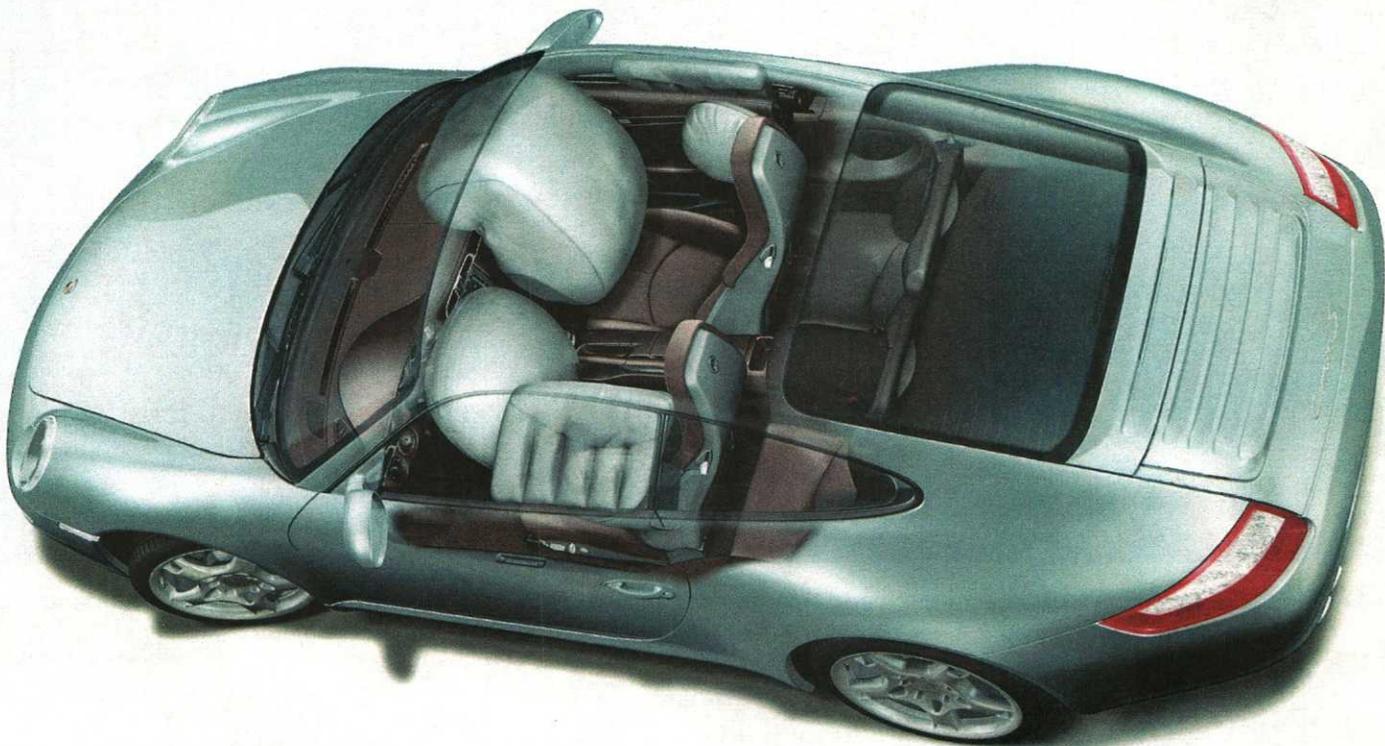


Porsche Airbag Systems

BY TONY CALLAS AND TOM PRINE



997-based 911s use six airbags (front, head, and thorax) to protect front-seat occupants.

Porsche introduced its driver and passenger airbag passive restraint system on the U.S. 1987 944 Turbo, making it the first vehicle with driver and front passenger airbags fitted as standard equipment. This system, standard on all 944 Turbos destined for the U.S., was also available here as an option on 1987 944s and 944Ss. By the 1990 model year, dual airbags were standard on all Porsches, as they have been on every production Porsche since.

Stuttgart was well ahead of the curve. Airbags with shoulder belts for the driver and front passenger were mandated by the National Highway Traffic and Safety Administration Act of 1991, requiring these systems to be installed in all vehicles manufactured after September 1, 1997. Porsche didn't rest on its laurels:

Its two-seat Boxster got door-mounted side-impact airbags for 1998, which were replaced for 2005 by seat-mounted airbags augmented by "curtain" airbags rising out of the tops of the doors to protect occupants' heads, another first.

