StarTuned®

Information for the Independent Mercedes-Benz Service Professional

March 2004 U.S. $6.00 € 12.50

Realworld Puzzles

ESP: Actuators & Diagnosis

Volume 4 Number 1

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 helpful and informative, 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:

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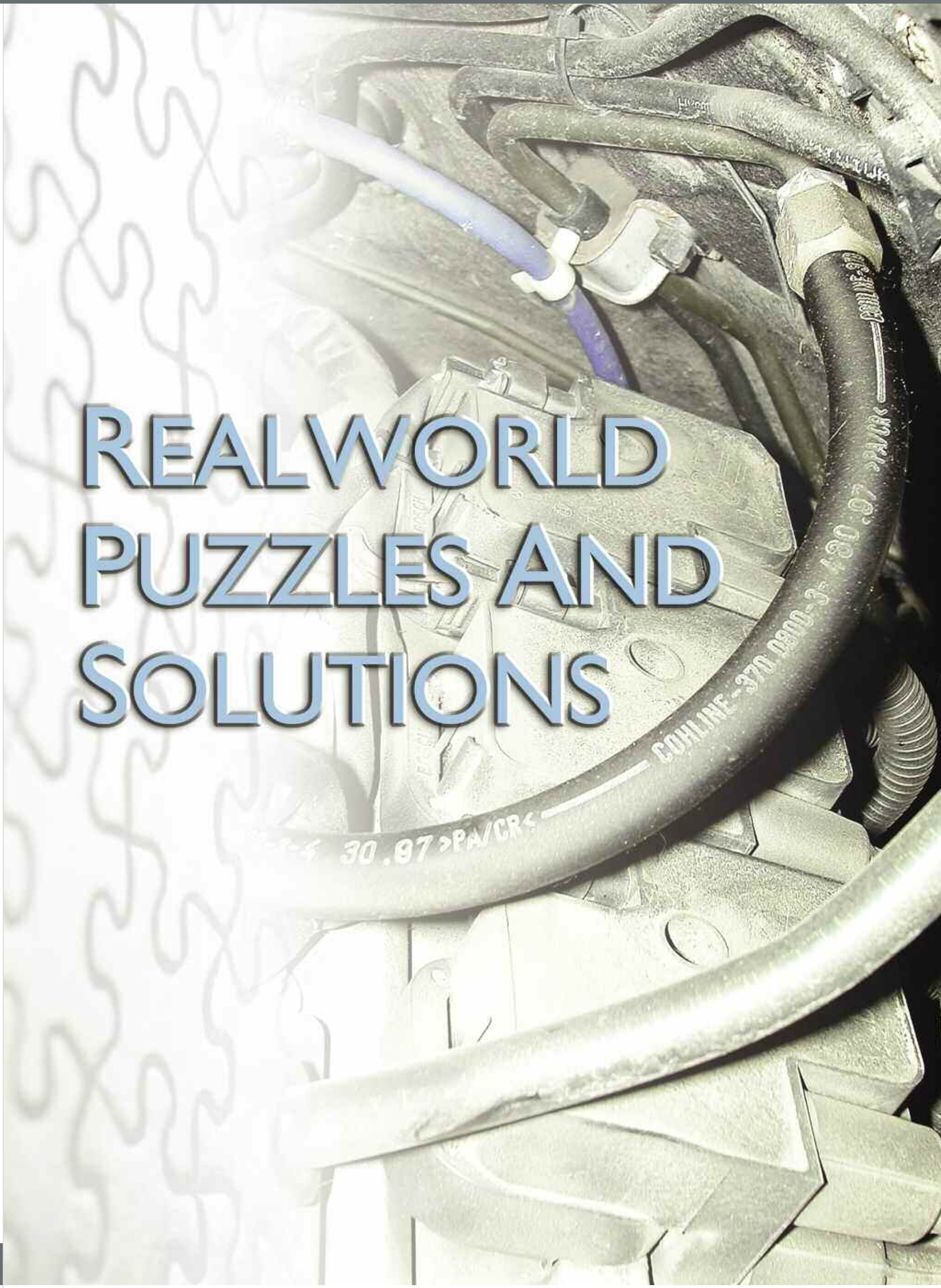
Realworld Puzzles And Solutions



...When Things **Aren't** So Simple

Though it's interesting to learn the intricacies of the most complex systems on vehicles, such as the various Mercedes-Benz traction control series we have covered now for well over a year, workbay work consists of solving gritty, realworld problems, not all of them conceptually 7. Often there is more than a single problem on a car; often there is the residue of previous repairs, not all expertly done. Beyond that, car owners sometimes skip routine maintenance, don't notice a problem or seem to wait for it to self-heal.

So every once in a while (this being one of those once's) we need to review cars repaired in shops we know or have heard about, shops without a full set of replacement parts on hand for ready SWAG test shops without every available special tool, shops working under the multiple pressures of time, money and other work that also has to be done. Repair shops in the real world.

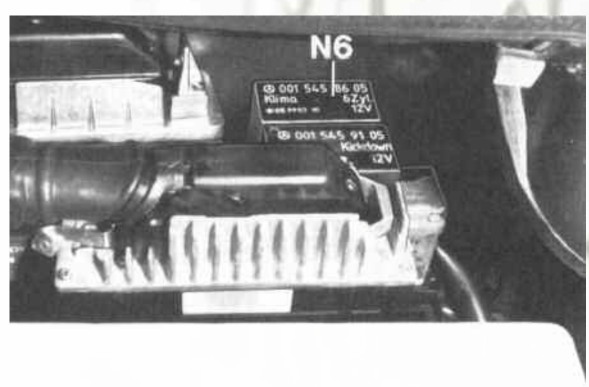
These problems and solutions aren't in any defined order, because the cars coming into your workbay don't bring their problems and require their solutions in any defined order. Some of the problems could potentially have arisen from other causes; sometimes a shop is just lucky and sometimes not.

OK, let's get to work!

The motorist called with a problem: Her spotlessly maintained 20-year-old Benz was suddenly very hard to steer, and there was oil leaking from somewhere near the front of the engine. Surmising the power steering pressure hose might have cracked, the shop foreman asked her, "Is there any oil on the exhaust manifold?" "What's an exhaust manifold?" was the answer.

To avoid the risk of smoke and fire if there were oil on the pipe, he towed the car in, to find his telephone diagnosis was exactly correct. It was a simple matter to replace the hose and bleed the system, and a somewhat less simple matter to clean up all the oil to the original state. But it wouldn't have done to leave a single drop to fall on her garage floor. Quite a few cans of engine cleaner and shop towels later, the car was ready.

Or so they thought. A day or so later the motorist called back. Her air conditioning was suddenly blowing hot air, and 'all the dash lights were flashing on and off.' With the car back in the shop, they set to work on the various problems. Perhaps oil might have gotten into the alternator and somehow contaminated the brushes? Hard to imagine it could have soaked something on the other side of the engine that much. The A/C compressor is sealed tight, but it's right under the PS pump, so maybe the oil got onto the magnetic clutch? Jumpering the clutch, however, kept it connected and the duct air cold. And what about all those warning lights? After much cleaning and probing, the answer became clear.



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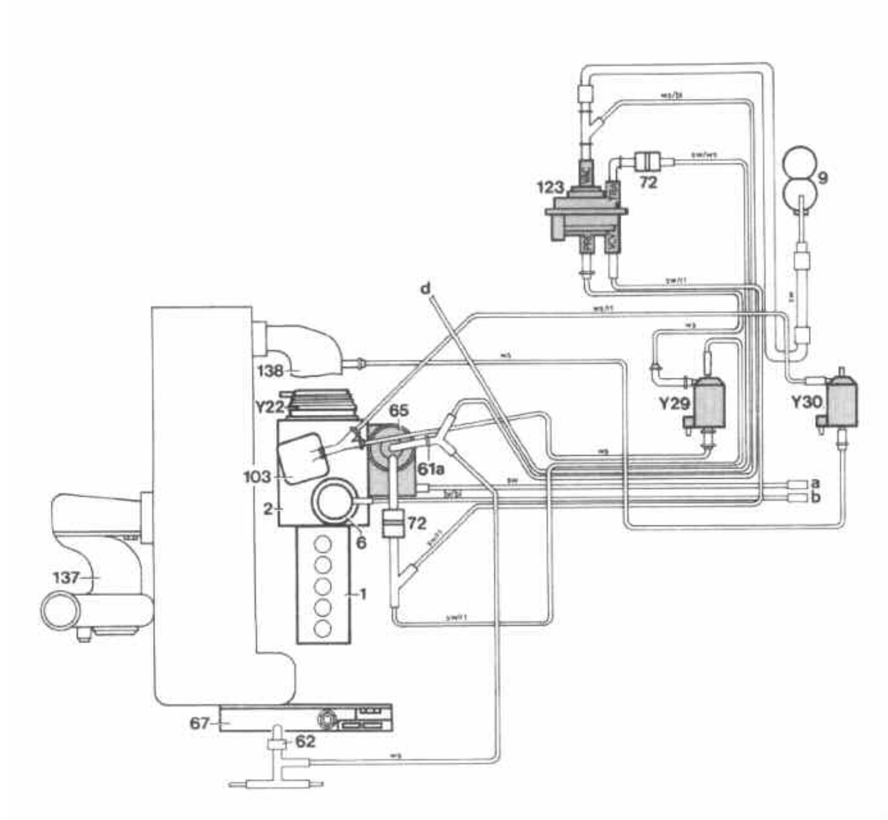
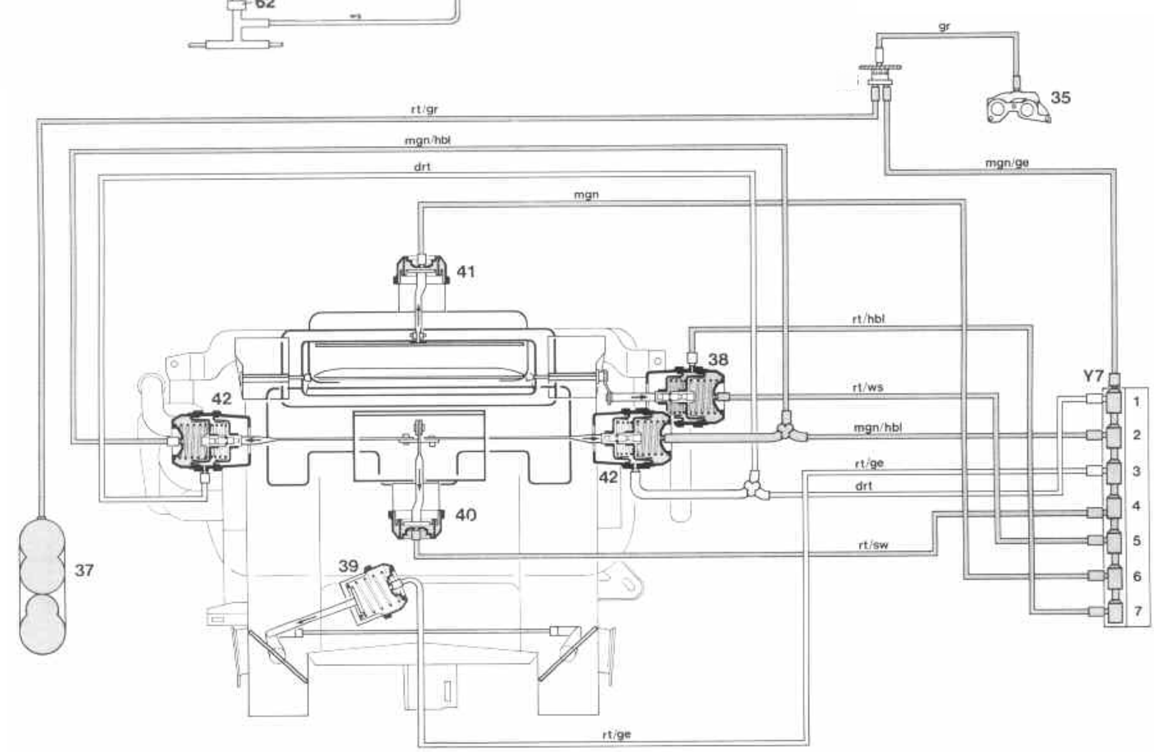
Remember the Klima relay? On later model cars its function falls within the MAS control unit, but the system works the same way. On the back of the A/C compressor is an rpm sensor. The signal goes to the Klima relay, which compares it to the crankshaft speed. If the speeds are not within the correct ratio, the system disables the A/C clutch until the next engine start.

