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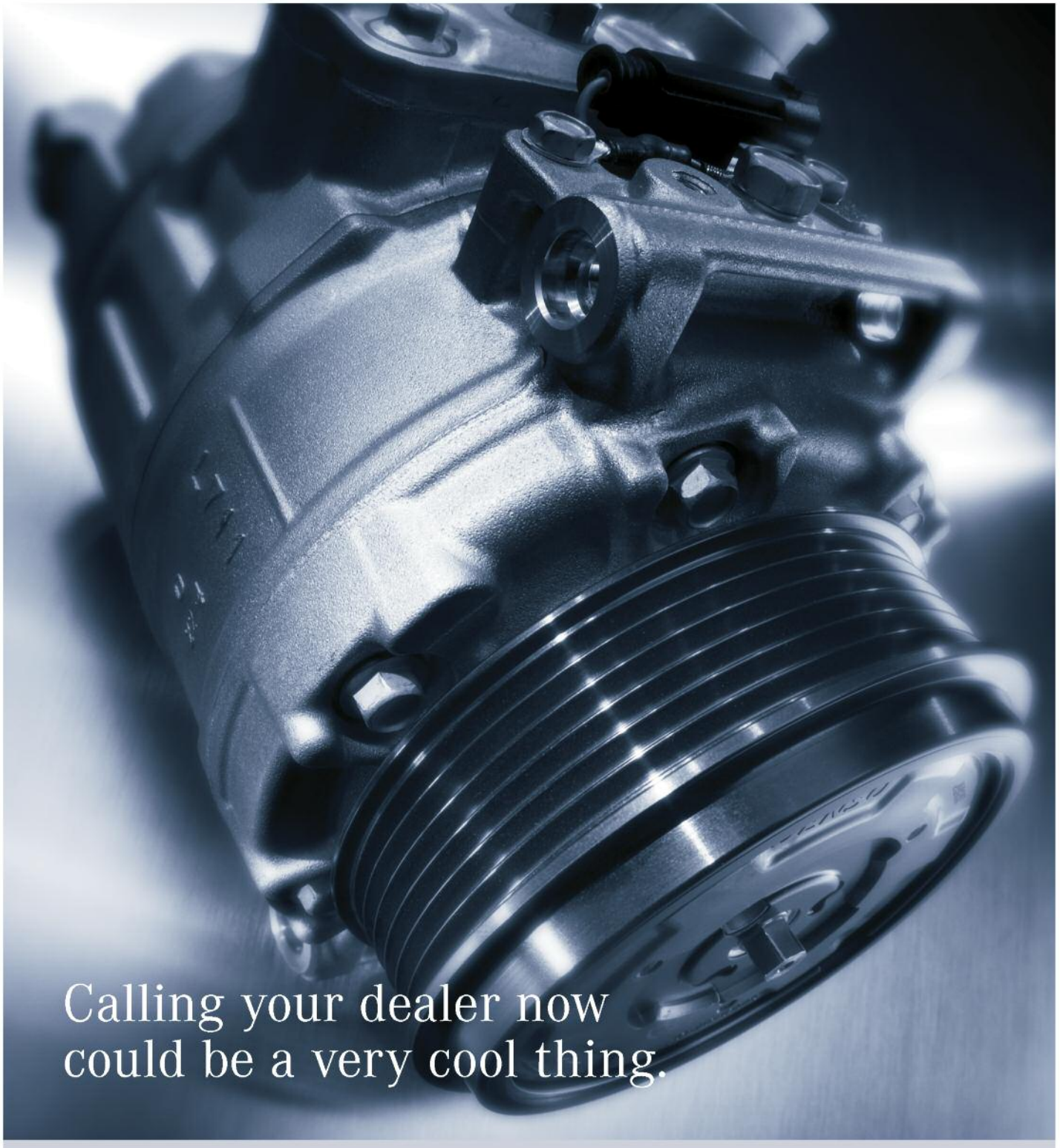
4MATIC and ETS

Textbook Case

Volume 4 Number 2

Mercedes-Benz



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StarTuned

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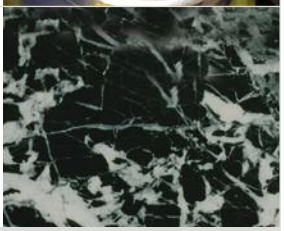

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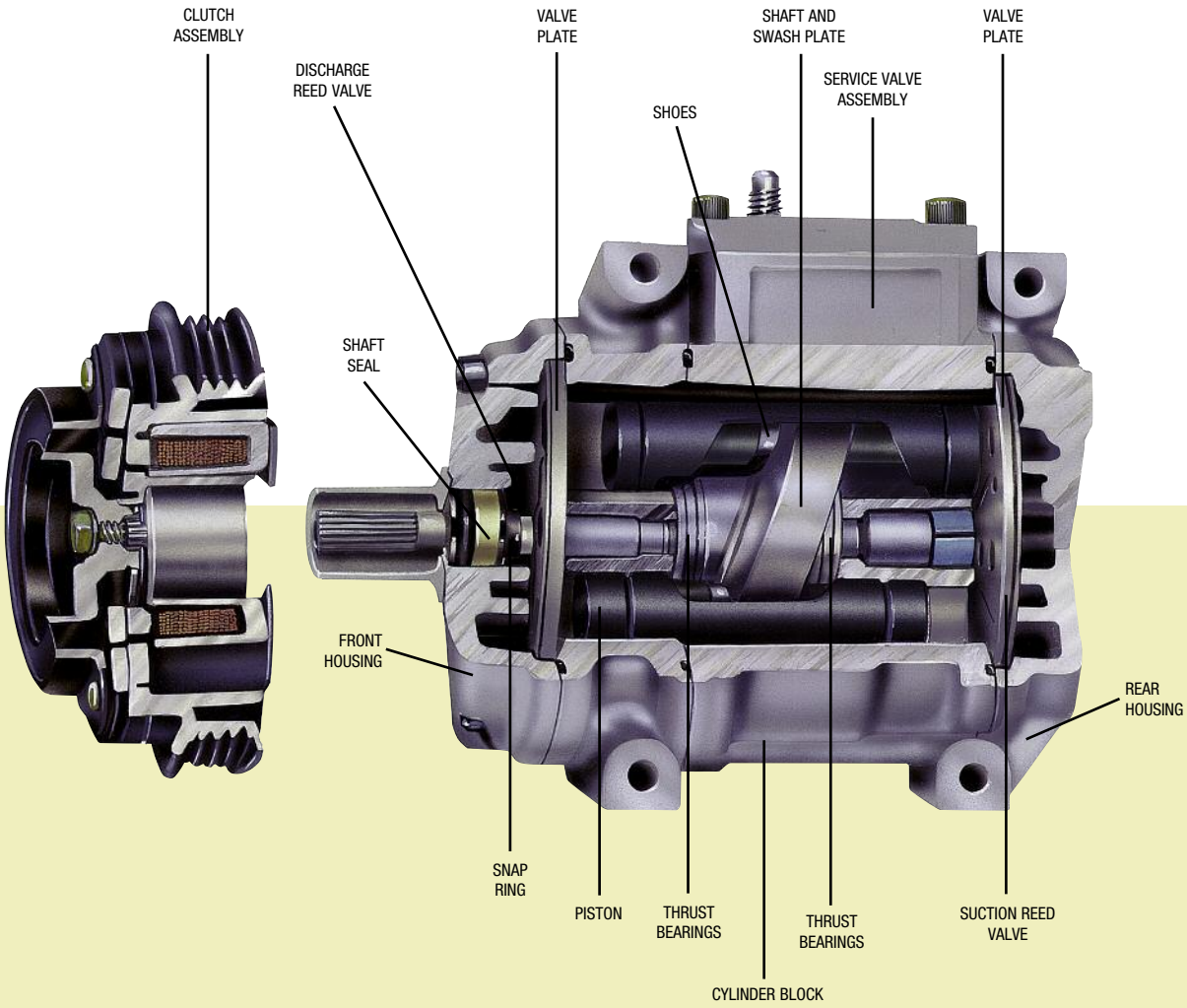

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4MATIC AND ETS

Traction Through A Pipe Traction Down A Wire

Four-wheel-drive increases traction, often enough to sustain movement and control under conditions that might otherwise mean the driver would choose to stop or would get stuck in snow, mud or sand. Four-wheel-drive is not constantly advantageous, however, because it mechanically couples all the wheels and drivetrains together; and sometimes, surprisingly enough, that connection can work against optimization of traction and control. There have been two quite different systems called 4MATIC, the first hydraulic, beginning about 1990 and the second electronic, working through the service brakes, starting in 1998. We concentrate here on the earlier system since you're more likely to see it in an independent shop.

Locked and Open Differentials

"Four-wheel-drive" can be a misleading description. In principle, of course, any driveline system conducting power through the transmission to all four wheels is 'four-wheel-drive.' There are, however, significant differences arising from the distinction between locked and open differentials. Let's have that clear first.

Later nonhydraulic versions of 4MATIC, employing 4ETS, use open differentials front, back and center, with no multidisk clutches at all. They can do this because the later system uses individual wheel brakes to keep individual drivewheels from spinning when their torque exceeds the traction available at that tirepatch. The brakes have the identical effect to that of the multidisk clutches in the hydraulic version: they prevent overspeed of the wheel with less traction. Similarly, there are two-wheel-drive brake-activated drive traction controls analogous to ASD.

The ordinary, familiar differential is an 'open' differential. Torque delivered through the driveshaft pinion and differential ring gear applies equally through the spider gears to each axle halfshaft, regardless of individual halfshaft speed. Aside from slight friction between internal parts, an open differential applies equal torque to each axle – with the consequence that the maximum torque the differential can apply to its drivewheels is just double what the drivewheel with less traction can transmit alone, the drivewheel that slips first. Once that first wheel spins, the vehicle stops progress. This is exactly what we see when a car spins a drivewheel in a snowpile or mudhole: Until that wheel regains traction, a stationary car doesn't budge. In the extremes of limited traction, an open differential gives you *one*-wheel-drive, and, worse yet, drive through whichever wheel has less traction.

So we move to the locked or limited-slip differential. "Locked" is an exaggeration, as you know, because inside and outside wheels must travel different speeds in a turn. Otherwise the inside wheel, usually less heavily loaded as centrifugal force throws the weight outward, must skid forward along the pavement.

At the heart of the 4MATIC system is the transfer case, splitting the torque from the transmission to each of the driveaxles.

The 4MATIC differentials 'lock' in a way similar to the limited-slip differentials you may know from domestic trucks or high-performance (at least fast-acceleration) vehicles. In most of those, a constantly spring-loaded multidisk clutch links the opposite-side axle shafts, through a friction material and special lubricant, both requiring periodic replacement.

The earlier 4MATICs use hydraulics to engage the clutches, as we'll see.