Because airbags are a critical safety component, because airbags are largely ignored in Porsche media, and because many airbags are getting older, they'll be the subject of this *Tech Forum*, the first by Tony Callas and Tom Prine.

Airbags 101

Performance of airbags and related safety systems is defined in the Federal Motor Vehicle Safety Standards Section No. 208, Occupant Crash Protection. The main dynamic performance requirement in FMVSS No. 208 is a "Successful" test

rating using a 50-percentile (average height/weight) adult male dummy built to measure impact loads at specific areas of the body. The tests require impacts into rigid barriers (an instantaneous stop) from speeds up to 30 mph and at all angles between perpendicular and 30° to either side of perpendicular.

Some "Successful" test results require that the dummy's measured Head Injury Criterion (HIC) be rated at 1,000 or less. (For reference, an HIC of approximately 1,850 is generally considered not survivable). Deceleration measured at the chest must not exceed 60 *g*, and compressive deflection of the sternum (pushed in towards the spine) cannot exceed 76 mm. Additionally, forces transmitted axially through each upper leg cannot exceed 2,250 pounds.



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Clearly, these are tremendous loads for our bodies to endure. Airbags are a critical advantage, allowing a somewhat gradual deceleration of the head and upper body over an additional fraction of a second. They can be the difference between walking away with bruises and sustaining far more serious injuries.

Porsche's first airbags, like others, were designed to function in a frontal or near-frontal impact. A collision to the side or rear is not recognized and should not deploy the airbags. The system is meant to be used in conjunction with other passive-restraint systems, including a properly adjusted three-point seatbelt and Porsche's integrated headrests. The system consists of two front impact sensors, a control unit with safety sensor, airbags with gas generators, ignition pills in both front-seat positions, and a system monitor lamp in the instrument cluster.

When an airbag-equipped car sustains a frontal impact, sensors immediately measure the impact force. Airbags are not designed to deploy at a specific vehicle speed but rather at a set threshold of vehicle deceleration based on the vehicle's design. If the forces meet or

exceed the set threshold, the sensor switch closes, the control unit receives this signal and, if the internal safety sensor also closes, the control unit sends voltage to the airbag's pyrotechnic charge, which ignites and deploys the airbag.

From impact to full deployment, a driver's airbag takes approximately 30 to 40 milliseconds (0.030 to 0.040 second) — a time span comparable to an upshift in a modern F1 race car's transmission and much faster than the blink of an eye (about 0.2 second). A passenger airbag is larger and requires approximately 40 to 80 milliseconds for gasses to fill it.

Side-impact airbags must deploy far quicker, as there is no crumple zone and little space between the occupant and the door. Side-impact detection must take place within three milliseconds and complete deployment of the thorax and/or side-curtain airbags must be accomplished within 10 to 15 milliseconds.