The cause of all the problems was residual oil deep in the grooves and back of the serpentine belt, allowing it to slip on the clutch and on the alternator. When the system voltage fell low, on came the warning lights.





Diesel Defrost

The early 1980's 300D ran fine, but there was no change in the ventilation air when the driver selected among the various options. Mercedes-Benz ventilation systems toggle to defrost whenever there is a serious problem with the vent-select mechanism. This keeps the inside windshield clear whatever the malfunction might be.

Anytime a Diesel-engined car has a problem with its cabin-ventilation system, your first suspicions should track the vacuum pump. Vacuum problems can also affect the operation of the EGR system on cars so equipped. A Diesel does not produce vacuum inherently, as gasoline-fueled engines do, because it uses no throttle, varying the fuel delivery directly to vary output torque. But since most cars use gasoline-fueled, spark ignition engines with their ready and inexhaustible source of vacuum, Diesels need a vacuum pump to work the various blend doors, lock mechanisms and so on. It just wouldn't be a reasonable manufacturing economy to invent a separate system for the oil burners.

Vacuum pumps are generally reliable and long-lived components, but eventually they do wear out, requiring replacement or rebuilding. And even when they work properly, there is no possibility they can generate so much vacuum as a gasoline engine naturally does. You've no doubt run across gasoline-engined cars that lose heat whenever the driver pushes the gas pedal toward the floor, to accelerate, to pass or to climb a hill. It isn't that the engine doesn't generate heat, of course. If anything, under high-torque conditions the engine generates more heat. But since high load means little or no vacuum, the blend doors can lapse to their spring-loaded rest position, defrost.

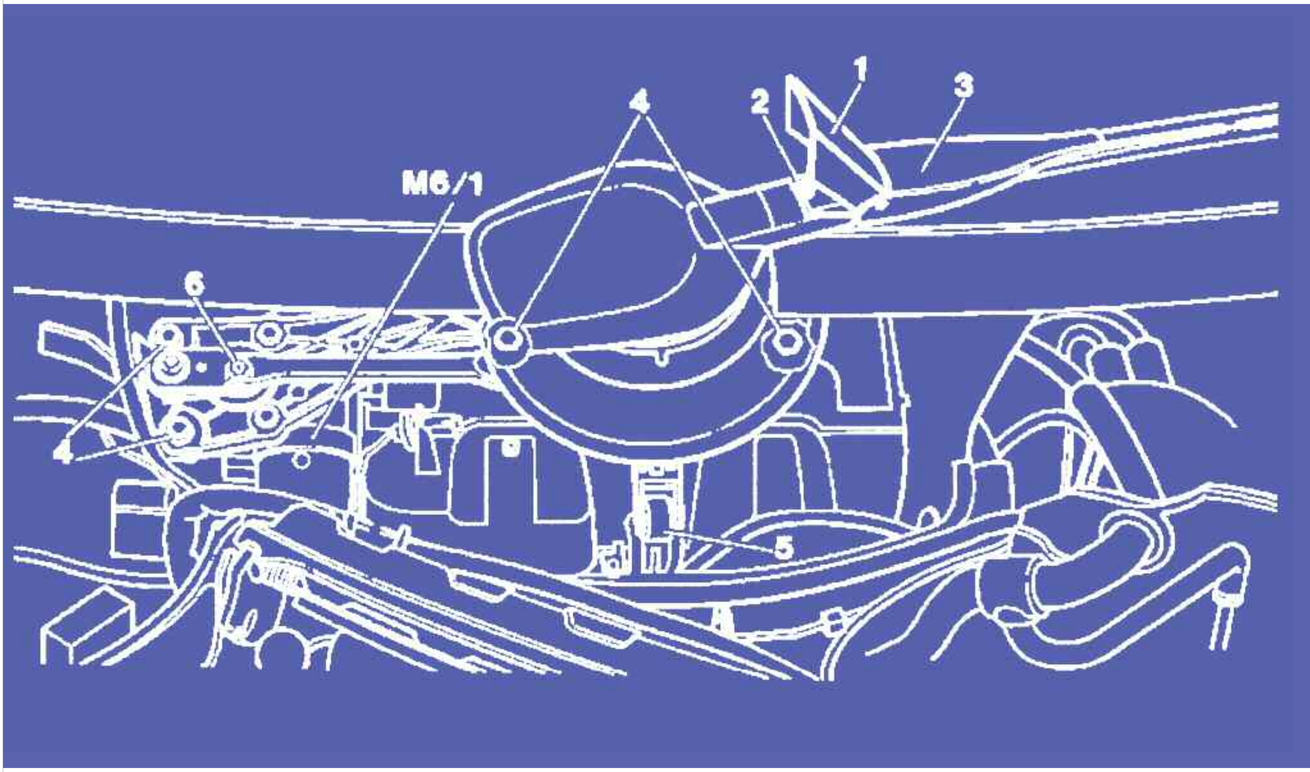
The vacuum pump on a Diesel engine produces vacuum by engine rpm, so hill climbs and acceleration ramps are not the same problem. But since the vacuum pump makes so much less vacuum (an odd concept, when you think of it, more or less vacuum), a leak of any kind will affect the system disproportionately more. A vacuum motor with a pinhole in its diaphragm lets its blend door pivot open or closed when enough air leaks into the vacuum chamber.

The vacuum pump is the first of the usual suspects to round up, but it may not be the guilty party if there is insufficient vacuum somewhere. Fortunately, you can isolate different sections of the vacuum system to draw a hand vacuum and measure how well that section holds. Don't neglect the vacuum reservoir, that plastic box on some cars that looks like it was made for holding tennis balls. Don't neglect the vacuum lines themselves. They are just as susceptible to cracks, porosity and acid damage (from a leaking or overfilled battery) as is the electrical harness. Rather than taking the dashboard apart to check the vacuum motors individually, get a vacuum diagram and draw vacuum on the different sub-branches, using the selector buttons for your test. If you find one vacuum motor that is not intact, it's usually a good economy to replace the set since they're all the same age.

Blasted Blower

If you feel a little daunted when a climate-control problem comes in, don't feel alone. The system is quite complex to achieve the levels of flexibility and convenience to the motorist. But when you find one with no blower action, the temptation is to start checking voltages at the climate control head or the blower motor harness, hoping to find a clue in the pattern.

But first, don't overlook the obvious. Most Mercedes-Benz models have a separate, high-amp fuse for the blower. Some like this one are adjacent to the spring coil tower, but check your wiring diagram and parts locator for the simple solution first.

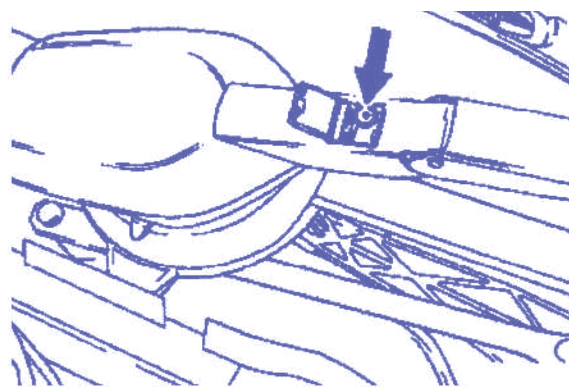


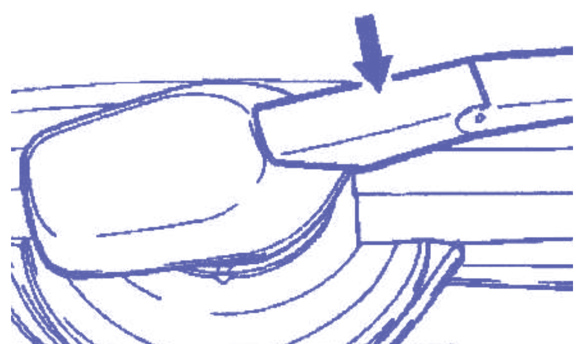
Wound-up Wiper

On all the Benz models with the unique, single arm windshield wiper system, you can see that it can be necessary to build something complex to achieve something simple. One wiper arm is simpler than two, but to make it cover the windshield properly, the arm requires a relatively complex set of geared eccentrics to pulse it radially inward and outward as it cycles.

Sometimes, this single arm wiper can develop a hesitation related to its radial motion. Perhaps this comes with age, perhaps from road salt or atmospheric grit, perhaps more frequently in areas with more rain. In any case, it is often possible to disassemble the mechanism and relubricate each of the pivot joints with a suitable, water-resistant grease. Before you work on the wiper system, be sure the ignition key is removed from the car, preferably safely in your pocket so you can be sure nobody can switch it on. The system can move to the Park position as the key toggles, regardless of the wiper switch position. There's enough torque in the wiper arm, particularly close to the shaft, to cause hand injury.

