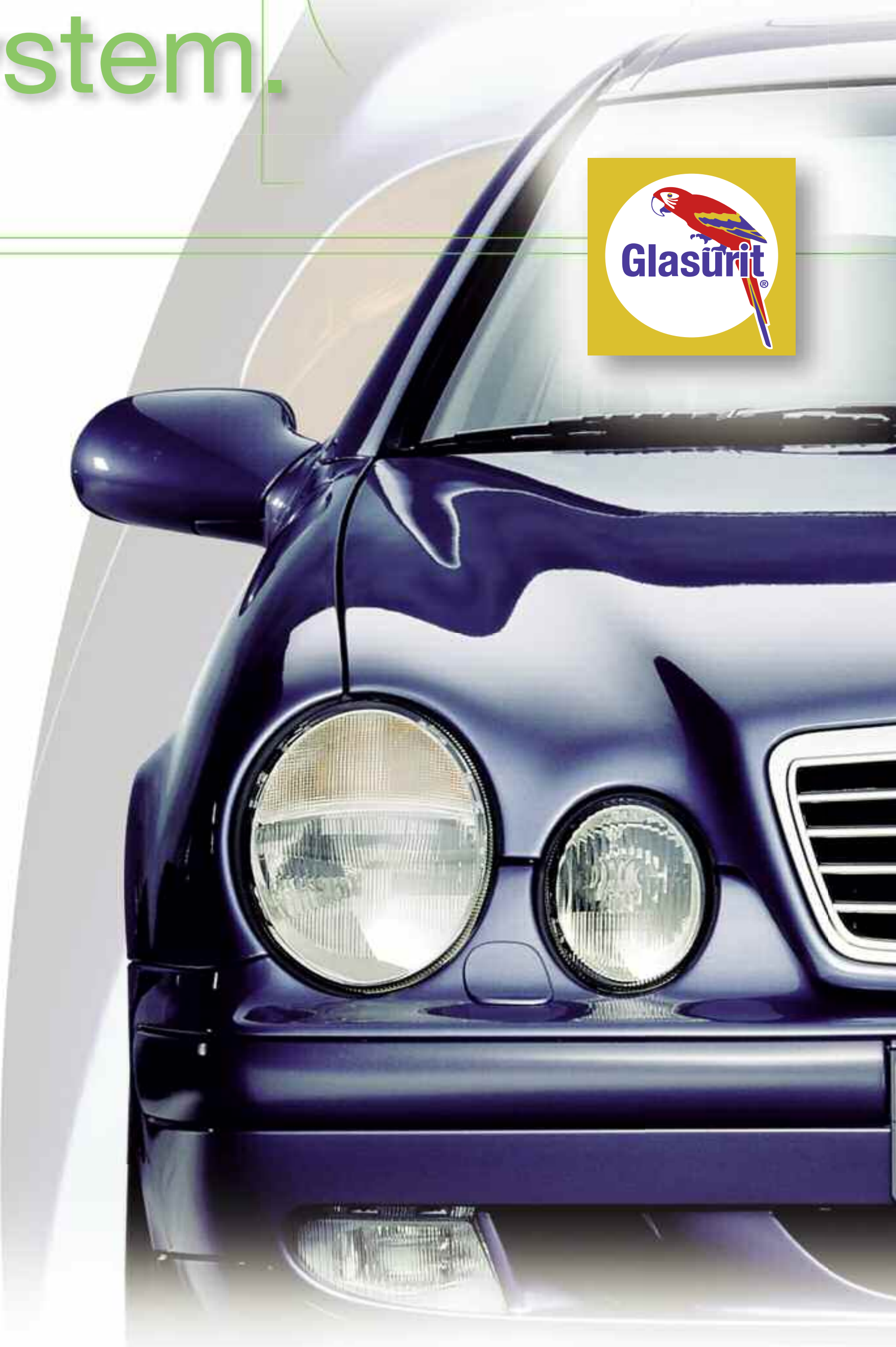

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