There are also true locking differentials using sliding-dog clutches, but these engage with an immediate, heavy clank, a force reminiscent of excavation or railroad equipment, an engagement force that would be quite unwelcome in a sedan. With an earthmoving implement, this doesn't matter since the grinding earth moves under the tire lugs and since neither driving comfort nor speed was a priority, anyway. With a sedan, that's out of the question. On a vehicle driving mostly on hard pavement, you don't want a truly locking differential, not only because that would abrade the tires with lower load quickly, but also because it would mean one or the other tire on an axle would have to slide in every turn, actually reducing traction even under what should have been ideal pavement conditions.

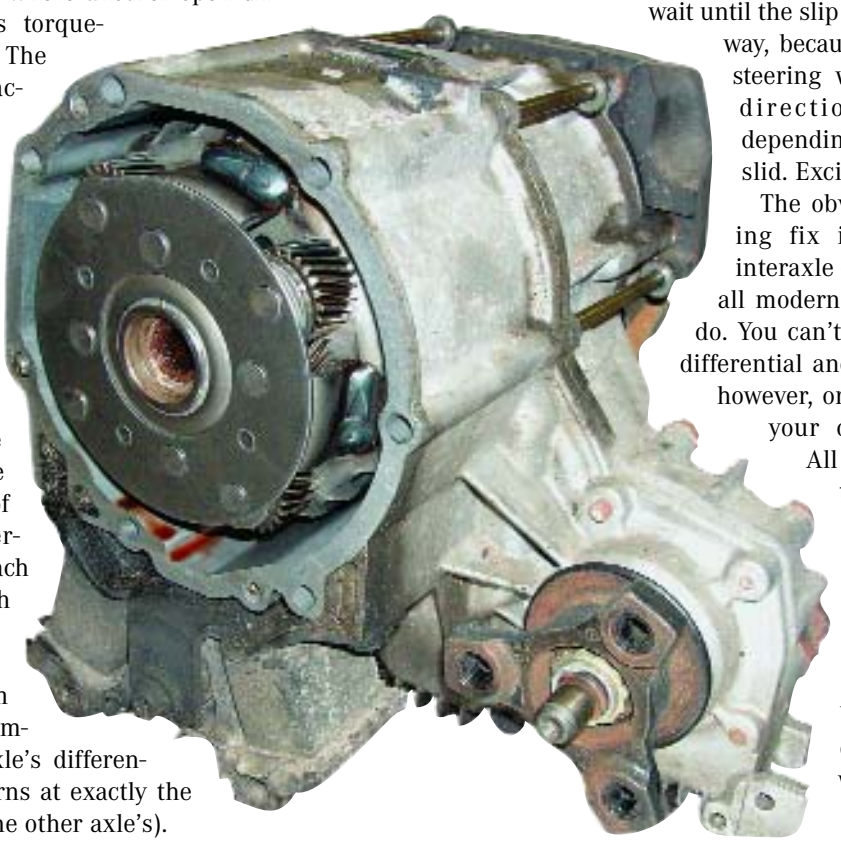
Torque through the Transfer Case

The earliest four-wheel-drive systems simply used a second driveshaft from a transfer case to the front axle differential, where another open differential did its torque-splitting work. The same 'less-traction' limitation still applies, but with this advantage: The average speed of the front wheels would, by solid mechanical linkage, move at exactly the same speed as the average speed of the rears ("average" because each wheel on each axle can still move at a different speed from its opposite number, but each axle's differential ring gear turns at exactly the same speed as the other axle's).

This means two wheels, one on each axle, have to slip simultaneously for the vehicle's motion to stop. Such four-wheel-drive will, however, represent a significant traction improvement over plain-vanilla two-wheel-drive. After all, it means at least a doubling of traction, and usually more than that, assuming somewhat different traction at each wheel. Just as two-wheel-drive through an open differential really means one-wheel-drive, four-wheel-drive through two open differentials really means two-wheel-drive. That's more traction, but it doesn't use all the traction available.

A four-wheel-drive system that locks the front and rear axles together still has the problem that one axle or the other must slip in every turn, because the front wheels will invariably follow a track along a smaller radius and shorter path than the rears. A long time ago, I had an ancient Jeep that never really got stuck, but took every turn with unpredictable directional excitement anytime four-wheel-drive was engaged. You could never tell whether the front or the rear axle would slide loose sideways first – that depended on everything from the load to the quality of the gravel on the road. And your corrective maneuver had to wait until the slip was clearly underway, because you turned the steering wheel in opposite directions to recover depending on which axle slid. Excitement, as I said.

The obvious manufacturing fix is to include an interaxle differential, which all modern four-wheel-drives do. You can't just add a center differential and let it go at that, however, or you're back with your original problem: All the torque goes to the first wheel that slips, and the vehicle stops there. Four-wheel-drive with three open differentials becomes, in the extreme, one-wheel-drive again.



The transfer case can engage two-wheel-drive only, four-wheel-drive or four-wheel-locked. In the last case, front and rear axles turn at the same speed.

4MATIC Progressive Locks

So the Mercedes-Benz 4MATIC system employs 'locked' four-wheel-drive when the various sensors indicate the need for the additional traction, but not under normal driving conditions when ordinary two-wheel-drive through the open rear differential is sufficient to conduct all the forward drive moment the engine can deliver to the wheels, and not under those special driving conditions when – paradoxically – a locked four-wheel- drive could make a low-traction condition worse.

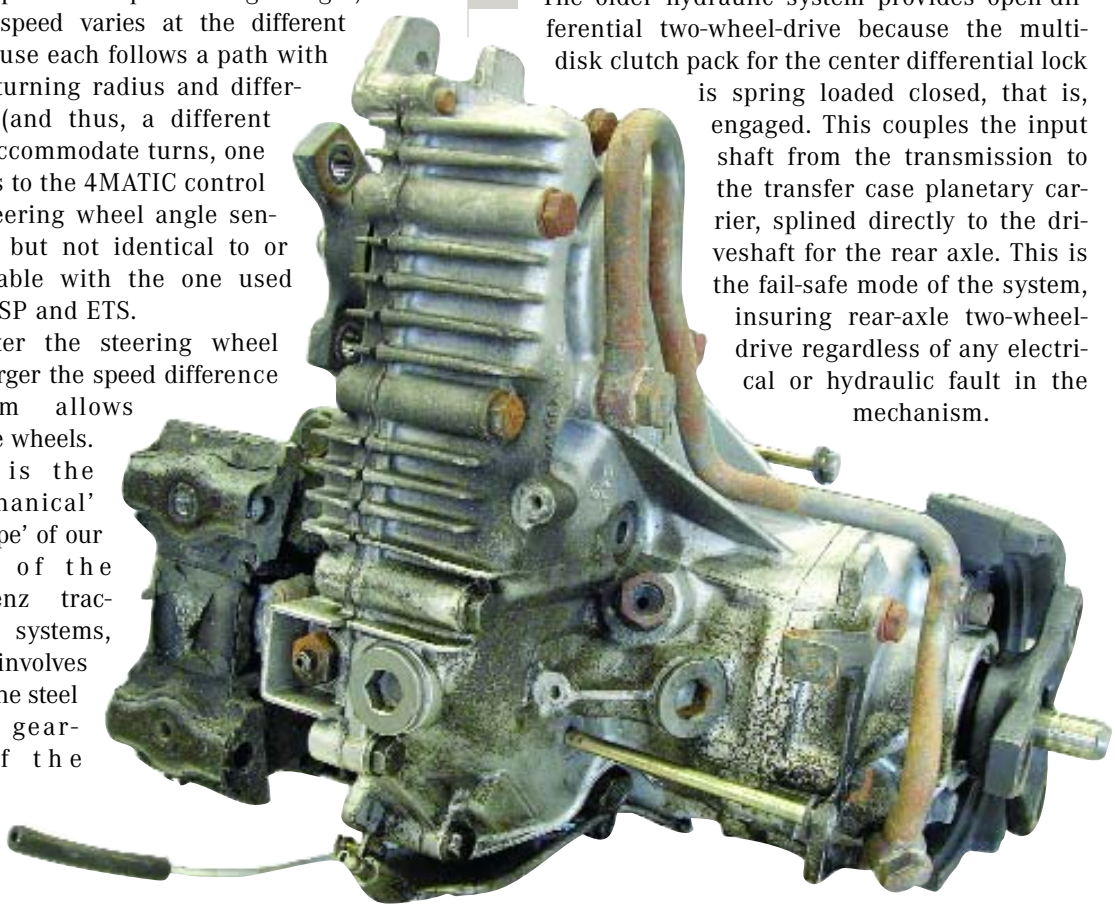
Perhaps the most important such contrary condition occurs during hard-braked, ABS-pulsed stops, particularly in turns. If four-wheel-drive were still engaged under those conditions, it would be possible for the interconnected drivelines either to mask a wheel's slip from the sensor's report and thus block the control unit's recognition and countermeasures, or to force a wheel with limited traction to turn at the same speed as the others (this last is most noticeable during a steep turn or rapid steering changes, when wheelspeed varies at the different wheels because each follows a path with a different turning radius and different length (and thus, a different speed). To accommodate turns, one of the inputs to the 4MATIC control unit is a steering wheel angle sensor, similar but not identical to or interchangeable with the one used with ASR, ESP and ETS.

The greater the steering wheel angle, the larger the speed difference the system allows between the wheels.

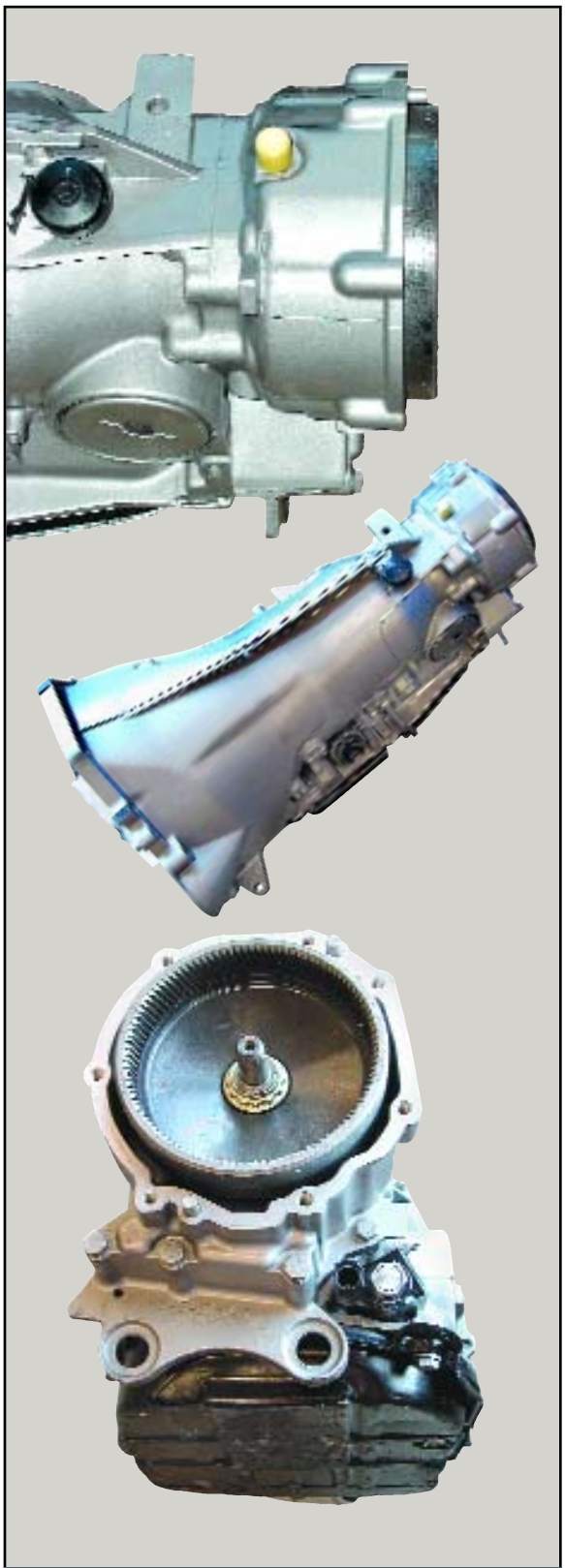
4MATIC is the 'most mechanical' (thus the 'Pipe' of our subtitle) of the Mercedes-Benz traction control systems, because it involves not only all the steel shafts and gearworks of the supplementary front drivetrain and the transfer case, but also a detailed hydraulic system, from pump to actuator pistons, to actuate the various differential locks that come into play under conditions we'll discuss in a minute. ETS, the new 4MATIC system employing 4ETS, in contrast, works mainly electronically (thus the 'Wire' of our subtitle), with the control unit activating specific wheel brakes to keep the wheel with the least traction from spinning. ETS works specifically with two-wheel-drive cars; 4ETS applies to those with a front driveaxle. Somewhat confusingly, 4ETS is also called 4MATIC.