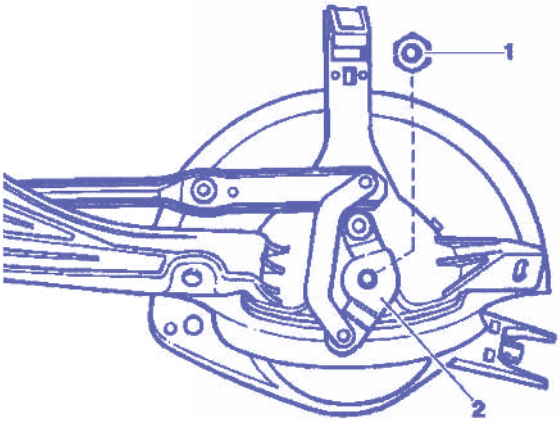
The wiper arm comes off in two ways, as indicated, depending on the car's vintage. Once up or down, as the case may be, with the arm fully extended unbolt the setscrew holding it. You can then lift off the arm

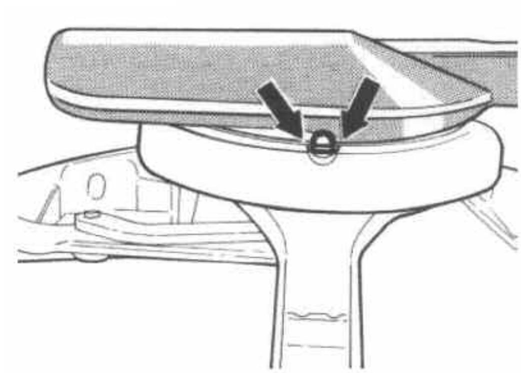




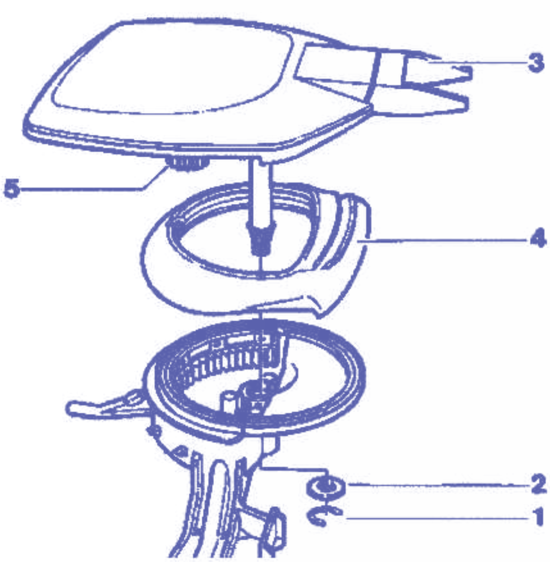
itself, leaving the actuator head. As you disassemble the internal components, keep track of how they combine, because while there is more than one possible configuration of parts, only one configuration can work.

Turn the wiper hub to the vertical position and remove the attachment nuts and retaining clip. As you lift the system out, disconnect the electric connector. If you're replacing the wiper motor, be sure to reconnect the electric harness and turn on the ignition key to confirm the shaft is in the Park position before you reassemble the mechanical links.





To remove the linkage from the motor, remove the nut. When reassembling the head, observe the 'timing marks' on the gearhead.



The wiper gear comes apart first by removing the snap ring and washer at the bottom. You can only take this off and apart with the arm in the center position. Don't try to remove it with a hammer or with the forceful use of a puller. It's good workmanship to replace the rubber seal once you've cleaned the gears and lubricated the works with a proper lubricant. The seal is held on with a clamp similar to those on CV joint boots. Reassemble everything with the mechanism in its center position to get the parts meshed properly.

Meandering Miss

This puzzle arose on a late-model E320, but as you'll see, it could have cropped up on almost any 'mature' car but the Diesels. A vague and transient cylinder miss seemed to move from one or more cylinder to others at all speeds above idle. Spark tested good; the injectors all got the same pulsewidth for the conditions. The shop dove in deeper and ran a compression test on the engine, with good results in every cylinder.

Since the CEL was on, they read the codes, which suggested the catalytic converter was dead: the oxygen sensors in front and in back read the same. Checking the voltage at the sensor harnesses confirmed this. They cycled up and down together reflecting no change as the exhaust passed through the converter. But how could a catalytic converter cause a wandering miss, unless it was so plugged up the engine couldn't run (and then they'd have heard the characteristic plugged-cat roar from the exhaust).

Complicated problems often arise from non-obvious simple causes. Spark plug cables have a certain electrical resistance built into them, to prevent radio interference and to insure a high enough voltage for the spark. With age, heat, use and so on, this resistance always goes up. Sometimes the cables develop electric leaks through the insulation, a malady you can detect immediately with a mist of water applied to the ignition secondary with the engine running in a dark place.

Worn spark plug wires don't necessarily look worn – they aren't the moving parts. Inside, the electrons can eventually start finding new paths to ground or burning the cables internally open enough to drive up the coil output to a threshold sufficient for idle, but not for any other engine load.

High Idle

Any engine can idle too fast, and the causes can be multiple, subtle and not obvious. Air leaks can develop in the idle circuits or even around the sides of the fuel injectors themselves. Some enginemanagement systems hold the engine speed elevated when the engine is cold, so a nonfunctional coolant temperature sensor can make the engine idle too fast even if everything else works properly. Some older cars use a separate idle speed control module, usually mounted on the firewall.

There are enough different possibilities that you need relatively complete knowledge of the particular system on the particular car, as well as a good sense of the other systems that can affect it.

Startlessness and Sparklessness

Coils, both waste-spark and conventional, can be very elusive and mysterious. It is easy enough for most coils (though not all!) to check the resistance of the primary and secondary circuits. Some include anti-voltage surge diodes to prevent damage to control units, but most are simply many windings of very small wires around a small, iron core.

But a coil can show exactly the right static resistances under the minuscule load of an Ohmmeter but fail entirely or intermittently under the rigors of running load. The most strenuous test, of course, is under full-load acceleration, when the voltage required to bridge the electrodes of the spark plugs can go to three or four times as high as at idle.

Only a dynamic test of a coil, a test that requires it to generate a normal, high-load spark can tell you whether it is working properly. The best way to conduct such a test is with an oscilloscope that allows you to see the shape of the primary and secondary voltage traces. On some systems where this is very difficult without dedicated special tools, it may be the best economy to keep a known-good spare coil on hand.

Lit ABS Light, Pulsing Brake Pedal

The basis of all the traction-control systems, from ABS to ESP and onward, rests on the signals from the wheelspeed sensors. While these are very robust collectors of information and generally entirely reliable, wheelspeed sensors work in some of the most challenging circumstances possible for electrical devices – bolted into the steering knuckles and wheel carriers of the car, bouncing over every bump and rut without benefit of suspension or dampers, directly contacting all the water, grit, road salt and miscellaneous abrasions of the roadway.

While it is possible for wheelspeed sensors to fail if their circuit is broken open by these various perils, more often they give rise to puzzles because the signal they generate at lower speeds migrates to lower and lower voltage levels. You don't need much in the way of A/C voltage for the control unit to track what the wheel is doing, but there is a bottom threshold. Even more, the slower the wheel turns, the less energetically the sprocket teeth pulse the magnetic field of the sensor because of the basic physics of electromagnets.

The systems make adaptations insofar as possible to accommodate signal range variations, but the first symptoms you're likely to see of a decline in the recognition of the signal are pulsing at the brake pedal as the ABS pump cycles on and off and/or illumination of the ABS dash light. At that point, get out your voltmeter, set it to A/C and connect it to the sensor cables.

Loss of Power Without Codes OR Codes Without Loss of Power

Mass-airflow sensors are unusual among engine management sensors in that there is seldom anything for the control unit to measure them against, a test for implausible signals. Keep in mind how the sensor works: it generates a signal corresponding to the current required to keep its sensor wire or film at a certain temperature above the incoming air. Not only temperature, but also altitude and humidity can change that signal output. And not only those

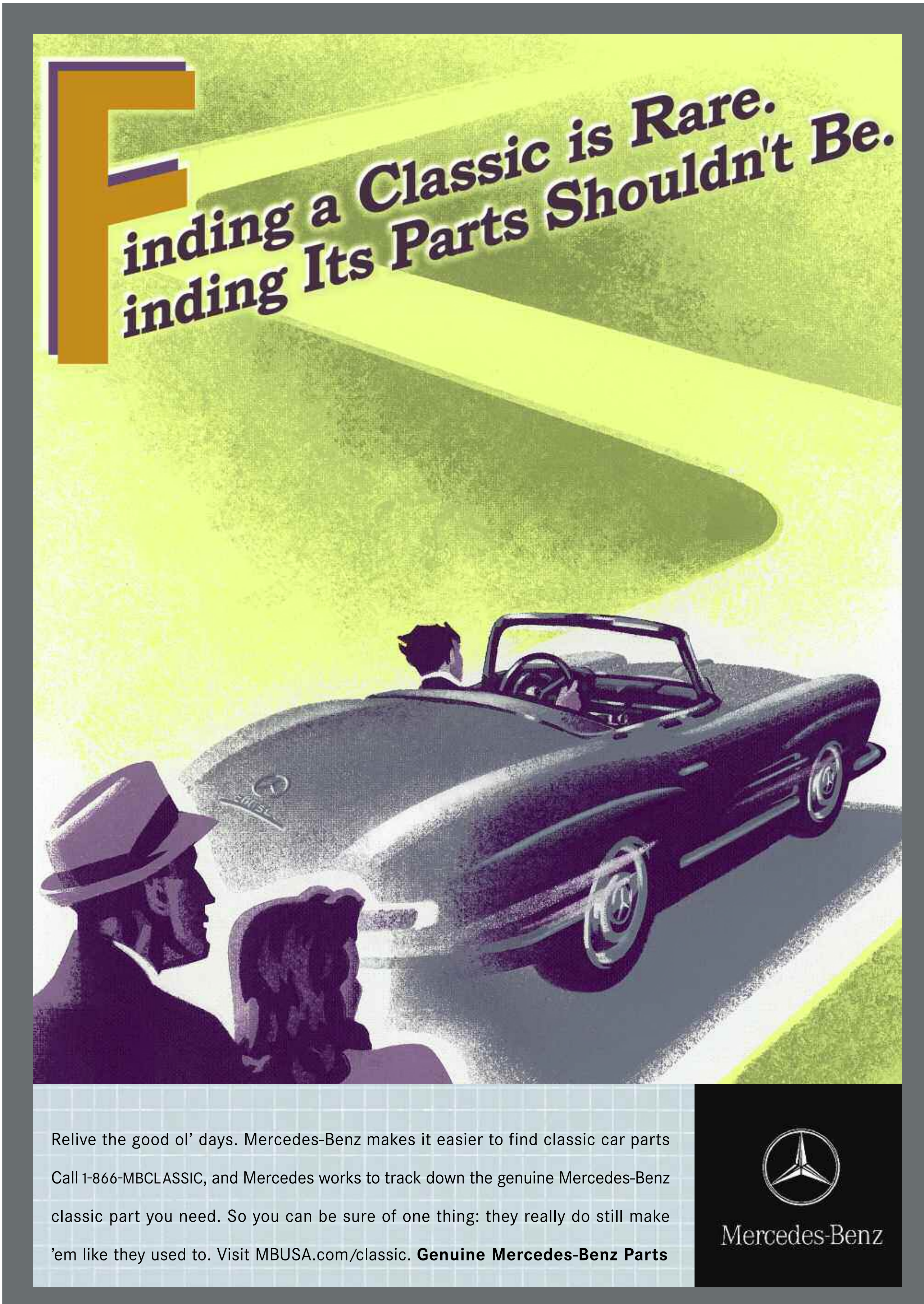
atmospheric factors, but also such things as fuel contamination, bits of air filter paper, dust that somehow got around the filter element can all blanket part of the sensor, falsifying its report. Even more seriously, 'false air' leaking into the intake manifold downstream from the MAF, drives the intake mixture lean.