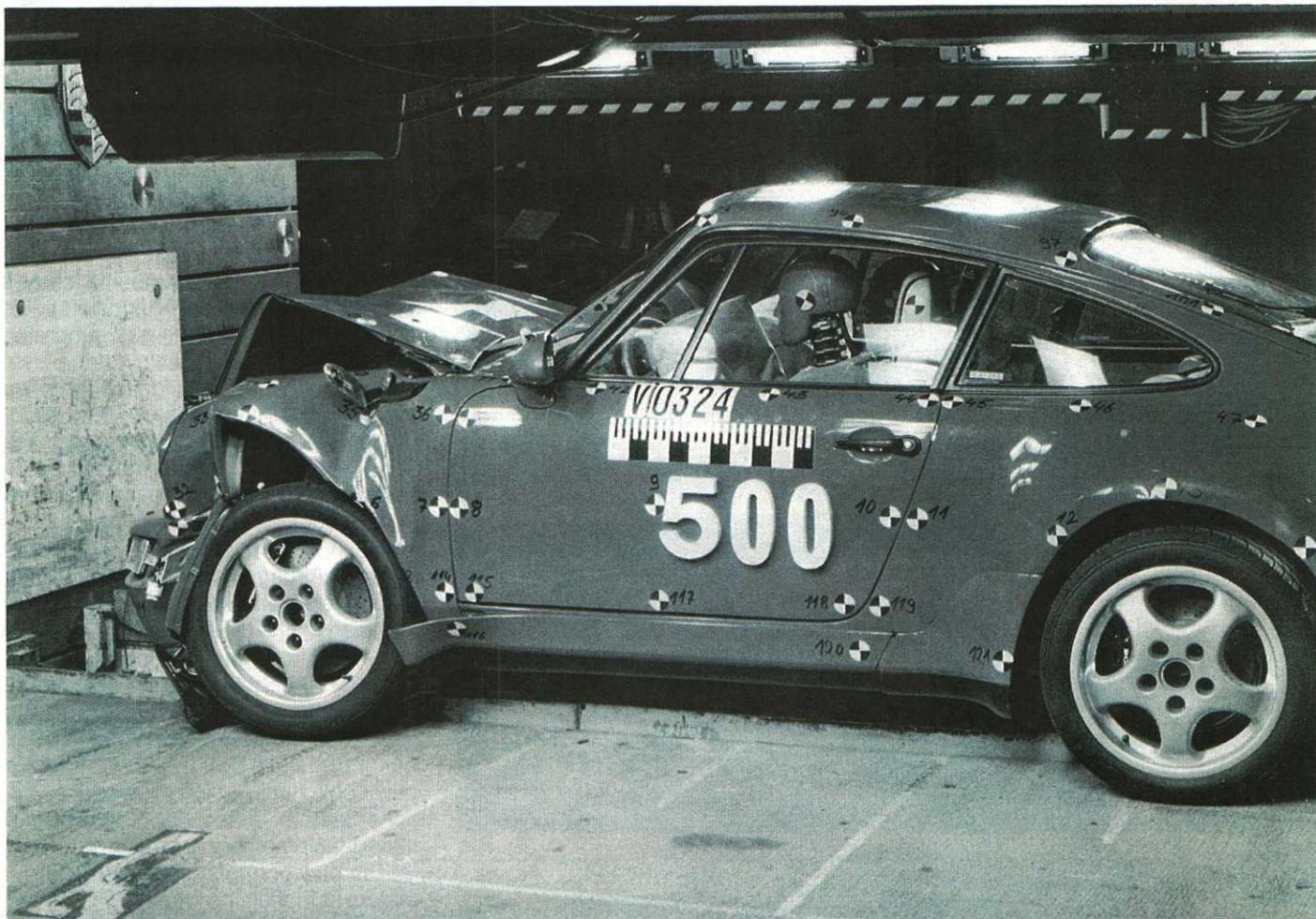
In the real world, crashes take place at various angles and with other vehicles at various relative speeds. An airbag will only deploy if the set deceleration threshold is met or exceeded. Hit a sizeable object or an animal on a highway

and your car will sustain moderate to serious damage, but the airbags won't pop unless the car decelerates abruptly enough to trigger a deployment.

Early Porsche Airbag Systems

The airbag system starts with a control unit, which provides diagnostic/fault monitoring with memory. It has a self-contained power supply with backup via a charging converter, a safety (triggering) sensor, and airbag firing circuitry. When the car's ignition is turned on, the system powers up and the diagnostic unit interrogates all airbag system circuits and components for resistance, capacitance, shorted or open circuits, power, and grounds. If operational status is confirmed, the airbag light turns off. Normally, the airbag light goes out in three to five seconds. Even so, a full diagnostic check continues for approximately 70 seconds.

The diagnostic unit monitors the system continuously, switching the airbag lamp on if a fault is detected. The airbag control unit utilized in the 944, 944 Turbo, and 944 S2 coupe (part number 944 618 217 00) stores faults in its memory and



The 1987 U.S. 944 Turbo (opposite page) was the first Porsche and the first vehicle to feature dual airbags as standard equipment. A 964-based 911 undergoes crash testing (above).

can be played back as blink-code sequences on the airbag light. Accessing fault memory requires activating the diagnosis circuit (pin 2) per the instructions in the 944 repair manual, section 68, pages 14–23. The 944 S2 Cabriolet utilized a new control unit (part number 944 618 217 01). With this unit, the fault memory could be downloaded using the Porsche System Tester 9288 (also known as the Hammer or Bosch KTS-300/301). In the course of the 1991 model year, all models were equipped with this unit.

The charging converter has a large capacitor that builds up internal power to 35 volts; this capacitor acts as backup power supply by holding the voltage needed to operate the system and ignite the airbags, even if power to the system is interrupted. The airbag system remains charged and completely operational for approximately 20 minutes after the car is turned off as voltage dissipates from the capacitor. Thus, before working on early airbag systems, wait a minimum of 20 minutes after disconnecting the battery to ensure airbag ignition power has dissipated. On later control units, starting with the 1995 993, the backup elec-

SAMPLE AIRBAG SYSTEM CHECK

The following is an example of a system inspection, this one specific to the 993-based Carrera. It is useful for other models as well, though details of item 2 vary by model.