Here are the progressive steps 4MATIC employs when the wheelspeed sensors and the steering wheel sensor information point to drive-wheel spin: Driving along an ordinary road with good traction and no wheelspin, the car works by ordinary two-wheel-drive with an open differential at the rear drivewheels. This provides the best combination of drive and directional traction in the absence of a problem.

The older hydraulic system provides open-differential two-wheel-drive because the multi-disk clutch pack for the center differential lock is spring loaded closed, that is, engaged. This couples the input shaft from the transmission to the transfer case planetary carrier, splined directly to the driveshaft for the rear axle. This is the fail-safe mode of the system, insuring rear-axle two-wheel-drive regardless of any electrical or hydraulic fault in the mechanism.



The system works hydraulically, but it's also internally lubricated with oil. If the seals on the multidisk clutch pistons start to leak, the hydraulic oil can fill the transfer case and begin to run from the vent. The loss of hydraulic fluid would be obvious long before that.



The transmission for 4MATIC is identical to the transmission for the car without that option, however the 4MATIC version includes a ring gear and flange on the output shaft of the gearbox.

When the sensors indicate the rear drivewheels are turning faster than the front wheels, at a threshold determined by the control unit as wheelslip, the system switches over to its first shift stage, 'compensated' four-wheel-drive. 'Compensated' four-wheel-drive is neither an open differential nor one that's locked. Instead, the geometry of the transfer case gears routes 65 percent of the torque to the rear axle and 35 percent to the front. This allows all four wheels to turn at different speeds, but within plausible constraints of how much traction they might have and how much drive torque they can absorb. The system selects this stage by applying hydraulic pressure to both the clutch packs in the transfer case, unloading the spring-loaded center differential lock and engaging the front axle drive clutch.

The third stage, the second shift stage, locks the interaxle differential by releasing hydraulic pressure to its clutch (allowing the spring to lock it) while maintaining engagement pressure to the front axle clutch. Now we have traction similar to that old Jeep – it won't get stuck easily, but a steep turn could be a problem, were it not for the steering angle sensor, which would signal time to return to the previous shift stage. To prevent engine surge, the system briefly engages this stage every time, releasing the center lock shortly thereafter.

The fourth stage, the third shift stage, adds the lock for the rear differential, preventing those drivewheels from turning at significantly different speeds. There is no differential lock on the front axle differential because that could cause a steering problem. Better that a driver gets temporarily stuck than temporarily loses steering.

Since the disks don't mechanically lock, there is still enough difference of speed between the halfshafts to accommodate the difference of speeds in ordinary maneuvers and turns. The system 'locks' with a substantial but not excessive resistance to turning at different speeds. There is, in fact, a test you perform with a torque wrench to check the frictional force of the hydraulic 'lock.' Specifications vary by model, largely reflecting the weight of the car and its consequent traction. Like any test involving a live drivetrain on a hoist with the engine running, this requires considerable attention to the correct procedures to prevent an accident.

There are three differentials involved in 4MATIC: the familiar one in the pumpkin case at the center of the rear axle, a similar one in front sharing a housing with the oilpan, and a sun-and-planetary design in the transfer case connecting the front and rear driveshafts. There is no locking clutch in the front axle differential, because locking the steering wheels together would destabilize the car during turns. The locking clutch in the rear axle differential is essen-

It seems odd to see front-drive components on a Mercedes-Benz, but that's what comes (in addition, obviously, to the rear drivetrain) with 4MATIC. The front differential shares the oilpan metal housing.

tially the same mechanism familiar from ASD, which we discussed in an earlier issue. Notice each of these differentials is necessary for all but the most primitive of four-wheel-drive systems. And the Mercedes-Benz system is far from the most primitive.

The interaxle differential does not look much like a differential, but here's how it works. The transmission for a 4MATIC car is the same as for the others, but the tailshaft ends in a ring gear shell rather than the output shaft and three-lobed driveflange that couples to the driveshaft through the flexible rubber joint (the 'Gobbo' joint). The internal teeth of that output ring gear shell engage what initially appear to be the planetary gears on a carrier. Closer inspection, however, reveals a second set of planetary idlers driven by the first set, and these second gears engage the sun gear at the center.

This arrangement of sets of planetary idlers on the carrier is called a "Ravineaux gearset," and grizzled *StarTuned* readers long on the job may recall that was the central gearset of the two-speed automatic transmissions long used in domestic automatic transmissions. The reason for using a Ravineaux gearset is that the geometry allows the sun and ring gears to turn in the same direction. The relative sizes of the sun and planetary gears determine the torque split front to rear when the center lock is disengaged.

Notice this may mean there is still no usable traction. It is much less likely that traction conditions will be so poor that none of the wheels will have sufficient traction to move the car, but that is possible. We can all imagine (and some of us who live in the North have experienced!) conditions under which this is just what happens – all the wheels spin, but the car still can't move. Like all the traction-control systems, 4MATIC is limited to working in the real world with real-world physical limitations. It works very well, but not magically.

Working with 4MATIC

The 4MATIC hydraulic pump is actually two pumps, the first for the power steering. The same hydraulics also serve the hydropneumatic suspension system, if the car includes that.

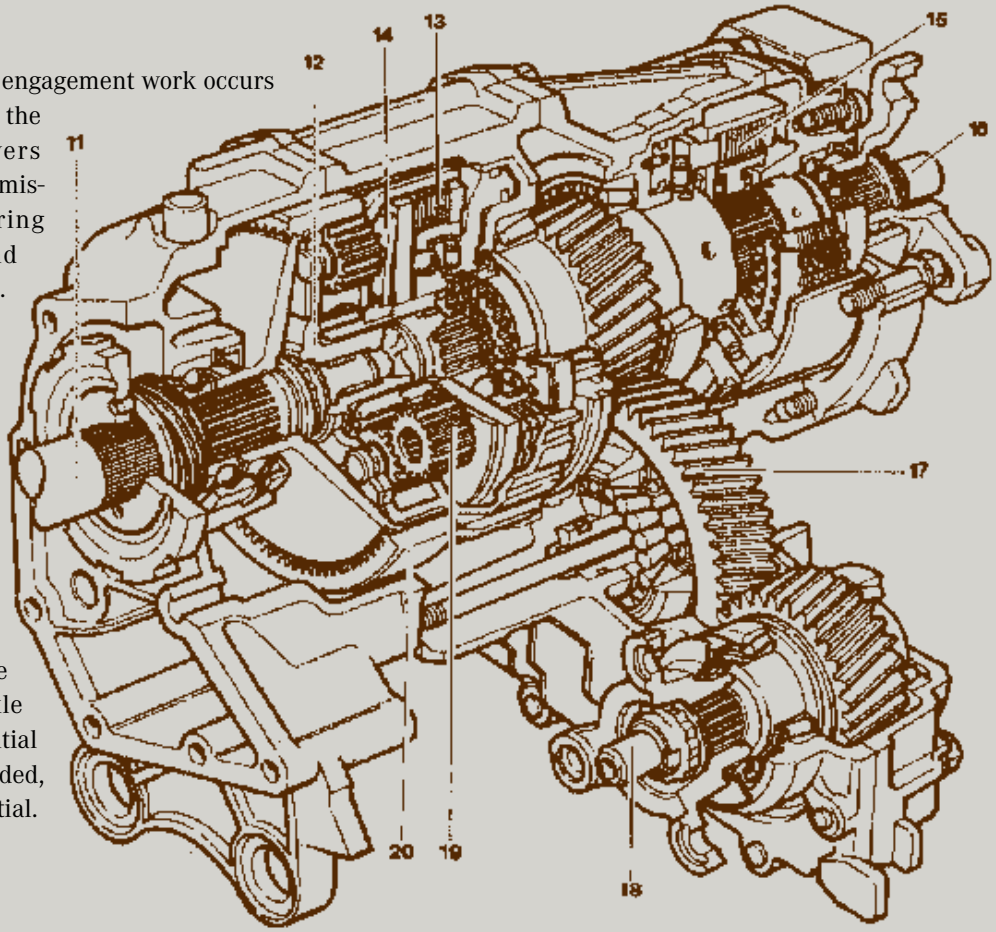
Here are some service points when working on a 4MATIC car. As with any hydraulic system, air bubbles and leaks sometimes occur. You can often flush air through the system by merely toggling the service valve forward to the test position and running the engine. This opens the circuits and lets the oil flow. If there is still air in the system, you can vent it from the caps on the rear differential pistons and by loosening the hydraulic lines at the transfer case until the oil flows clear – usually only a few seconds. By anecdote, the most common part requiring replacement is the pump, but this is probably because the pump is the high point in the system and loses lubrication first if there's a leak. This tandem pump forms a unit with the power steering system and also provides hydraulic pressure for any vehicle with hydropneumatic suspension.