The computer can make certain corrections for these signal distortions, based on other information from various temperature sensors, the TPS and the oxygen sensor feedback signal, but beyond a certain point, what you'll find is a mixture going beyond the capacity of the fuel trim to correct

No Spark, No Fuel, No Start Or Intermittent Dead-on-the-Road

Not much will happen in an engine without fuel or spark, and a running engine that loses it will grow still very quickly. The most frequent source of these problems seems to arise from a combination of ordinary operating heat with a crankshaft position sensor that has passed its electrical maturity or an EZL module in a similar state.

You test the sensor just like a wheelspeed sensor, checking for an A/C pulse corresponding to the flywheel teeth passing beneath its pickup. No signal from the sensor means no start, loss of signal means immediate shutdown. A sensor with a signal of very low A/C voltage amplitude (a natural consequence of time and use) can produce a signal intermittently sufficient or not. Allowing the sensor or module to cool often allows them to return to normal function temporarily as the internal electrical resistance goes down.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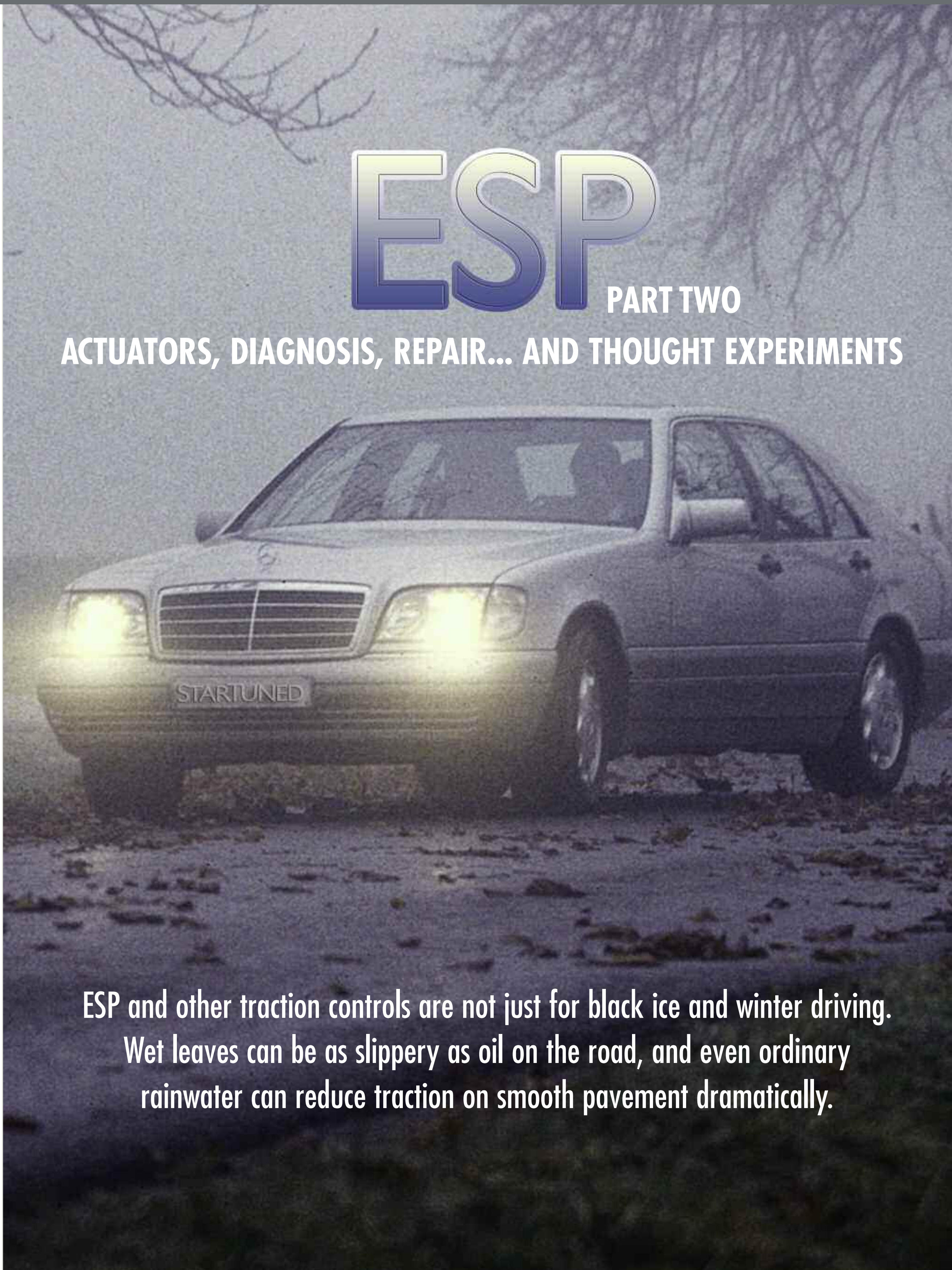
ESP PART TWO

ACTUATORS, DIAGNOSIS, REPAIR... AND THOUGHT EXPERIMENTS



ESP and other traction controls are not just for black ice and winter driving. Wet leaves can be as slippery as oil on the road, and even ordinary rainwater can reduce traction on smooth pavement dramatically.

In the last issue of *StarTuned*, we described how the Mercedes-Benz ESP system works and how its various sensors provide information for the electrical and hydraulic control units. This issue, let's shift to the components that do the traction control work, how to isolate and solve any problems that come up and conduct a few thought-experiments that can be useful both for diagnosis and for understanding.

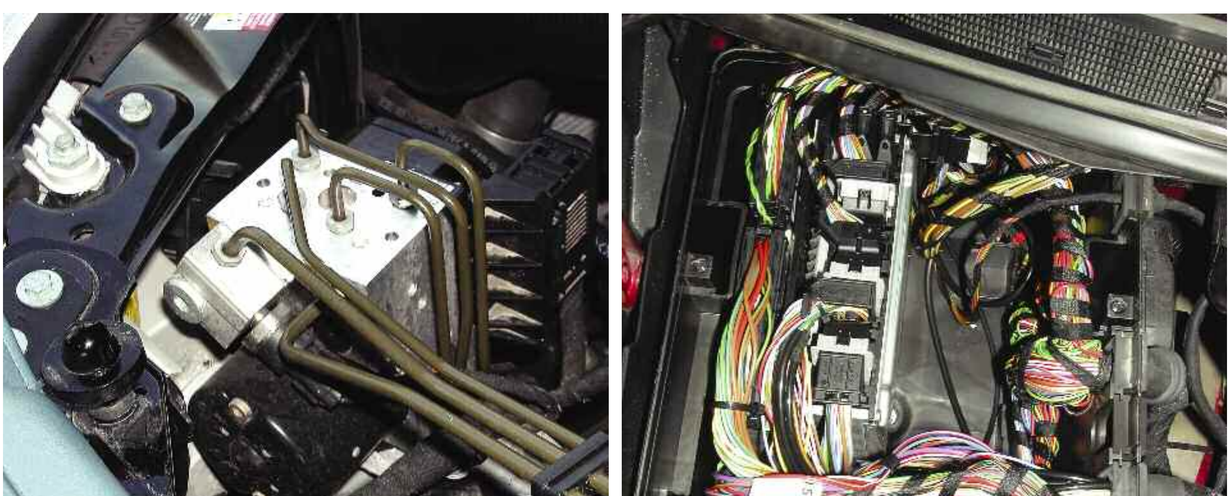
What say, we work conceptually backwards from the actuators to the controls? The final actuators, of course, are the four tiretread patches against the pavement. As with the earlier traction-controls and any yet-to-be-developed analog systems, ESP cannot recover from slipping and skidding forces that exceed the maximum traction available at the individual wheels – from maneuvers, in other words, that would violate established laws of applied physics.

If you hold a car at 75 mph and suddenly crank the steering wheel to full lock, you're going to lose control of the vehicle with almost any set of tires, on almost any pavement. With ESP and Mercedes-Benz' carefully engineered steering and suspension, you'll retain control for a fraction of a second longer, but you'll still lose it, no matter how powerful and complex the car's traction control system. As we said last issue, it's machinery, not magic. Neither ESP nor any other traction control system can achieve maneuvers requiring more traction than the tires and pavement can deliver.

ESP incorporates the earlier traction control systems ASR and ABS as subsystems of itself, as we mentioned last issue. Though we're focused here on the ESP side of the system, they're only separate because we talk about them separately. It is interesting to notice certain symmetries and asymmetries among them. ABS, the oldest system, can work on all the brakes, but can only reduce or release brake hydraulic pressure. ASR can actively apply – increase – brake pressure, but only to one or the other or both of the two drivewheels, not to the freely rolling fronts (we'll get to the system complications with 4MATIC and 4ETS next issue). ESP, the latest traction control, can only activate one brake at a time, whichever its electronic algorithms designate as the wheel that can correct sideslip on the other axle, in response to all the sensor inputs.

Of course, it's the same electronic and hydraulic control units performing each of the traction control functions, so the distinction between the subsystems is logical, not mechanical, hydraulic or electrical.

The ESP system is not just the sideslip control sensors and measures. Subsumed into ESP are our old friends ABS and ASR, as subsystems within the overall traction control. There are malfunction indicator lights on the dash that reflect the state of the system. It is possible to lose one function without losing all of the others, depending on circumstances. If something disables the electronic accelerator system, for instance, ASR cannot employ all the tricks in its engine output torque repertoire. But the overall system can still activate each of the ABS and ESP brake functions, which are generally independent of the engine. Certain failures, however, like a low charging system voltage or an open-circuited wheelspeed sensor, may affect or disable all of the traction-related subsystems.



Circuits, hydraulic and electrical, are the muscles and nerves of the ESP traction controls. The hydraulic control unit straddles the brake lines between the master cylinder and the four calipers. It includes the pressure pump and the solenoid valves for all ABS, ASR and ESP actuations. The control unit resides in the electrical control unit compartment, just in front of the bulkhead in most car models.