1. Functional check of the airbag warning lamp: Switch ignition on. Airbag light must illuminate for about 3–5 seconds. If warning lamp does not come on, check condition of bulb and/or that supply voltage is present.
2. Functional check of fault memory: Turn on ignition (but do not start the car), pull out fuse supplying voltage to clock (fuse number 18), for approximately 30 seconds and then reinstall fuse. Airbag warning lamp must now display a fault. Connect a diagnostic tool and check the fault code; fault code 19 "airbag warning light, open circuit, fault not present" should be displayed.
3. Erase system's fault memory.
4. Check to confirm that no trim parts, decals, or other items are attached on the steering wheel or passenger-side airbag.
5. Check components visually for damage and/or any changes to the equipment.
6. All checks of the system must be recorded in stamp areas provided in the Warranty and Maintenance Book.



By 1990, Porsche made dual airbags standard equipment in all models. Top to bottom: 944, 964-based 911, and 928.

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trical charge is held for approximately one minute after turning the car off.

The control unit's internal safety sensor functions like the front impact sensors, by closing a switch at a specific threshold of vehicle deceleration. The airbags will deploy only when the unit's internal safety sensor and at least one front impact sensor switch have closed. The logic behind the internal safety sensor is to prevent accidental airbag deployment caused by something like a hard hammer blow near a front impact sensor while service work is performed.

The front impact sensors are located on the right and left wheel-housing walls,

with cables running from each sensor to the control unit. The front sensors function mechanically but are monitored electronically. Each sensor has a hollow roller that allows for the insertion of calibrating weights held in place by a tensioned spring band (wrapped around the roller) and mounted to the base plate of the sensor. An isolated electrical contact sits next to the roller and, in a frontal impact resulting in sufficient deceleration to overcome the spring tension, the roller moves forward to the contact and closes the circuit to the control unit. This type of sensor switch, called a Rolamite switch and developed by Sandia National Labora-

tories, was commonly used for airbag impact sensors until the mid-1990s.

Airbags are made of nylon cloth with an internal coating of Neoprene. Straps within are arranged to form the desired shape when inflated. The internal volume of a driver's airbag is approximately 60 liters while a passenger-side airbag is approximately 150 liters. The airbags are mounted on the housing of a gas generator filled with solid fuel in a closed combustion chamber. An ignition pill is fitted in the center of the gas generator. When the pill receives an electric pulse, it ignites, which in turn ignites the main pyrotechnic propellant fuel. The exploding fuel process produces nitrogen gas that flows into the airbag through outlet ports that filter combustion materials and help to cool the hot expanding gases.

Porsche Airbags Evolve

By the 1990 model year, all Porsches destined for the U.S. were equipped with driver and front-passenger airbags. The 944 S2, 968, 964 Carrera 2 and 4, 928 S4/GT, and 964 Turbo all utilized the basic design first released in the 1987 944 Turbo. For 1991, all models got a new control unit, which allowed the Porsche System Tester 9288 to download stored fault memory and clear it.

The new control unit also provided a means of identifying whether the airbag control unit had been replaced. From the factory, the control unit's power connector came attached to the chassis by an orange securing bracket. If the control unit must be replaced, this bracket must be destroyed to release the connector. Since the replacement bracket is available only in green, a look at this connector will shed some light on the history of a used Porsche from this era.

The 1995 993-based Carrera saw the removal of the right and left front impact sensors. The Rolamite type switches were replaced by the Micro Electro Mechanical System (MEMS) Accelerometer — allowing complete crash detection for airbag actuation within the airbag system control unit. The MEMS Accelerometer is a very small integrated circuit with an internal mechanical element that moves in response to rapid deceleration. Such a motion causes a change in capacitance that is detected by the control unit, prompting it to send a signal to fire the airbags. While this control unit does not need to be replaced following a single airbag deployment, it must be replaced after the system has been triggered three times. Faults that cannot be erased require control unit replacement. Internal

(backup) power remains in these control units for one minute after turning off the ignition or disconnecting the battery.

While some features of the 993 were incorporated in the 1997 Boxster, several important changes were made. First, the passenger-side airbag no longer used a breakaway cover; the airbag itself is visible in the dash. Next, the passenger-side solid fuel gas generator was replaced by a pressure canister filled with 95-percent argon and five-percent helium pressurized to approximately 2,940 psi.