The accumulator, a compressed nitrogen chamber atop the hydraulic control unit, includes a diaphragm to separate gas from oil. If that diaphragm eventually

Continued on Page 14

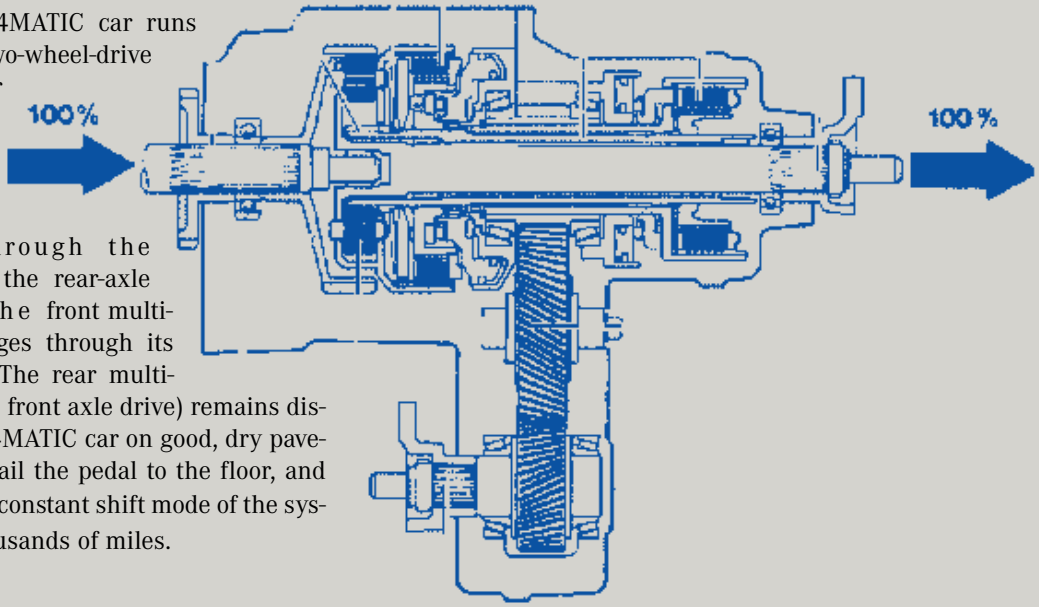
Shift Modes

The earlier, hydraulic 4MATIC works through the transfer case and rear differential, so it is worthwhile seeing exactly what happens when the system functions normally. There are three differentials: in the rear axle, in the transfer case and in the front axle; and there are three multidisk clutches: two in the transfer case and one in the rear axle. Here's how they sequentially engage as traction conditions require (reflected in the sensor input information):

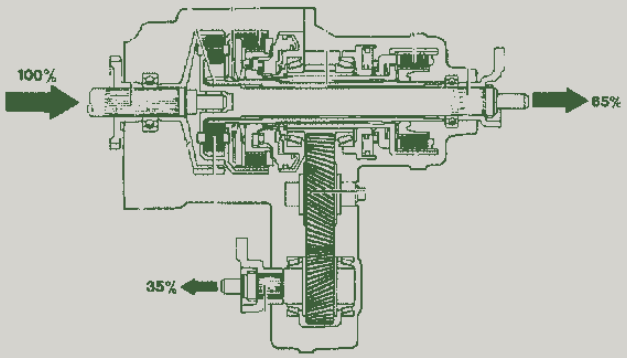


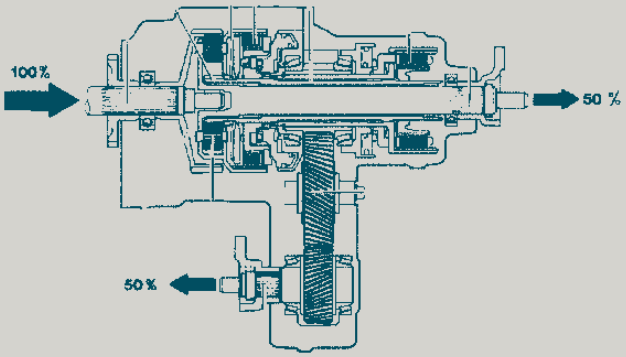
Most of the 4MATIC engagement work occurs in the transfer case, the gearbox that delivers torque from the transmission output shaft's ring gear to the front and rear differentials. Initial drive torque is 100 percent to the rear axle, switching to 35/65 front/rear or 50/50 front/rear, as calculated by the electronic control unit from the wheel-speed and steering-wheel-angle sensors. The final shift mode engages the interaxle (transfer case) differential at 50/50 and, as needed, locks the rear differential.

First Stage



Normally, the 4MATIC car runs under the same two-wheel-drive as every other Mercedes-Benz. Engine output torque through the transmission twists through the transfer case to the rear-axle output shaft. The front multidisk clutch engages through its preload springs. The rear multidisk clutch (to the front axle drive) remains disengaged. Keep a 4MATIC car on good, dry pavement and don't nail the pedal to the floor, and this could be the constant shift mode of the system for many thousands of miles.





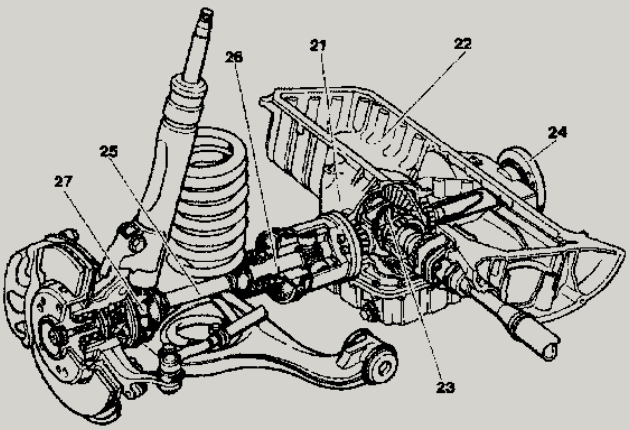
Second Stage

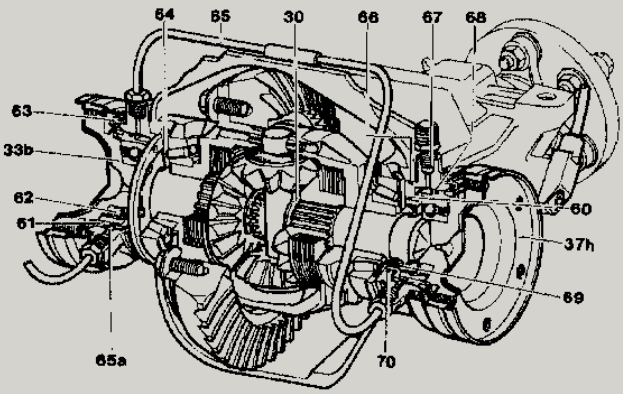
If the wheelspeed sensors report a difference between rear drivewheels and fronts beyond a certain threshold (a somewhat flexible threshold depending on the steering angle sensor input as well as the vehicle speed), the first traction-control measure is to engage the front axle drive. The system does this by engaging the multidisk clutch at the rear of the transfer case. Once this clutch engages securely, the system then immediately disengages the spring-loaded front transfer-case clutch. A check valve and fixed orifice preclude disengagement of the front should the rear engagement fail – to insure the vehicle can still drive with at least rear-axle two-wheel-drive under all circumstances, as well as to prevent engine overspeed.

This shift mode is called "compensated four-wheel-drive" because the torque to the wheels falls into a 35/65 front/rear proportion as a geometric consequence of the relative sizes and configurations of the gear wheels in the transfer case's Ravineaux gearset. Except for the momentary pause to confirm engagement of the rear multidisk clutch before the front releases, all three of the car's differentials are open at this point, and you have drive to both axles.

Third Stage

If there is a difference in wheelspeed from front to back even with the compensated four-wheel-drive engaged, the system locks the center differential. The mechanism for doing so is to vent the pressure at the front multidisk clutch, allowing the spring to re-engage it. Once both transfer case multidisk clutches engage – the rear by pressure applied, the front by pressure released – both output shafts rotate exactly together. As explained, this improves traction as long as the vehicle moves in a straight line, but can be a problem in a turn. However, 4MATIC includes the steering wheel sensor, so that problem should not occur.





Fourth Stage

The front differential is a permanently open differential because otherwise there might be a problem with steering. The rear differential is usually open, but if there is still a difference in drivewheel speed, after all the corrections of the previous shift modes, the system locks the rear axle to make its wheels turn at the same speed. This final state of the 4MATIC system has both rear wheels turning exactly together and the front wheels turning an average speed exactly equal to the rears. Only if all these measures are insufficient will the driver have to call for help.

Continued from Page 11

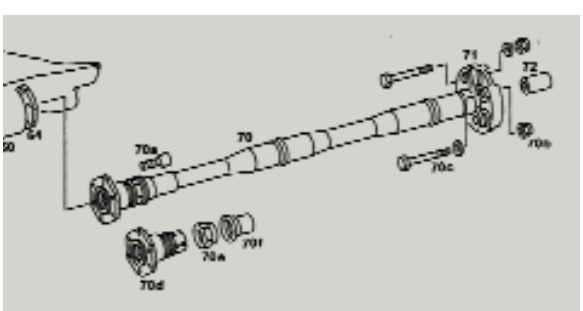
leaks, the accumulator can cease priming hydraulic components and can allow the system to make periodic 'water-hammer' clunks as the pump cycles. If the noise goes away with the service valve in the test position, suspect the accumulator.

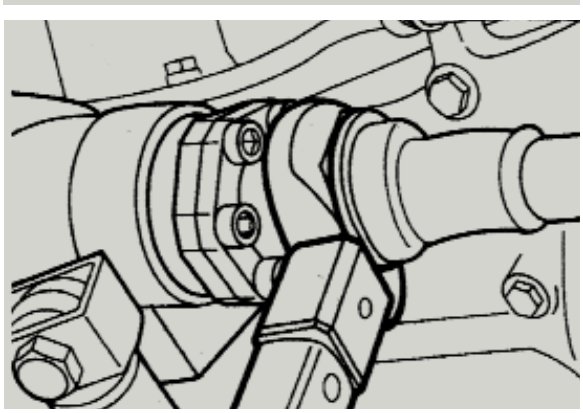
A mechanical problem that may set you to scratching your head comes if you remove the front driveshaft. With the rear driveshaft, you can bend it in the middle at the center bearing to shorten it and remove it from the car. But there is no joint in the short front driveshaft. Instead, you pull back the rubber boot at the front, loosen the locking cap and slide back the splined coupling. Pay close attention to centering the shaft in the flexible joints on reassembly, or you could have a running noise that will be very hard to diagnose. Match-marking the parts with chalk or paint is a reasonable precaution.

Traction by Wire

ETS and its multi-axle analog, 4ETS, are simpler, electronic variants of ASD and the earlier hydraulic 4MATIC. The simplification comes from the absence of the hydraulic distributor-lockup components involved in ASD and 4MATIC. Don't be misled, however, there is still plenty of hydraulic work afoot – but through the brake system. Instead of controlling wheelslip by locking one or more differentials, ETS selectively actuates the brake on whichever drivewheel slips. Not all ETS cars have four-wheel-drive, but those that do employ plain open differentials all around, counting the unclutched sun-and-planetary in the ETS transfer case as plain and open.

Such traction increase must obviously toggle on and off very rapidly, as fast as the driving conditions change. This is possible only with a digitally controlled automatic system, one that works directly from sensor inputs rather than just from driver controls. The driver, after all, has many other tasks to perform.