Continued on Page 18

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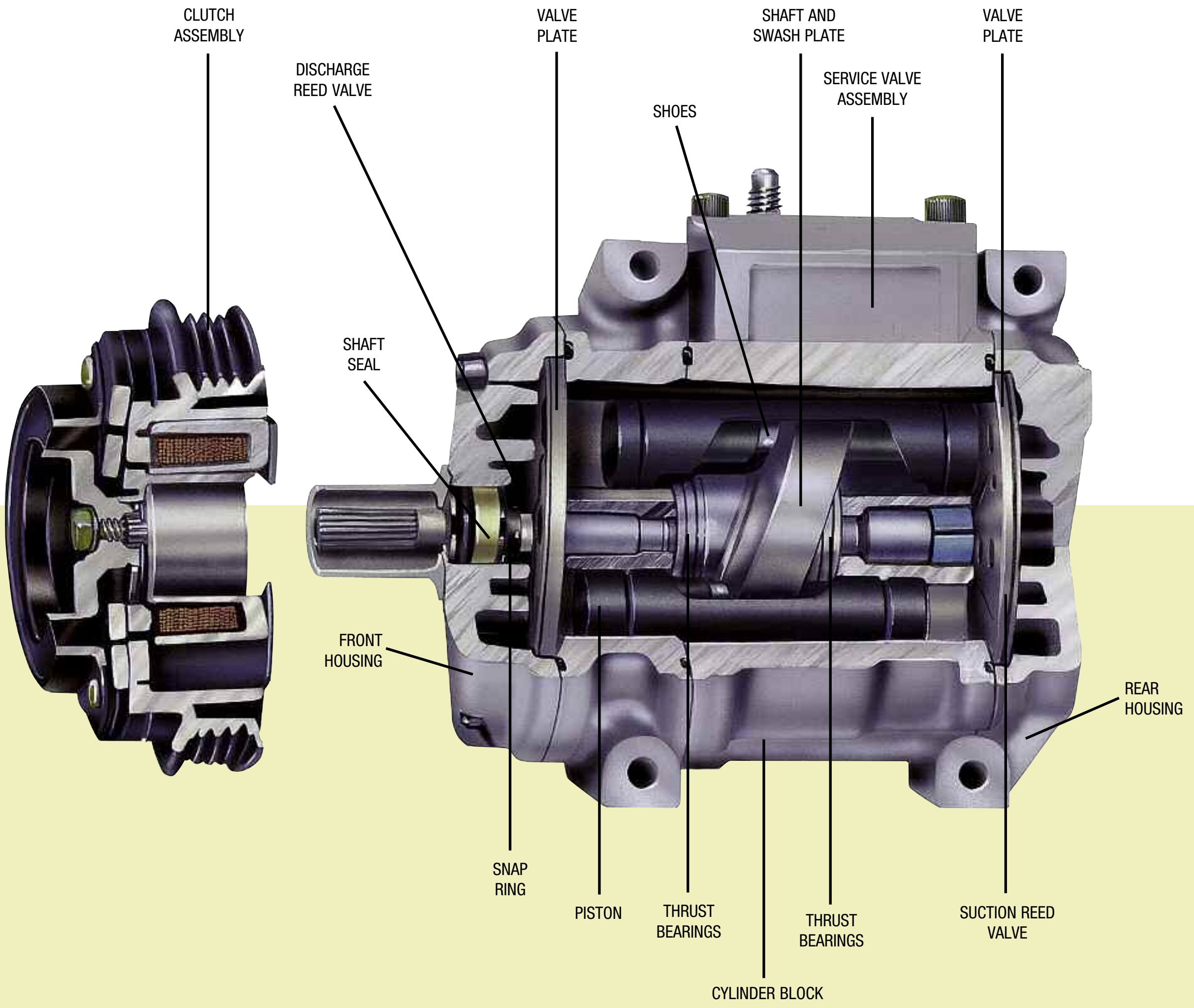

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Self-Diagnostics

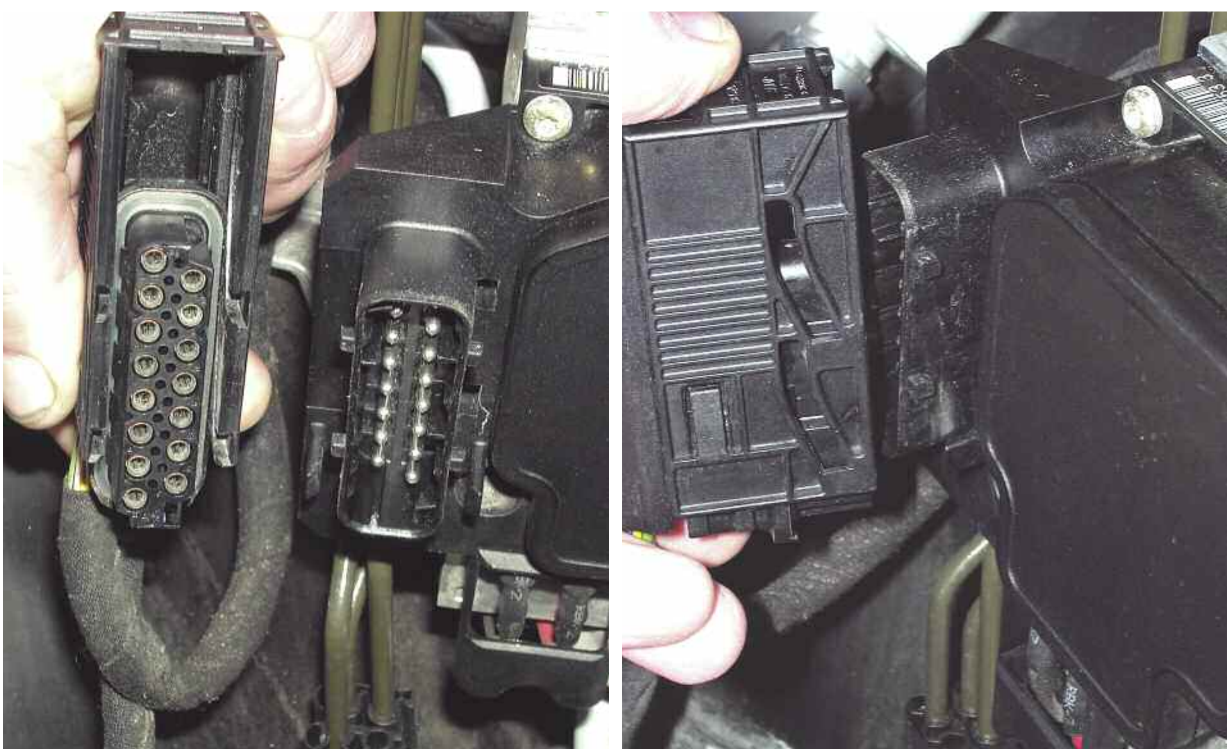
The ESP system does much of the diagnosis for you. When you first turn on the ignition key, the system goes through the ordinary bulb check, not just for the traction control systems, but for everything that appears on the instrument panel. When the engine starts, it runs a basic self-test. Among the other items checked are voltage supply, continuity through sensor and actuator circuits and plausible position information from the various switches.

Two dynamic self-tests follow, one as the vehicle just exceeds 6 km/h (about 4 mph) and the second at 15 km/h (roughly 10 mph) as long as the engine speed simultaneously exceeds 2500 rpm. If the system tests functional, the indicator light stays out, and the ESP traction control is at work. The triangular warning lamp, with the exclamation point symbol, does not indicate any problem with the system. Instead, that warning lamp flags driving conditions in which the system is actively taking steps to maintain traction. A driver should reduce his speed and moderate his driving style when that lamp flashes, because he has approached the limits of traction adhesion.

Active Diagnosis

When doing a complete diagnostic sequence, it is helpful to have the full scope of Mercedes-Benz diagnostic special tools to analyze problems that come up with the ESP system. But for a quick pinpoint diagnosis, most of the sensors and actuators work in ways you can test directly with an ordinary volt-ohmmeter. For some tasks, an oscilloscope can provide additional information. For mechanical and hydraulic work, you can work on individual wheel calipers, replace hoses, flush fluid and all the routine brake work in familiar ways.

Many of the sensors and inputs are just on-off switches, even though their effect on the system may be more complex. The ESP-off switch on the dash, for instance, is an ordinary continuity switch, but when turned off it tells the system to restrict ASR operations to brake actuations only. The test for the switch is, thus, simple. The test for the system is dynamic – drive the car and see whether it does what it is supposed to. Other inputs, however, require more detailed diagnostic approaches. Let’s look through them.

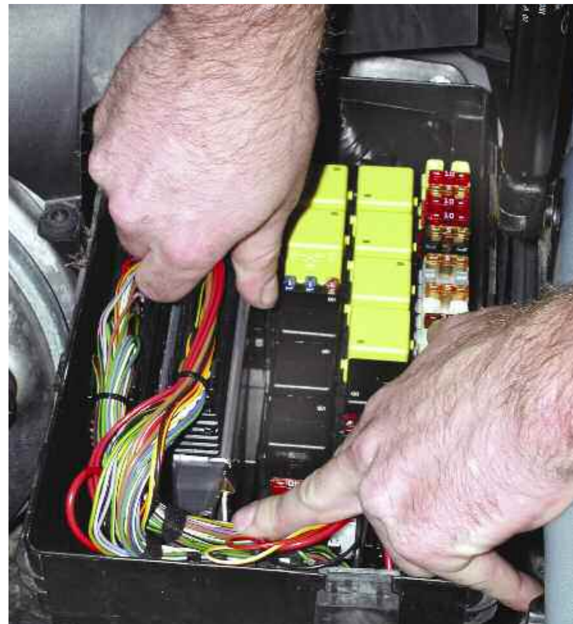


For testing both harnesses and individual components, understand how the connectors lock before you release them. None of them should require force beyond the stiction of the terminals themselves, but most do have a locking tab or other mechanism to keep the connection secure.

When traction is sufficient for the moment, the ESP hydraulic control unit rests with all its solenoids and valves in their deactivated position, passing whatever hydraulic pressure the driver produces in the master cylinder along to the wheel cylinders when braking. Only when there is wheel slip, from excessive braking, excessive engine torque for conditions or axle sideslip do the pumps and selective valves get to work to control the direction of the vehicle according to what the driver evidently wants, as indicated by what he does with the pedals and steering wheel.

You can test each solenoid's coil individually through the connector. They should be approximately the same, since it is quite unlikely they have all failed simultaneously in exactly the same degree.

The electric pump in the hydraulic control unit provides both the activation pressure and returns the brake fluid to the master cylinder once the traction-control event is complete.



Release the tab lock to disconnect the electronic control unit harness for testing the continuity of circuits and such diagnostic procedures. As with all complex systems, the temptation is to suspect the most complex element of the system when there is a problem, while the probability is that any problem results from something much simpler and – if you do a careful visual inspection – more obvious.

The muscle for ESP's brake activation comes from the electric quill pump in the hydraulic control unit. Because the ESP pump is of higher capacity than earlier electric hydraulic pumps, there is no need for a pressure reservoir to store active pressure for brake applications, though most models include a hydraulic accumulator to reduce noise and brake pedal pulse as well as individual acoustic silencers on each brake circuit. ESP functions ordinarily require less hydraulic pressure and volume than ASR since they only apply to one wheel at a time and since it requires much less brake force to prevent excessive yaw than to rein in the engine torque. Since the fluid in a hydraulic system is incompressible, the pressure application at the caliper is practically instantaneous when the control unit activates the solenoid valve.