Like ASD, this could mean there would still be drivewheel slip if there were more delivered engine torque than the available traction could employ. In such a case, both drivewheels would slip, not just the one; but a driver with any level of awareness of driving dynamics should have noticed the problem and lightened his foot. To encourage development of this awareness, the instrument panel includes a warning lamp that the system is at work retaining traction, and that the driver should accommodate his expectations to the physics of the available wheelpatch-to-pavement friction.

ETS works in ways quite familiar to people who know ABS, ASR and ESP. Preventing drivewheel spin by applying the wheelbrake, in fact, could be marginally more effective than locking a differential, since the system could control all four wheels at different speeds effectively. With the open front differential, the older, hydraulic 4MATIC cannot do that.

Off road, More Offroad and *Way* Offroad!

Four-wheel-drive for vehicles that mostly remain on paved roads serves a different purpose from four-wheel-drive for tractor-lug wilderness explorers. Just as with the other traction-control systems, this one increases the effective use of the limited traction to help maintain optimized control for the driver, even under circumstances of unexpectedly slippery surfaces or other such control risks. Cars driving on pavement have different, but not less serious need for traction controls. They may not be called upon to climb over a fallen log or obstructing boulder, but they may have to deal with a pothole, a patch of black ice and a graveled surface, all within a fraction of a second and at different wheels. The drive traction enhancement is similar, but for quite different purposes.

4MATIC and 4ETS cars are the subject of our major feature this issue, but four-wheel-drive is nothing new to Mercedes-Benz. While these cars can drive on unimproved roads and even briefly on relatively smooth fields, the company builds other four-wheel-drive vehicles more suited to greater distances from the pavement.

No doubt, you're familiar with the M-class Mercedes-Benz, Stuttgart's entry into the SUV market. It actually hails from Tuscaloosa, Alabama, but it's still a Benz. We plan to carry features covering the M-class in upcoming issues of *StarTuned*.

A bit more rugged and a bit more suited to offroad travel is the *Geländewagen.* While this is an established design (the bulletproof 'Popemobile' has been around for years), the carmaker has been importing them to the USA since 2000 so you should be seeing them in your workbay.

Finally, and most gnarly of all, is the Unimog. Probably the most capable offroad vehicle on wheels, if you can't get somewhere in a Unimog, you should probably reconsider whether you really want to go there. When somebody with a Monster-Mudder truck gets buried in the muck, he has to find a helper to come with a Unimog. When somebody with a Unimog gets mired, he has to find someone who can come help with a vehicle that clanks along on its steel tracks. There are various sizes and types of Unimog, from about the size of a pickup to a match for a quarry truck. 'Mogs have been imported in small numbers for many years, often used for heavy construction, railroad switch engines, expedition mother vehicles or, equipped with some of the huge variety of special-purpose implements (even snorkels – really!), doing everything from digging ditches, plowing snow and blasting out rain sewers to cutting weeds and planting telephone poles. If you want to learn more about Unimogs, let us know. We would, too!

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 technical sources combine to make this possible.

Feature articles, derived from approved company sources, focus on being useful and interesting. Our digest of technical information 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 diagnostic 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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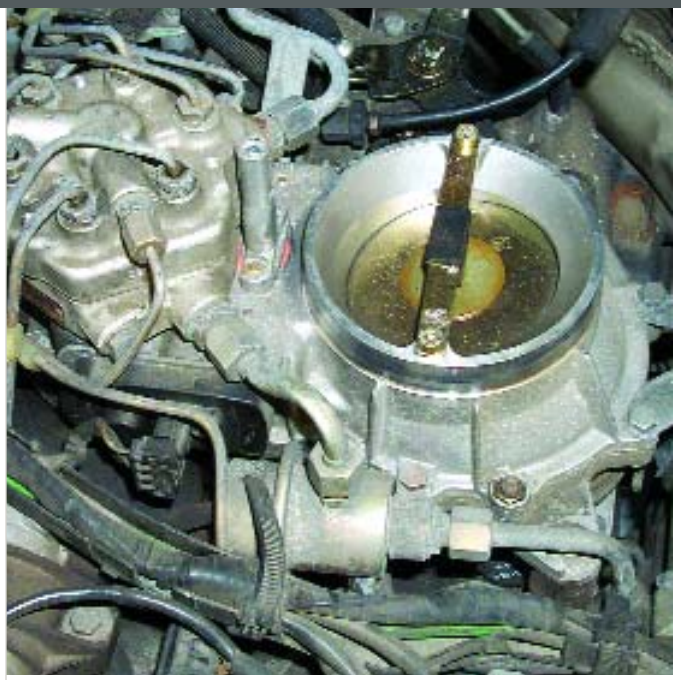
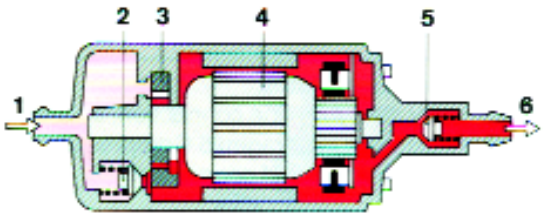


FUEL PRESSURE AND VOLUME

It's not always easy to check something simple

In days of techno-yore, when carburetors mixed the fuel and air for an engine's intake, you could usually check for fuel with a glance at the dash gauge followed by a look down the venturi as you cycled the linkage. If you saw a squirt from the acceleration-enrichment pump nozzle, there was fuel; otherwise, the bowl was empty. Then the question was *why.*

11) Electric fuel pump.
1 Suction side, 2 Pressure limiter, 3 Roller-cell pump, 4 Motor armature, 5 Check valve, 6 Pressure side.



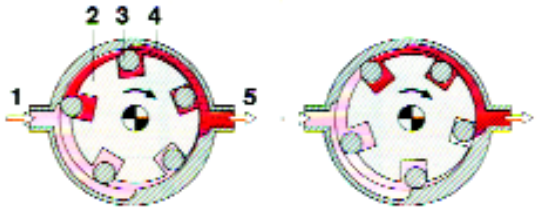
The electric fuel pump used for fuel injection is an electric motor and a meshed lobe or roller forced-displacement pump running in and cooled by the fuel. Wear points include the brushes and commutator at the pressured end of the armature, the bearings at either end, the check valve and the pressure relief. With enough grit in the fuel, there could even be wear of the lobes or rollers themselves.

Fuel injection brought many combustion and emissions advantages, but it did not bring diagnostic simplicity. You still glance at the dash gauge first (and if a functional Benz gauge says the tank is empty, it's empty), but you need more than your eyes and fingers to check fuel delivery now. If you don't find the right pressure and volume, of course, the question is still *why*.

The tools necessary are a fuel pressure gauge and suitable adapter fittings, a graduated two-liter flask or beaker, a switchable electric jumper (like a remote starter button), a clock with a second hand, and (for many models) a hand-actuated vacuum pump and gauge. You also need to know what to do with them, which is our business here. Finally, though we certainly hope it's permanently unnecessary, have a fire extinguisher within reach. For safety, disable spark and any other source of flame. Don't smoke or let anyone else smoke nearby. There's a lot of heat energy in sprayed gasoline, and it catches fire very easily. That's why we suggest the pushbutton jumper – if you suddenly jump back, the pump stops.

Generally, we think of pressure and volume tests as the procedure to check the fuel pump. That's true, of course, but that's not all. Those people who think working on cars is easy now because 'the computer detects the problem and tells you what to replace,' should consider what you can find with pressure and volume tests, neither one of them from the computer. Ten potential problems immediately sprung to mind, though pinpoint tests remain on the agenda to determine which. You can probably think of more:

12) Operation of roller-cell pump.
1 Suction side, 2 Rotor disk, 3 Roller, 4 Roller race plate, 5 Pressure side.



As on an oil pump, the armature is slightly eccentric to the pump housing centerline, so the rollers move in and out as the armature turns, forcing fuel by positive displacement through the fuel filter and through the supply lines to the fuel rail and injectors. Wear or scoring on the lobes, rollers or races allows fuel to bleed back toward the low-pressure side.

1. The fuel pump. An electric motor coupled with a roller pump, the fuel pump lasts a long time. But not, usually, as long as a car. Bearings, brushes and the commutator all wear; the check valve may develop leak back after time. How long the pump lasts depends largely on the quality of fuel, but you can begin to wonder about a pump when a car has between 100 and 200 K on the odo-clock.

2. The fuel filter. Current fuel filters can contain an amazing amount of dirt and grit before they clog up, and modern fuels are cleaner than ever. But some people still manage to collect enough debris into their tank to block passages. A motorist who regularly uses offbrand fuel or drove with the tank filler cap open for a time is a good candidate for a new filter.

3. The fuel pressure regulator. If it spills fuel back through the return line before there's enough pressure, a bad regulator can prevent starting or cause reduced power at every throttle setting. Like a defective check valve in a pump, a defective pressure regulator can dump system pressure right after the engine shuts down, requiring a long crank to restart.

4. The fuel lines. The most obvious loss of pressure and volume comes with an active leak, but that's rarely hard to diagnose. A more subtle and difficult problem comes with an air leak upstream of the pump, drawing in bubbles to displace fuel and absorb pressure.

5. The fuel injectors. If you clamp off the return line to eliminate the regulator from question, know the pump holds pressure but observe loss of pressure in the fuel rail beginning with shutoff, you have good reason to suspect one or more injectors of leaking.

6. The fuel sock and pickup. Most problems with these components arise after a tankful of dubious gasoline, leaving a coating on the initial filter and blocking suction to the pump. Sometimes you may discover problems resulting from earlier work in the tank.

7. The fuel tank. Some cracks or broken welds at the top of a fuel tank can go unnoticed since there's no visible leak, but they can allow moisture into the unprotected steel interior, producing rust that abrades the pump's working surfaces and plugs the filter.

8. The vapor/evap system. If a car has good pressure and volume to begin with but gradually loses both as it travels a hundred miles or so, the fuel delivery problem may not arise from the pump but from a plugged vapor/evap system vent. That can produce a vacuum in the tank working against the pump, enough of a vacuum sometimes to let the fuel vaporize at the pump intake.

9. The pressure retention valves. The regulator and the pump contain check valves and pressure limiting valves that can allow pressure loss if the seal between their mating surfaces becomes pitted or a piece of grit lodges in between.