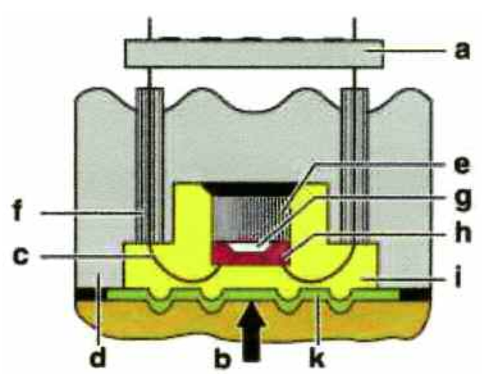
The quill-type charging pump builds 7- to 15-bar pressure. Its pressure is internally regulated in the hydraulic control unit. If you actively test the system, don't run the pump longer than one minute. Most vehicles run the pump briefly upon engine startup as part of the system's initial self-testing procedures, and that can let you know what the pump sounds like (it's audible even with engine running and the hood closed). If you don't hear the pump, start chasing powers and grounds.

The pressure transfer piston unit separates the hydraulic control unit from the master cylinder. Its chief purpose is to retain pressure in the ESP-activated wheel circuit, not returning it to the master cylinder until the event is over.

ESP Pressure Transfer Piston

This component connects the hydraulics between the master cylinder and the ESP hydraulic unit. It functions to separate the brake pressure built up by the charging pump for ESP application from the rest pressure in the master cylinder. This component also has the brake pressure sensor incorporated at one end. The pressure transfer piston actually contains two separate pistons, held in their normal position by springs in the cylinder bore. In their normal position, the brake circuits are both open for ordinary braking purposes. This unit is ordinarily just behind the left front wheel on the fender.

The signal from the brake hydraulic pressure sensor is one of the inputs to the electronic control unit in calculating whether and how much brake force to apply to a given wheel. Interesting aspects of this feature are its range and threshold. It can report up to 200 bar, though even 100 bar (1500 psi) would be a very forceful brake application. The system regards a tolerance of +/- 17.5 bar as accurate. This suggests to us the conjecture that ESP does not require finely detailed information about hydraulic pressure, perhaps largely signals that pressure has increased or decreased.



*Included at the left end of the pressure transfer piston unit is the hydraulic pressure sensor. Elements: **a** electronics, **b** brake fluid under pressure, **c** wire, **d** case, **e** glass element, **f** insulator, **g** reference pressure, **h** pressure sensor (strain gauge), **i** silicone oil, **k** spring metal diaphragm*

The sensor requires a 5-volt reference feed and ground, and it has a signal return. While we don't have any suggestions to check its accuracy (what would be your more accurate gauge to measure brake hydraulic pressure?), you can check its output to see whether there is any change when you press and release the brake pedal. Like most electronic devices, it may short or open, but it is unlikely to get out of adjustment.

Stop Lamp Switch

ESP uses the same multiple-circuit stop lamp switch used on most cars without ESP: one contact is normally open; the other normally closed. Both must make and break connection in the expected way for the system to determine the brake pedal is in use. Check for power to the switch as well. The larger pins are for the normally open circuit, and the smaller pins for the normally closed.

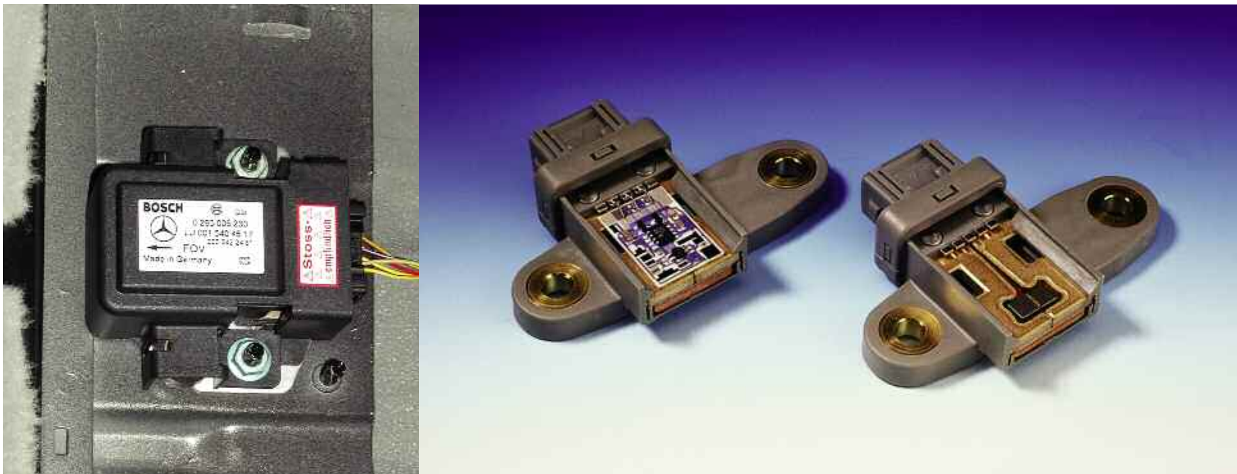
Master Cylinder Switchover Valve

Inside the master cylinder is a device to take advantage of the ABS system: the switchover valve. While it is not unique to cars with ESP, it allows equal hydraulic pressure to front and rear wheels (thus a 60/40 front/rear braking force, given the relative size of the pistons), achieving more uniform brake pad and tire wear. In the absence of ABS, this could represent an increased chance of rear wheel lockup, but the ABS system protects against that as long as it is functional. If it turns off for some reason, that de-energizes the switchover valve, making the hydraulic pressure 70/30 front/rear, further hydro-mechanical insurance against rear brake lockup.

Wheelspeed Sensors

Finally, and the most common reason for ESP problems, the wheelspeed sensors are the same inductive pickups familiar from ABS and ASR. Riding where they do, exposed to road hazards, with their connector harnesses flexing back and forth with every suspension movement, wheelspeed sensors can become nonfunctional, especially on high mileage cars, merely because the circuit goes intermittently open.

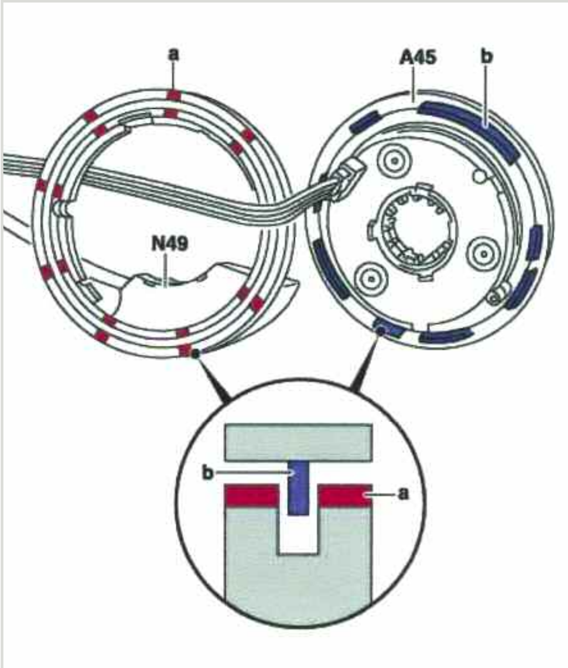
The best way to check them is with an oscilloscope. ESP cars have wheelspeed rotors with 48 teeth per revolution, and the standard the control unit looks for is a minimum of 0.12 volt AC. With the oscilloscope connected to the two wires from the sensor, spin a wheel and watch the pattern. A notch in the pattern every 48 cycles suggests a damaged tooth or a piece of ferrous metal caught between two teeth. A constant misshapen pattern suggests a cracked magnetic pickup, or a piece of ferrous debris sticking to the tip. No signal at all suggests a broken wire.



The lateral acceleration sensor is a Hall-effect device at the center of the car, as described last issue. The HHT can access this sensor (you grab the roof rail and rock the car back and forth to see the signal respond), or you can measure it directly. Gently unbolt the sensor and lay it on one side, observing the output signal. Then lay the sensor on the other side, watching for the change of signal. Remember the sensor is delicate, so don't drop or strike it.

The yaw sensor, as we saw last issue, measures the rotation of the vehicle around its vertical axis and sends that information, encoded as a voltage, to the electronic control unit. While HHT testing is easier, you can test this with a voltmeter. In a clear space with no risk of striking any obstruction, turn the steering to full lock and drive at about 4 mph. This should complete a 360 turn in about 18 seconds. If you turn to the right, you should see close to 1.78 volts; if you turn left, you should see about 3.22. The sensor receives a 5-volt reference signal and produces a 2.5-volt comparison signal at pin 4. The purpose of this signal is merely to give the control unit something to factor against electrical noise in the circuit (the noise will affect the 2.5-volt signal in the same way and to the same extent as the 'real' signal.

The sensor also conducts its internal self-test when the control unit sends it a 20 ms 5- volt signal to pin 5. If it passes this test, it responds with a 3.40 (+/- 0.32 volts) signal momentarily at the output pin.



The steering angle sensor works by precisely segmented blades interrupting the optical signal between individual sensors, as described last issue. The output signal from the sensor is a digital stream generated by its internal microelectronics from the raw data from the light receptors. While in principle you could decode the digital stream, this is another case where the best procedure is to merely check for its appearance. An oscilloscope is best for this test. A new sensor or one that has lost its power and ground connections will have to be 're-initialized' as described last issue.

THOUGHT EXPERIMENTS

Testing and experimentation are critical research in the design and manufacture of vehicles, as Mercedes-Benz has done for over 100 years. Some experiments and testing require precision instrumentation and measurement, but other types – the thought-experiments we'll consider here – are entirely instruments of the mind.

Mercedes-Benz tests the cars they make. These tests range from the very dramatic, like crash tests, to the mundane, like wheelspeed and temperature tests. All these tests contribute to improving the quality and performance of cars over time.

Thought-Experiment One
Fixed Circle

Imagine a wide, flat section of good pavement. There is a circle painted with a 100-foot radius and another concentric circle with a 110-foot radius. The object is to drive the car in the space between the painted lines, gradually increasing the speed until centrifugal force overcomes traction and you can't control the car within the 110-foot circle.

Without ESP, the car can maintain the circular path (with increased body lean and tire squealing) up to the point at which the axle with lower traction can no longer hold its end of the car in the chosen path. If that's the front axle, the car will understeer and nose out of the circle, regardless of steering angle input. If the rear axle comes loose first, the car will oversteer and pivot toward the center of the circle, sliding sideways to a halt. Oversteering cars can slide toward the circle center or outward, depending on a variety of chassis and steering dynamics not directly relevant to our thought-experiment.

With ESP, what happens? If the car understeers because the front axle is sliding outboard, the system applies the inside rear brake, pivoting the car back onto the intended track. Does this mean the circular speed can be increased indefinitely?

No. Our conceptual car's drive axle has one wheel pushing the car forward and the other pulling the car back, with just enough difference in force to keep the front axle from sliding out of the track. But working against itself like this, either the force on the drivewheels will become equal and the speed will stay constant. Or the car will increase up to the combination of centrifugal and traction forces such that it slides outside the circle with all four wheels sliding roughly the same. This will, of course, be a somewhat higher speed than the non-ESP car could manage. But the ESP car cannot accelerate indefinitely, either.

(If we added ASR to our thought-experiment, the car would reach the speed at which the second drivewheel started to slip. And then the system would apply drivewheel brakes and/or reduce engine torque output. The car would reach and hold its maximum traction speed, but would not slide out nor increase in speed. Limiting factors would be rapid wear of the outside tires and the driver's rapidly eroding sense of balance.)

If the car oversteers, with the rear axle sliding outward, the system applies the outside front brake to correct the excessive yaw. It would be interesting to know whether the outside front brake might have more effect than the inside rear on the understeering car, supposing that the additional traction of the weight shift would have such a result. But now we have the rear drivewheels pushing forward and the outside front braking. Just as with the previous example, this can't continue beyond a certain speed, at which the car slides outside the circle, with all four wheels ideally sliding equally.

What's the point of this thought-experiment? No matter what the dynamic conditions of a constant turn, there is a speed beyond which the car cannot go, ESP or not. A motorist who reports his ESP system does not maintain traction control could possibly be trying this thought-experiment on real-world roads.

Thought-Experiment Two Straight Line Into Circle

Hang onto that painted conceptual circle. Now let's approach it in a straight line that enters the circle where they intersect. Hold a constant speed along the straightaway and into the circle.

Clearly, below a certain speed, there is no problem at all. The car just makes the turn and continues around the circle in control. Above that speed, we encounter a situation almost exactly the same as our first thought-experiment. There will be a speed above which the car will understeer or oversteer out of control, ESP or not. In fact, this may be an easier slide to achieve than our first example since ESP will do nothing to restrict the approach speed to a pace that can maintain the circle.

Aside from that, the major difference is that the car abruptly yaws as it begins the circle. This compels the ESP system to actively balance traction just as the curve ensues, at least at the limits of traction. As with the constant circle, the car with ESP can take this path somewhat faster than a car without, but it can't do so without limits.

Thought-Experiment Three Progressively Banked Road

Finally, let's consider a dead-straight road, but one that gradually, over the space of a mile or so, tilts more and more to the side, all the way to 90 degrees. No car, ESP or not, will make it all the way to the place where the road surface is perpendicular to the surface of the earth. But how will an ESP-equipped car work differently from one without? Can it travel any farther down the ever-tilting road, and if so, how?

We can dispose of the non-ESP car simply enough. One or the other axle starts to slide to the side, and the car moves off the tilted road, either front axle first (understeer) or rear axle first (oversteer). It does seem odd to speak of a car either understeering or oversteering with the steering wheel held dead center, but that's exactly what's happening.

The ESP car will also slide off the road, but what can the system do to forestall the slide? Can it hold onto the pavement longer?

As the car tilts, neither the yaw sensor nor the steering angle sensor reports much change to the control unit. True, the driver will have to turn slightly uphill to counteract the drift from the road bank. The car's vertical axis rotates with the road surface, but the car does not rotate around the axis, so the yaw sensor reports nothing amiss. The lateral acceleration sensor, however, maps the road tilt exactly, so the control unit certainly can calculate increased side-load and the imminence of a sideslip.

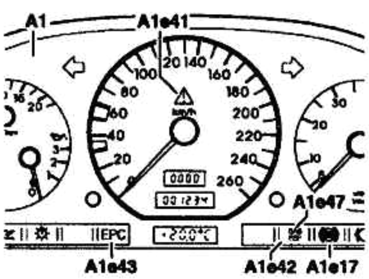
At the very moment one or the other axle starts to slide off the road, the yaw sensor detects vehicle rotation around its vertical axis, even though the vertical axis is now tilted substantially to the side. From the direction of rotation, the control unit can determine which axle has begun to slide. From the lateral acceleration sensor, the control unit can tell there has been a sudden reduction in lateral acceleration, because the car is now moving to the downhill side. That movement reduces the traction the tires would otherwise transmit.

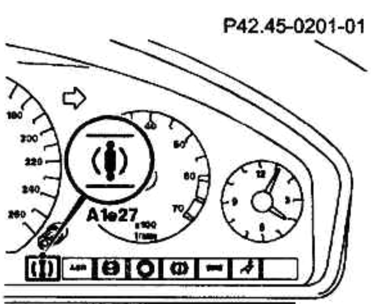
STARTUNED

FACTORY SERVICE BULLETINS

These suggestions and solutions for technical problems come from service bulletins and other technical information published by Mercedes-Benz, selected and rewritten for independent repair shops.

ESP Malfunction Lamp After Battery Replacement

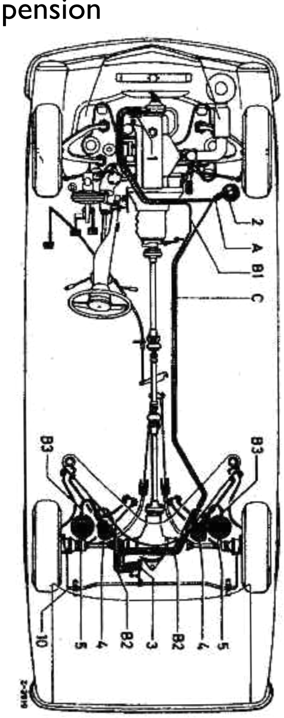


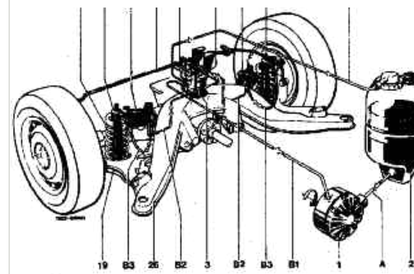


Some shops, I understand, clip on a small 12-volt motorcycle battery to the cables when they replace a car's main battery (because motorcycle batteries have various fluid baffles to prevent acid spill if they tip). Aside from losing the radio station settings and various other kinds of vehicle memory, the voltage interruption can addle the calibration of the steering angle sensor. If that happens, the ADS or ESP warning lamp will turn on (the lights are different for different vehicles – check in the owner's manual), and the corresponding traction control system will turn off.

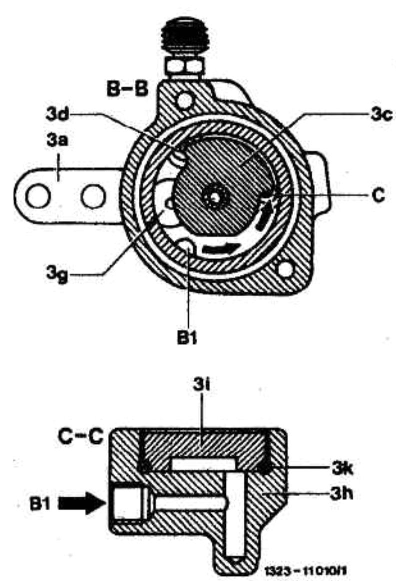
The recalibration is quite simple. Start the engine and let it run at idle. Slowly turn the steering wheel from lock to lock. Some info sources say this must be done twice; others don't. The system has accepted the recalibration and reset itself as soon as the lamp goes off.

Hydraulic Load-Leveling And the Hydropneumatic Suspension





Most Mercedes-Benz cars using the semi-trailing arm rear suspension offered a hydraulic load leveling system, effectively a hydraulic auxiliary suspension, as an option or as standard equipment, depending on the model. The 116, in fact, one of the most mechanically complex vehicles ever built, used a full hydropneumatic suspension on all four wheels.



If you prefer working on mechanical systems to electronic, this is the diagnosis and repair for you. Of course, if what you really want to avoid is complexity, it's not. The Mercedes-Benz technical information includes complete information on how these systems work and how to diagnose and repair them when they don't

Even though some of these cars were built and sold over 30 years ago, you can still get practically every part you need through your Genuine Mercedes-Benz Parts source, as listed in this magazine.

Airbag Replacement Model 201 (Others Similar)

If you have to replace an airbag, there's always some level of interest to see you do the job correctly. After all, the wrong kind of mistake could not only cause expensive damage, it could result in injury as well. Here's how to do the job properly:

Turn the ignition key off and remove it from the lock. Then disconnect the battery negative cable and cover the post for safety. Lift out the passenger's side floor mat. Loosen the foot support bolt and remove the support.

Disconnect the 10-wire connector plug to the control unit at the foot support. Unscrew the fillister screws, breaking the circuit to the release unit. It is not separate from the contacts. You are ready to remove the airbag from the steering wheel safely.

Pull the plug connector from the airbag gas generator. This will automatically engage a short circuit bridge in the gas generator. You can now remove the airbag from the steering wheel and the car. Do not attempt any further disassembly, repair or exploration of the airbag (it's available only as a complete piece as a replacement part, anyway). Always store it with the pad side up, and keep it in a safe place, under lock and key, because if accidental detination occurs, the airbag may propel dangerously through the air. While it is not inherently dangerous, the removed airbag is a chemical pyrotechnic device and cannot be left sitting around casually. The person who removes it from the car is responsible for its secure storage or disposal.

You're not done quite yet. Unscrew the countersunk bolt holding on the steering wheel and lift off the steering wheel. The object is to inspect the carbon brushes for the airbag as well (as long as you're there) for the horn. There is a cover plate to remove in case you need to remove either or both of these sets of brushes.

When reassembling the steering wheel, Mercedes-Benz recommends replacement of the countersunk bolt. In the absence of a replacement bolt, at least employ a secure threadlocker on this critical fastener. 80 Nm is the tightening torque.

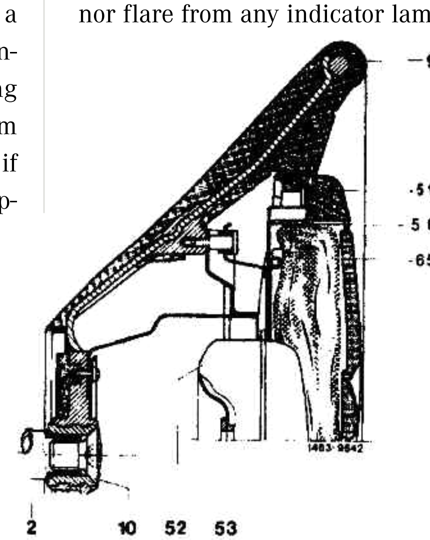
Disconnect the plug cable at the contact ring long enough to make a short test drive to confirm the centering position of the steering wheel. You can move it a maximum of two splines in either direction, if that is necessary to center it properly. Once that position is determined, reconnect the plug cable at the contact ring.

To install the new airbag, observe these modest precautions against its percussive vulnerability: do not expose it to temperatures over 100 degrees Centigrade (212 F); do not drop it from even a modest height (50 cm). Dubious airbags should be returned to the manufacturer in the original packaging.

Before you reconnect the airbag, go back to the battery and confirm the ground cable is still disconnected. Check that the ignition switch is still off and the key removed. These steps may seem redundant, but a single adverse mishap would put that impression in its proper perspective.

When you reconnect the airbag cable, listen for the audible click as it connects. Place the airbag on the steering wheel, close to its proper position. Replace and tighten thefillister bolts into the generator carrier. Replace the foot support in the front passenger's footwell.