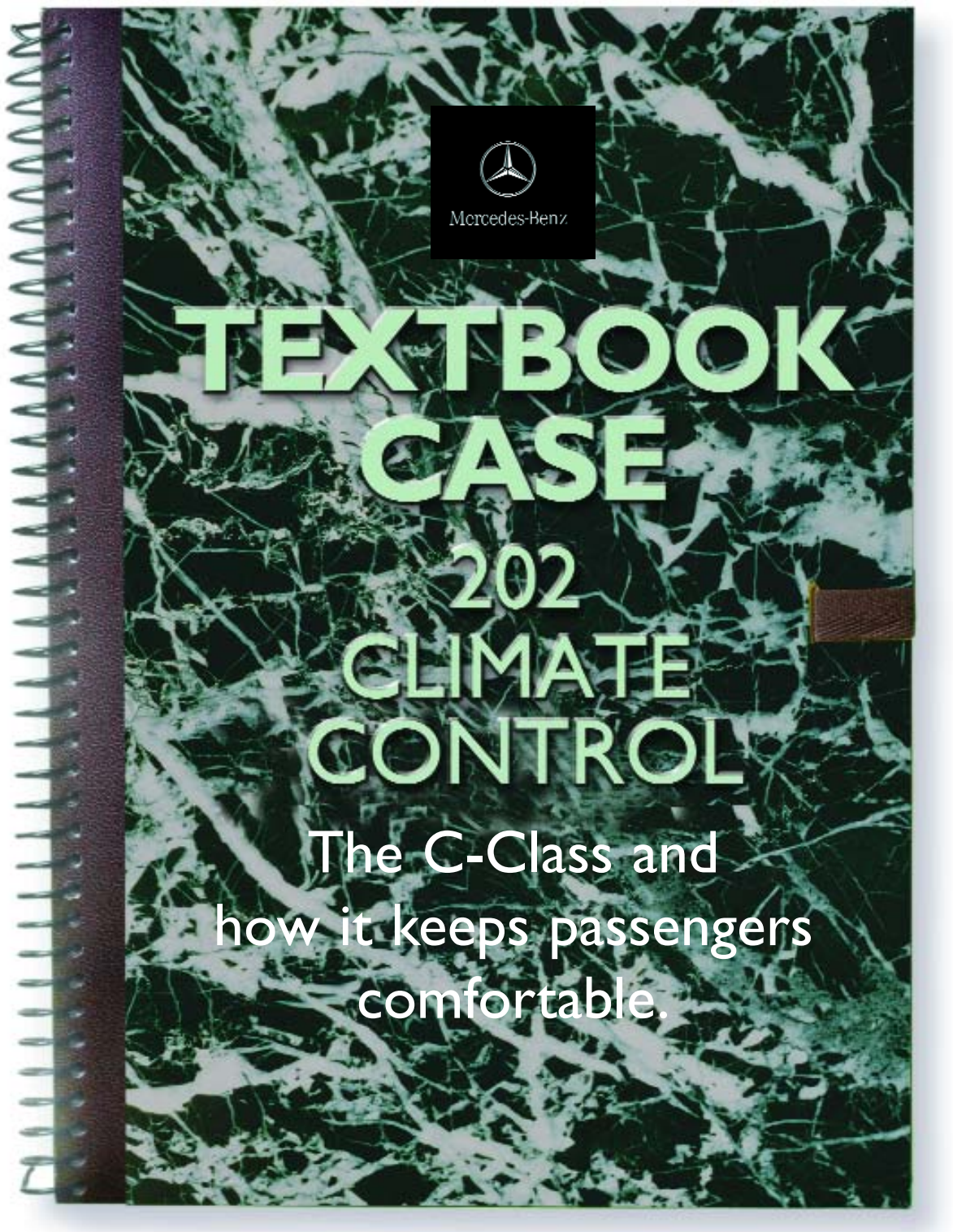
10. The electrical circuit. If there is notable resistance on the power line to the pump or on the ground line returning the current, that resistance effectively throttles the electric motor down, reducing both speed and torque. It doesn't take much loss of electrical power to drop the pump below minimum delivery thresholds.

Keep in mind the delivery specifications are not approximations and rough guesses. If the pressure doesn't reach the minimum, the injectors may deliver no fuel at all. If the volume isn't enough, the car will run out of power before the pedal runs out of travel. Be sure the pressure reaches the specified level and there is the specified amount of fuel in the beaker within the time limit.

The general procedure is this: Connect the pressure gauge to the test port following the diagrams for that model; clamp off the return line with a suitable, non-damaging clamp; route the line into a suitable graduated container.

When you complete a fuel pressure and volume test, make perfectly certain all the fuel lines you opened are securely sealed, without the slightest seepage of fuel. As dangerous as a fuel fire is in a shop with knowledgeable professionals available to put it out, it's much more so as a surprise on the road with no equipment or people to extinguish any flame.

In following issues we'll cover fuel pressure and volume tests model by model.


Mercedes-Benz
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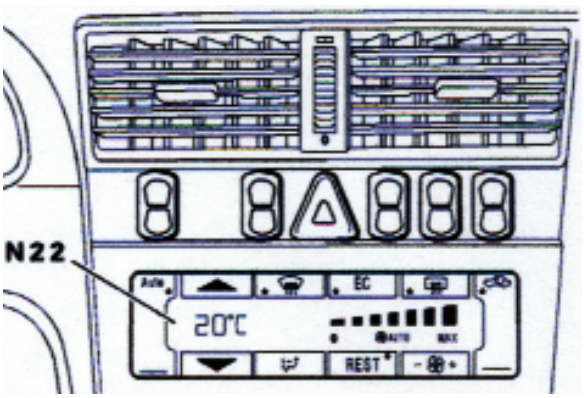
202 CLIMATE CONTROL
The C-Class and how it keeps passengers comfortable.

Slightly smaller and slightly simpler than some Mercedes-Benz systems, the 202 climate control nonetheless includes everything to do the job. The control unit behind the pushbutton plate, the boxes for the heater core and A/C evaporator, the ductwork, vacuum motors and lines to work the blend doors and finally, a dust filter.

There are many similarities from one Mercedes-Benz climate control system to another, but it can be useful to look in detail at one of the more common, as that's one you're more likely to see. The Model 202 C-Class was built between 1994 and 2000 and, by Mercedes-Benz standards, in relatively large numbers.

Neither the car nor the climate control system is the most complex of the company's products. The 202 HVAC, however, can keep its owners as comfortable as almost any automotive heating and cooling system. About the only climate-system luxury it lacks is a separate temperature selector for each front-seat passenger.



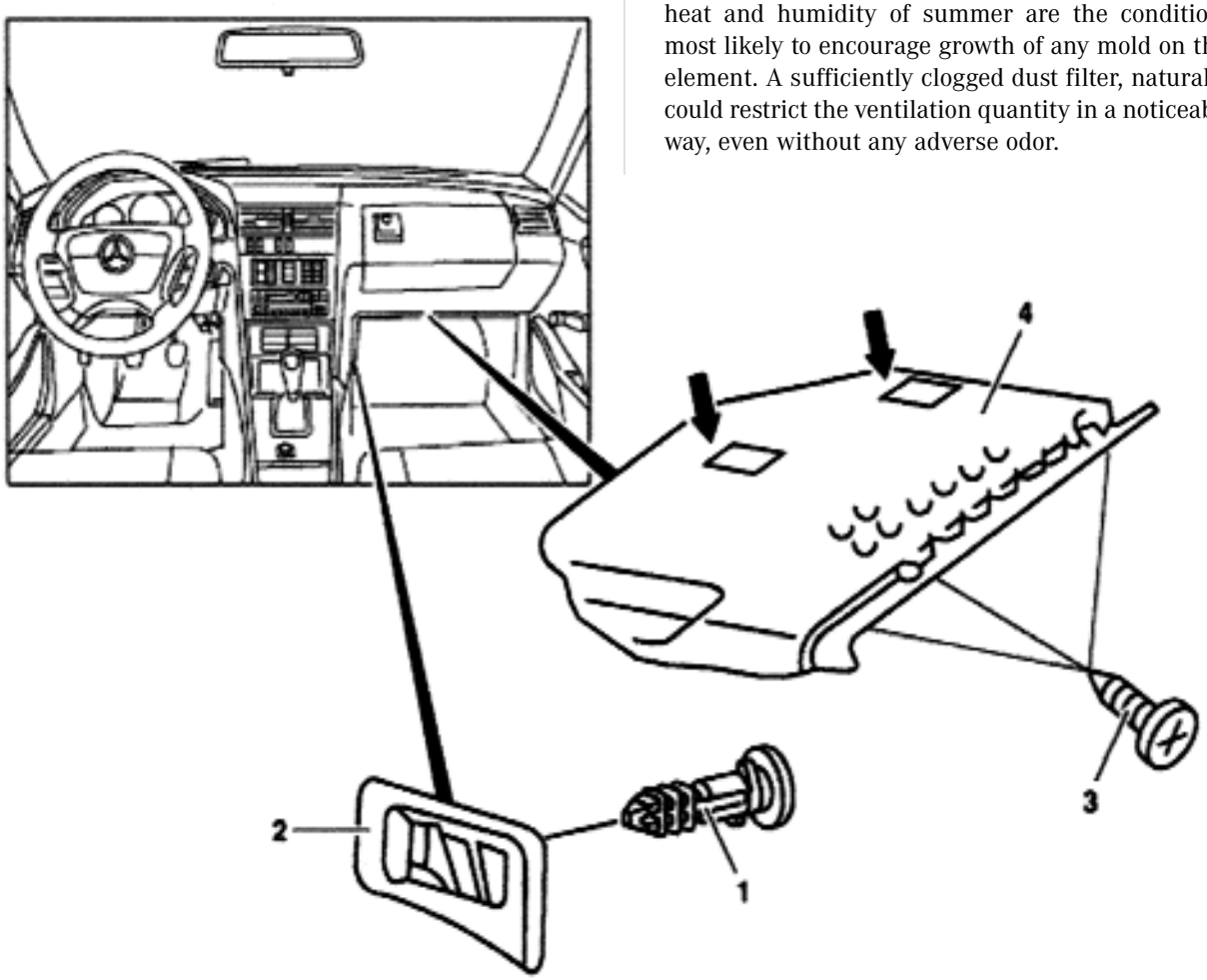
Like other Mercedes-Benz climate control systems, the 202's is fully automatic. The driver sets the desired temperature, and the car engages either the heater or the air conditioner to realize that temperature inside the car. Given normal comfort settings, this means the air conditioner starts as soon as the engine is running smoothly or the heater begins blowing warm air as soon as the engine coolant temperature rises to a range at which it can contribute something. If you're familiar with how automatic climate controls worked in older vehicles, like the 190, the 124 or the 126, there aren't many surprises waiting for you in the 202.

This time of year, air conditioning is likely to be more on your mind than heating or defrosting, but the system is not so distinct. Defrost, for instance, toggles both heat and the air conditioning on, to insure the driest and hottest air possible blown across the windshield. The system will do this regardless of climate control setting when the defrost button is pushed. This arrangement is not unique to the 202, nor is it for that matter to Mercedes-Benz. Given that safety considerations come first, the defrost mode must use every possible measure to dry and clear the windshield. Both air conditioning and heat are humidity-reducing

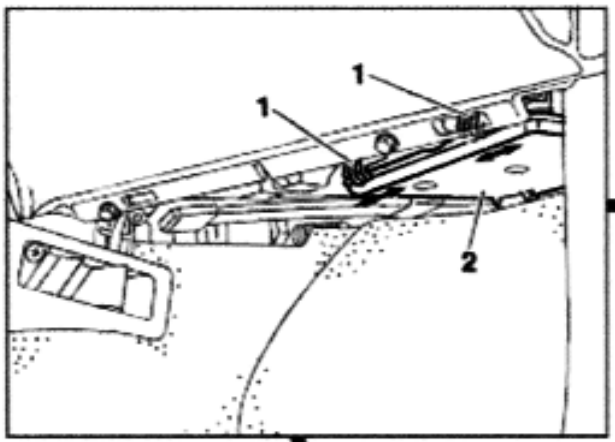
functions, the first by condensing moisture out and the second by raising the capacity of the air to absorb moisture in solution. Thus both come on simultaneously.