With the battery reconnected, turn the steering wheel from lock to lock. There should be no flash nor flare from any indicator lamp.



2 Steering shaft
9 Steering wheel
10 Countersunk screw
51 Airbag unit
52 Gas generator
53 Gas generator plug connection
56 Generator carrier
65 Airbag

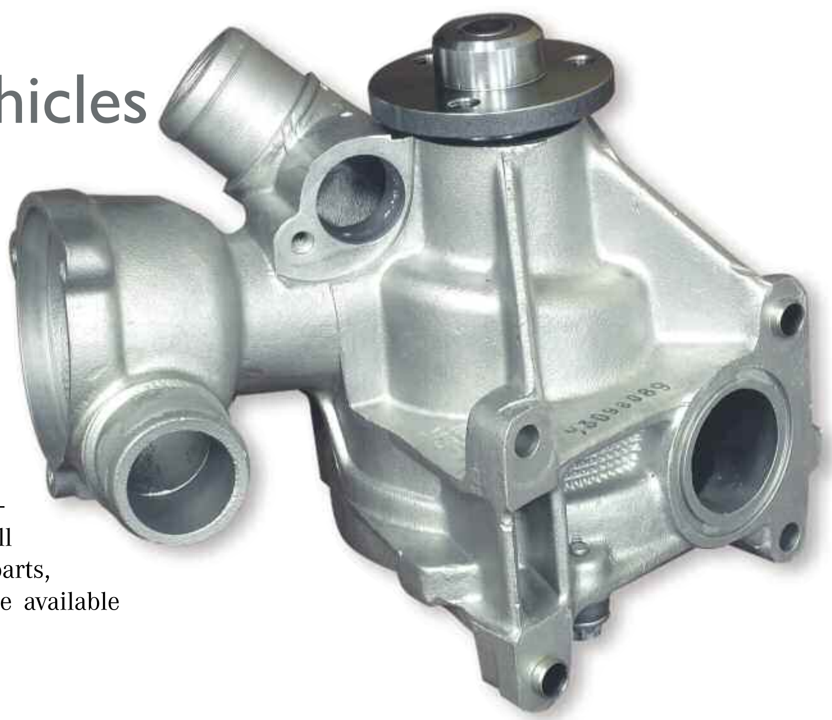
Parts News

ESP From Start To Finish

The ESP system is a closed-loop control system to retain steering under as many conditions as possible. Except for the wheels and tires, everything in the system falls between the wheelspeed sensors and the brake calipers. There's much more involved, as our ESP articles cover, including inputs from yaw and lateral-acceleration sensors, information from the engine and transmission management system, signals from switches indicating the state of the brake pedal, the ESP toggle and the steering angle sensor and more. Electronic and hydraulic control units at the center of the system take in the data and trigger actuators to retain control as long as possible.

These components are all available from your Genuine Mercedes-Benz Parts source, but it is critical you conduct a thorough diagnosis of any non-functional ESP system on a vehicle before you start replacing individual elements.

New Parts For Older Vehicles



The 103 engine powers many Mercedes-Benz cars, but its water pump like most other components is still available new from your Genuine Mercedes-Benz Parts supplier. Mercedes-Benz is determined that while many of the company's cars have become and will become classics, few will become obsolete because of parts availability problems. Your local dealer will probably not stock the rarest of parts, but any the company provides are available through his parts department.

GENUINE MERCEDES-BENZ PARTS... NEARBY

Alabama

Dothan
Mike Schmitz Automotive
334-794-6716

Hoover
Crown Automobile
205-985-4200

Huntsville
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

Alaska

Anchorage
Mercedes-Benz of Anchorage
907-277-3383

Fairbanks
Cook's Import
907-459-7070

Arizona

Chandler
Mercedes-Benz of Chandler
480-403-3444

Phoenix
Phoenix Motor
602-264-4791

Scottsdale
Schumacher European
480-991-1155

Tucson
Mercedes-Benz of Tucson
520-886-1311

Arkansas

Fayetteville
Jones Motorcars
479-521-7281

Little Rock
Riverside Motors
501-666-9457

California

Anaheim
Caliber Motors
714-777-1900

Arcadia
Rusnak/Arcadia
626-447-1117

Bakersfield
Mercedes-Benz of Bakersfield
661-836-3737

Belmont
Autobahn Motors
650-637-2333

Beverly Hills
Beverly Hills
310-659-2980

Buena Park
House of Imports
714-562-1100

Calabasas
Calabasas Motorcars
818-591-2377

Carlsbad
Hoehn Motors
760-438-4454

Chico
Courtesy Motors Auto Center
530-893-1300

El Dorado Hills
Mercedes-Benz of Eldorado Hills
916-567-5100

Encino
Auto Stiegler
818-788-0234

Escondido
Mercedes-Benz of Escondido
760-745-5000

Fremont
Claridge's
510-623-1111

Fresno
Mercedes-Benz of Fresno
559-438-0300

Glendale
Calstar Motors
818-246-1800

Laguna Niguel
Mercedes-Benz of Laguna Niguel
949-347-3700

La Jolla
Heinz Gietz Autohaus
858-454-7137

Long Beach
Mercedes-Benz of Long Beach
562-988-8300

Los Angeles
Downtown L.A. Motors
213-748-8951

Modesto
Modesto European
209-522-8100

Monterey
Mercedes-Benz of Monterey
831-375-2456

Newport Beach
Fletcher Jones Motor Cars
949-718-3000

Oakland
Mercedes-Benz of Oakland
510-832-6030

Palm Springs
Mercedes-Benz of Palm Springs
760-328-6525

Palo Alto
Park Avenue Motors
650-494-0311

Pasadena
Rusnak Pasadena
626-792-0226

Pleasanton
Mercedes-Benz of Pleasanton
925-463-2525

Riverside
Walter's
909-688-3332

Rocklin
Von Housen Motors
916-924-8000

San Diego
Mercedes-Benz of San Diego
858-279-7202

San Francisco
Mercedes-Benz of San Francisco
415-673-2000

San Jose
Beshoff
408-239-2300

San Jose
Smythe European
408-983-5200

San Luis Obispo
Kimball Motor
805-543-5752

San Rafael
R.A.B. Motors
415-454-0582

Santa Barbara
Cutter Motors
805-682-2000

Santa Monica
W.I. Simonson
310-829-4511

Santa Rosa
Smothers European
707-542-4810

Stockton
Berberian European Motors
209-944-5511

Thousand Oaks
Silver Star A.G.
805-371-5400

Torrance
Mercedes-Benz of South Bay
310-303-3500

Van Nuys
Keyes European
818-461-3900

Walnut Creek
Stead Motors of Walnut Creek
925-937-1655

West Covina
Penske Motorcars
626-859-1200

Colorado

Colorado Springs
Mercedes-Benz of Colorado Springs
719-575-7950

Denver
Murray Motor Imports
303-759-3400

Littleton
Mercedes-Benz of Littleton
303-738-7700

Connecticut

Danbury
Mercedes-Benz of Danbury
203-778-6333

Fairfield
Mercedes-Benz of Fairfield
203-368-6725

Greenwich
Mercedes-Benz of Greenwich
203-869-2850

Hartford
New Country Motor Cars
866-346-2369

New London
Carriage House of New London
860-447-3361

North Haven
Mercedes-Benz of North Haven
203-239-1313

Delaware

Milford
I.G. Burton
302-424-3042

Wilmington
Mercedes-Benz of Wilmington
800-800-1949

Florida

Clearwater
Lokey Motor
727-530-1661

Coral Gables
Bill Ussery Motors
305-445-8593

Daytona Beach
Mercedes-Benz of Daytona Beach
386-274-4775

Ft. Lauderdale
Mercedes-Benz of Fort Lauderdale
954-462-4381

Ft. Pierce
Coggin Motor Mall
772-466-7000

Ft. Walton Beach
Quality Imports
850-863-2161

Gainesville
Kraft Motorcar
352-332-7571

Jacksonville
Brumos Motor Cars
904-724-1080

Lakeland
Central Florida Eurocars
863-688-8111

Maitland
Mercedes-Benz of Orlando
407-645-4222

Melbourne
Continental Motorcars
321-956-0600

Miami
Mercedes-Benz of Miami
305-919-8000

Naples
Mercedes-Benz of Naples
239-643-5006

Pensacola
Centennial Imports
850-432-9903

Pompano Beach
Autohaus Pompano
954-943-5000

Sarasota
Glauser
941-923-3441

St. Petersburg
Crown Eurocars
727-526-3738

Tallahassee
Capital Eurocars
850-574-3777

Tampa
Mercedes-Benz of Tampa
813-870-0010

West Palm Beach
Mercedes-Benz of Palm Beach
561-689-6363

Georgia

Albany
Hentschel Motorcars
912-883-2040

Athens
Mercedes-Benz of Athens
706-549-6600

Atlanta
Mercedes-Benz of South Atlanta
770-964-1600

Atlanta
RBM of Atlanta
770-390-0700

Atlanta
Mercedes-Benz of Buckhead
404–846-3500

Augusta
Rader
706-860-1111

Columbus
Columbus Motor
706-327-3636

Deluth
Atlanta Classic
770-279-3600

Macon
Jackson Automotive
478-477-4858

Savannah
Critz
912-354-7000

Hawaii

Honolulu
Mercedes-Benz of Honolulu
808-592-5600

Idaho

Boise
Lyle Pearson
208-377-3900

Pocatello
Robert Allen
208-232-1062

Illinois

Arlington Heights
Mercedes-Benz of Arlington Heights
847-259-4455

Barrington
Motor Werks of Barrington
847-381-8900

Bourbonnais
Napleton's Autowerks
815-933-8221

Champaign
Sullivan-Parkhill Imports
217-352-4161

Chicago
Mercedes-Benz of Chicago
312-944-0500

DeKalb
Brian Bemis Imports
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Mercedes-Benz of Hoffman Estates
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Napleton's Autowerks
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Foley-Sweitzer
618-997-1313

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Mercedes-Benz of Naperville
630-305-4560

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Sud's Motor Car
309-454-1101

Northbrook
Autohaus on Edens
847-272-7900

Orland Park
Mercedes-Benz of Orland Park
708-460-0400

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Sud's
309-347-3191

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J.P. Chevrolet GEO Nissan
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Isringhausen Imports
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Laurel Motors
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D-Patrick
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Fort Wayne
Shaver Imports
260-432-7200

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Terry Shaver Imports
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World Wide Motors
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Mike Raisor Imports
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Gurley-Leep Motorwerks
219-256-1500

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Lujack's Northpark
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Mercedes-Benz of Des Moines
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Shawnee Mission
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Sunflower Motors
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Sim Fryson Motor
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Bowling Green Imports
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James Motor
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Louisville
Tafel Motors
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Walker Automotive
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Audubon Imports
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Metairie
Benson Motor
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Holmes European Motors
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Quirk Auto Park of Bangor
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Mercedes-Benz of Annapolis
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Euro Motorcars
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Grand Blanc Motorcars
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