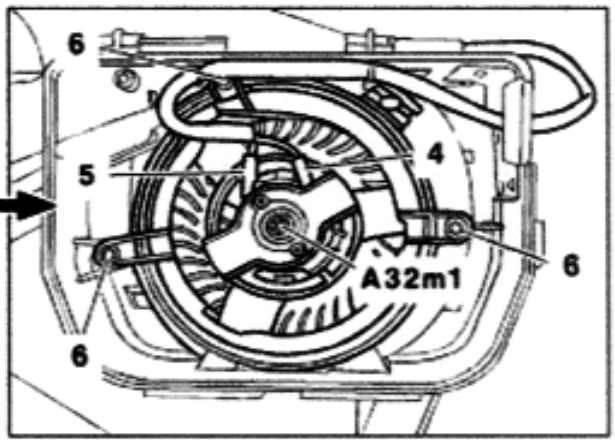
Clearing the Air

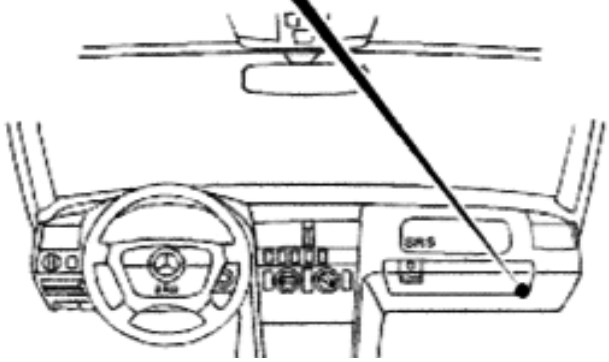
Almost the first element of the climate control system the incoming air encounters, whether the system is heating or air conditioning, is the dust filter. This is a relatively new component in cars (not just in the 202) and one that many car owners are not aware of in the car. Not being aware of it, they also are often not aware that it requires periodic replacement, like any filter. There is no set interval since there is no set amount of dust and pollen a driver will drive through, but checking at least once a year is a reasonable precaution, more often where there's lots of airborne material. At the beginning of air conditioning season is a good opportunity, since the heat and humidity of summer are the conditions most likely to encourage growth of any mold on the element. A sufficiently clogged dust filter, naturally, could restrict the ventilation quantity in a noticeable way, even without any adverse odor.



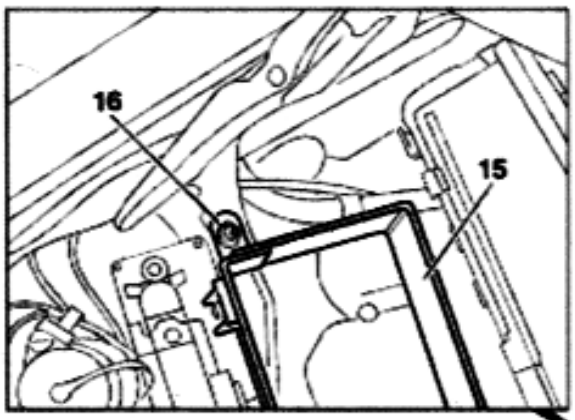
The filter comes out through the passenger side footwell. Remove the access panel and pull out the old one. This cabin filter does not use an evacuated bead to seal the edges of the filter, as was true on some other models. That means it's easy to remove and replace. Some cars have a charcoal-element filter; some do not. The two types are not interchangeable.

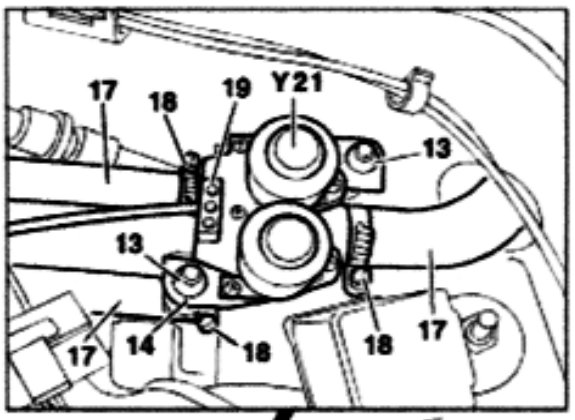


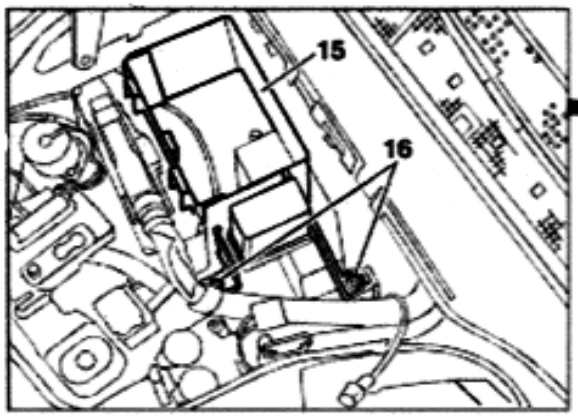


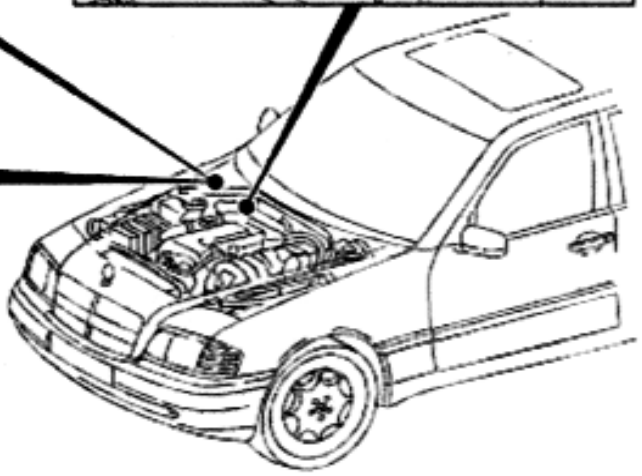


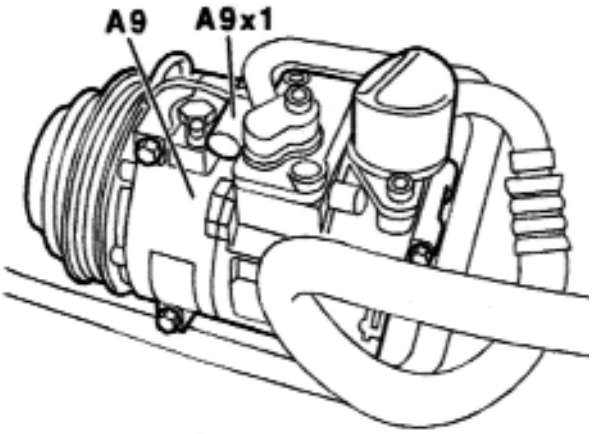
Just 'upwind' of the filter is the hood inlet drawing ventilation air in. One aspect of this requiring occasional inspection is the water separator and drain system just below the windshield wipers. Ordinarily, water and relatively small grit will just wash down through the trough and pipe to the pavement, but if there are many leaves, insect parts or other such debris in the air locally, it is possible to clog the drain and allow water to remain. This could possibly allow moisture into the ventilation intake.

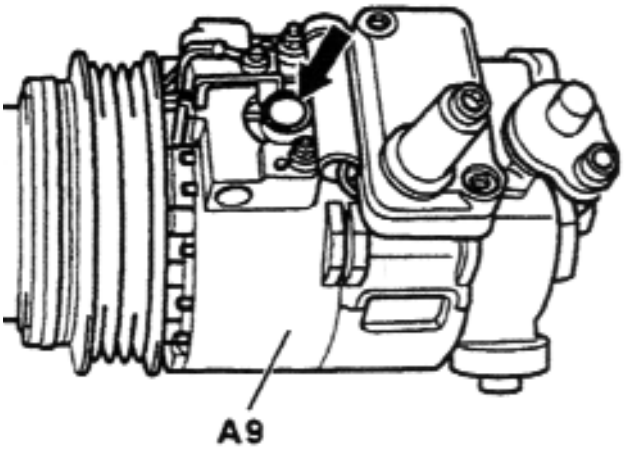


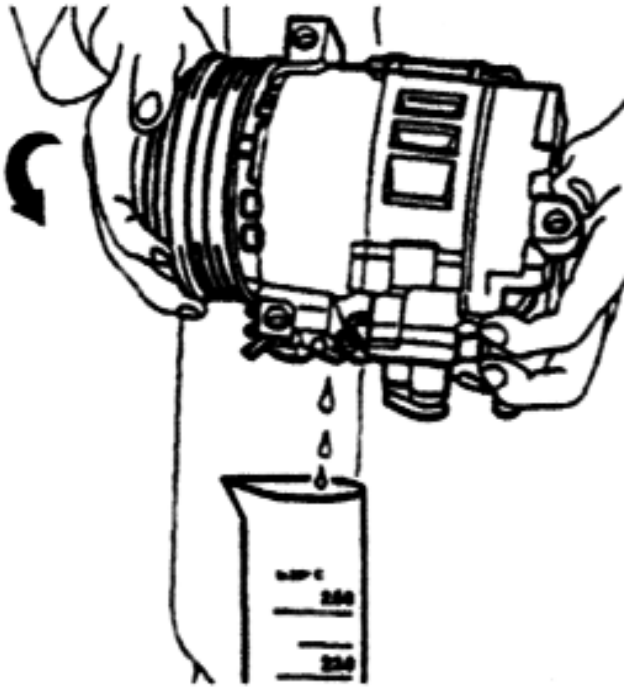


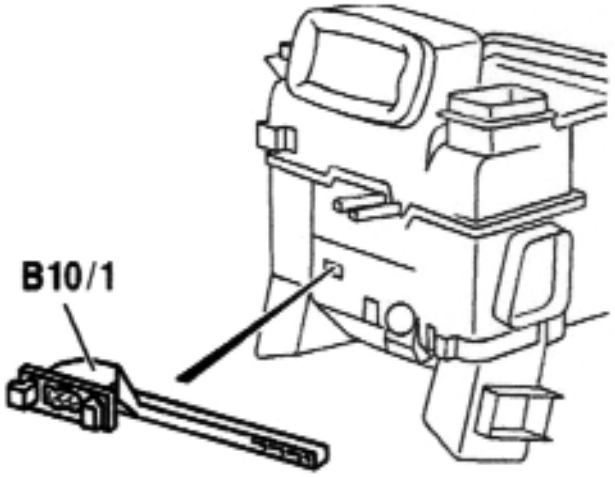












It's fairly easy to remove the lower panel under the passenger-side instrument panel and replace the heater blower. Be careful doing this, however. In particular, don't replace the blower merely because there is audible noise coming from it. Possibly the bearings have worn out after many years' service, but these are very long-lived components – it's more likely the blower has gotten louder because of debris reducing airflow, just as a vacuum cleaner gets louder if you cap off the hose with the palm of your hand. A slight piece of debris in the squirrel cage could also produce noise by unbalancing the cylindrical fan and introducing a slight wobble. By the way, don't 'test' the blower by jumpering it with a straight 12 volts; the system never uses that much to run the blower. It usually runs between 4 and 6 volts, with system voltage reduced through the series-resistor block.

The air conditioning compressor includes an rpm sensor to enable the MAS control unit to toggle the compressor off should the drive belt slip, as indicated by a change in the ratio of compressor to crankshaft speed. Because the system makes very efficient use of the modest amount of refrigerant, it is critical to measure the amount of oil in the system precisely if the compressor is replaced. Neither an excess nor a shortage of air conditioning oil is compatible with proper functioning of the climate-control system.

Sometimes problems with the entire climate control system arise from the simplest of causes. Like most Mercedes-Benz heating and cooling systems, the mechanism in the 202 employs a cabin temperature sensor in the overhead compartment. A very small fan draws air through

Continued on Page 28

Testing and Design

Perhaps some engineers and designers chose their work so they could travel to exotic and beautiful locations and enjoy the weather. That's probably not true of climate control gurus, though. They must test their prototypes in places that will challenge the capacity of the heat exchangers to shift enough BTUs, whether into or out of the car.

If they go to Houston, it's in August, to see whether their new, low-profile A/C condenser can cope with 130 degrees in the shade. If they go to Bemidji, Minnesota, it's in January, to see how long it takes to clear a windshield of the Arctic hoarfrost.

Often, of course, they don't go anywhere special. Instead, they build a little cube of Greenland or the Sahara at the plant near Stuttgart, using insulated chambers and overwhelming heating or refrigeration equipment.

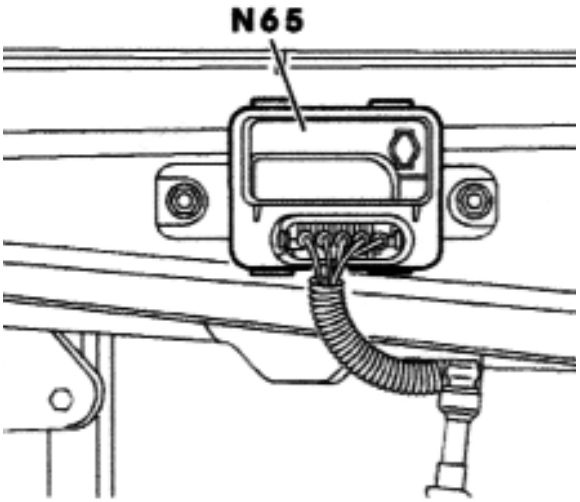
Is it overdone? Of course. If it weren't, there would be no way to insure the climate control systems could work in ordinary conditions. After all, ordinary conditions are not always so ordinary. Any idea how hot it can get in stalled traffic on the Cross-Bronx Expressway on the Fourth of July? Or how cold when the Alberta Clipper swoops through Minneapolis in February?

And this is not just for passenger comfort. Absent a driver who can pay attention to what he or she is doing with the wheel and the pedals, you can't have automotive safety. A climate control system can and does save lives.

Continued from Page 26

the louvers at that sensor anytime the car is running. The test for that fan is amazingly low-tech: take a small shred of paper and hold it against the louvers while the engine runs. If the fan is working, the paper will stay against the grate. If not, the paper will fall away.

Anytime you open up the refrigerant side of the air conditioning system, there are two precautions to observe. Oil for the system, like air conditioning oils for previous refrigerants, is hygroscopic, so it will draw moisture from the air, even from air that seems entirely dry to you in the shop. Once in the refrigerant passages, of course, that could quickly produce rust, and there's hardly a worse place for rust in the car. Be sure to cap any open pipe securely right away, or flush the system if it remains open for any length of time. When in doubt, evacuate the system again.



Second, it's almost always a good practice to replace the receiver/drier when you open the refrigerant side, just to be safe. Besides its function as a moisture absorber, the receiver/drier is also a filter that can catch most bits of debris that may work loose in the system. Otherwise, they could just cycle through the compressor, expansion valve and heat exchangers over and over until they found the most inconvenient and expensive place to lodge.

Finally, it sometimes happens that the windows fog and stay partly fogged, even when you push the defroster button. The first place to check with such a problem (after you're sure there's no sodden mass of wet leaves at the base of the windshield) is the switchover valve and linkage working the fresh/recirculate door, all of it in the same passenger-side area where the blower motor resides. There is a small hook working the door that may have broken or may have disengaged from the vacuum motor.

Keeping Cool, Keeping Warm

The now-discontinued Model 202 Benz can nonetheless keep its driver and passengers at a reasonable temperature in the passenger compartment, regardless of the outside climate. Follow standard diagnostic and maintenance techniques, and you can keep your customers happy and their cars comfortable.

Whenever you find the temperature control system doing something unfamiliar, it's worth your while to review what the system is supposed to do with the controls in a given position. Don't be embarrassed to look in the owner's manual to determine that. That little booklet can be a surprising source of good diagnostic information.

STARTUNED

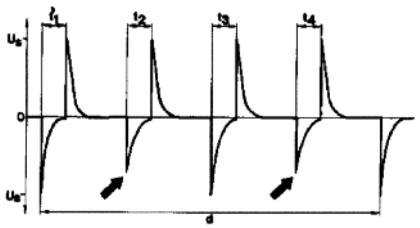
FACTORY SERVICE BULLETINS

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.

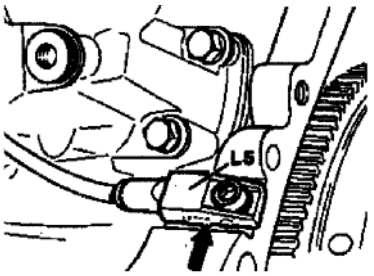
Sparked, Unsparked and Clanked
All Models with Engines 102 or 103

There's not much you hear in a car more alarming than a knocking metallic sound coming from the engine compartment. Sometimes, happily, the cause is not mechanical within the engine but something else. Check with your stethoscope and pay attention to the high voltages, but one more thing to check is the ignition coil itself. If the iron core in a coil comes loose internally, the electromagnetic pulses in the windings can bang the core to and fro rapidly, causing this suspicious noise. Coils known to have this problem have production codes between FD 845 and 847. There could be others.

Crankshaft Position Sensors

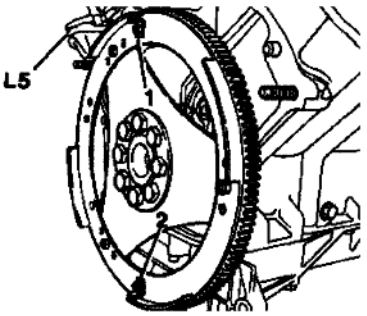


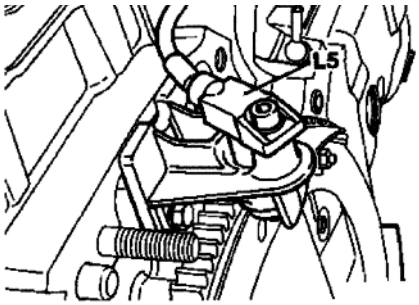
If the crankshaft position sensor doesn't work, the engine won't start. If it fails while the engine is running, it stops immediately. A loss of crankshaft position signal, however, does not mean a failure



of the crankshaft sensor. There could be other sorts of problems.

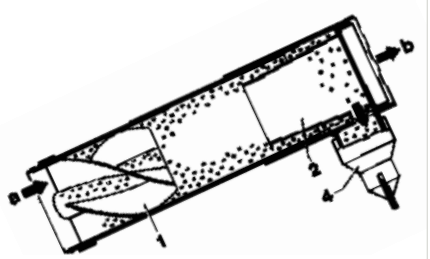
If you find an alternating current signal, but there is still a starting or running problem, check the signal not only with a voltmeter but with an oscilloscope. Some sensors should have pulses of sequentially variable amplitude when the flywheel includes segments and magnets. On cars where the sensor follows the flywheel teeth directly, the signal should be even.

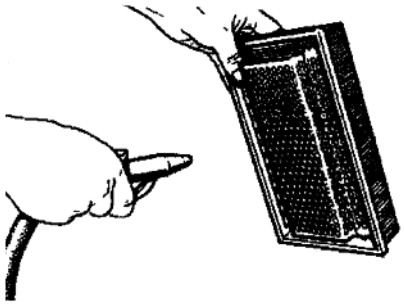




When replacing the sensor, make sure it does not contact any part of the flywheel, but also measure to confirm that it is close enough to the teeth to generate the signal (check the specifications for the car to confirm the minimum alternating voltage

Cleaning the Cleaners





You don't have to replace every filter anytime you discover dust on it. Certain air filters, like the cyclonic version or the steel-mesh backed flat filter, allow removal of large amounts of dirt by compressed air. In areas with very large amounts of airborne dust, it is frequently good practice to clean out the filter housing and the surface of the filter itself periodically before you replace the filter element itself. Many air filters actually become more effective with use, as particles fill the larger micropassages. Eventually, of course, all filters will present enough obstruction to airflow to impede the engine's breathing, and then it is time to replace them.

StarTuned

Parts News

Cabin Filters

We don't always think of the quality of the air as part of a climate control system, but one of the most important improvements in the internal atmosphere of vehicles in recent years comes from the dust filters that clean the air passed through the heating, air-conditioning and ventilation system. The most obvious benefits are a reduction in road dust in the passenger compartment, making life more comfortable for almost everyone, but particularly for those who have allergies or who drive in very dusty places.

The filters do more than that, however. You've probably tried to clean air conditioner evaporators and heater cores by spraying various chemicals through the ductwork. If there is much growth of mold at all, it's a pretty thankless task, unlikely to work for long. With a dust filter, however, it is possible to prevent that problem from arising at all. If the mold spores stop on the accordion-fold paper, you can remove them with the old insert.

Besides what the cabin filter does for the driver and passengers in terms of the comfort level from a cleaner air to breathe, it also has a safety function. Most people are relatively careful about keeping the outside of the windshield clean, so they can see what is coming down the road. It's much less common, however, for car owners to clean the inside of the windshield. Besides being less convenient to clean, the buildup of dust and grime is much more gradual, so there isn't the kind of perception of the vision-obstructing layer there is from road spray or bugs.

The cabin filter can't eliminate that problem, but it can reduce it substantially. The amount of dust and small particulates that used to collect on the inside of the windshield is much lower, so the need to clean the glass from the inside is proportionately reduced.

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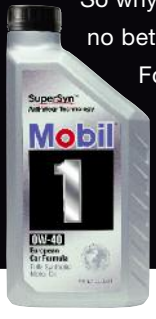

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