The canister approach offers distinct advantages. First, its gas is released cold, so there are no hot spots. Because the gas is stored under high pressure, the 140-liter passenger-side airbag deploys faster, at about 30 milliseconds — similar to a driver-side airbag and about twice as fast as previous versions. When the unit receives an ignition signal, an internal steel cap is blown off, allowing pressurized gas to fill the airbag through holes and duct plates in the canister.

Porsche's technical documentation for 1997 shows the factory had intended to include a passenger-seat occupancy sensor pad integrated into the seat surface material. If the seat was not occupied, the passenger-side airbag would

not deploy. However, we've never seen a 1997–2004 Boxster equipped with a passenger occupancy sensor. Interestingly, Porsche PST-2 and PIWIS diagnostic/programming equipment have areas for coding this sensor even though it appears that Porsche did not install it.

The Boxster also got a new airbag control unit like the 993's, with its internal MEMS accelerometer crash detection. The control unit will store up to ten faults, with a start-and-stop log kept for each fault. Data can be accessed and downloaded with the PST-2 or PIWIS testers. As in the 993, the Boxster control unit does not need to be replaced until the airbag has been triggered three times or if its fault memory cannot be deleted.

In 1998, Porsche introduced the 996 to the U.S. as a 1999 model with all airbag upgrades seen in the 1997 Boxster plus more new technology that would be added to the Boxster. First and most important was the Porsche Side Impact Protection system (POSIP). The system deploys a 30-liter flat-cushion airbag between the occupant and door panel and side window to better protect the head and chest cavity (generally referred to as the thorax). The extra-large airbag was effective in any fore/aft seat position.

The new side airbags utilized argon/helium-filled canisters pressurized to approximately 270 bar (3,969 psi). Side-impact sensors located in the doorsills triggered deployment depending on the angle of impact and measured acceleration. Unlike other airbags, these do not deflate after deployment. The door and door panel were redesigned to better help protect the pelvis, while a new control unit was used and referred to as the Multiple Restraint Systems unit, as it controlled front and side airbags. MRS also has a crash output, which signals the central-locking system to unlock the doors while shutting off the fuel supply.

Porsche, never content with what is, added seatbelt tensioners and belt-force limiters in all 2002 models. The new seatbelt design used a pyrotechnic belt tensioner working in conjunction with the airbag system. When activation takes place, the three-point seatbelt tightens against the occupant's chest, pulling the occupant firmly into the seatback so that less forward body movement takes place during abrupt deceleration.

Operation is achieved when the seatbelt tensioner receives a firing signal that ignites a pyrotechnic charge. The explosion creates gas pressure that pushes a

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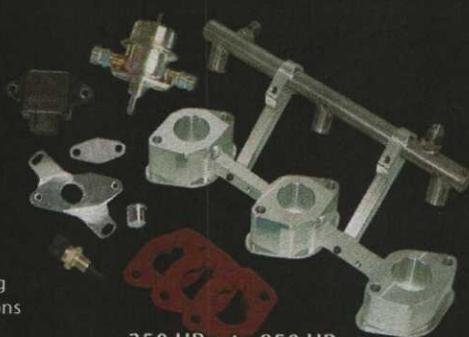
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piston that moves a line of ball bearings past a pinion at the reel, which winds the belt back in. The event takes place in approximately 20 milliseconds. The system also incorporates a belt-force limiter to stop the belt from tensioning beyond a specific point.

One year later, Porsche introduced its Cayenne, a new model and a new direction. While engineering the large, five-passenger SUV, Porsche reconsidered some aspects of its passive-restraint system. While the Cayenne's basic system layout remained the same, its front airbags offered two stages of deployment based on impact severity. Impact sensors in the control unit distinguish between lower- and higher-force decelerations. Two impact sensors were added near the front bumper for earlier and more precise determinations of crash scenarios, including more complex offset frontal impacts to offer improved airbag deployment options. The airbags are fitted with two-stage gas generators to allow them to deploy less aggressively if possible.

The Cayenne also offered a new side-collision system made up of 10-liter, seat-integrated thorax airbags and 30-liter side-curtain airbags built into the roof frame, all using acid-free gas generators.

The system has four side-impact sensors, two at the B-pillars and two at the rear wheel housings. The Cayenne carried the pyrotechnic seatbelt tensioner first seen in the 2002 986s and 996s.

For 2005, the 911 and Boxster were new. Both cars, known internally as the 997 and 987, got two additional impact sensors near the headlights to detect the point and direction of an impact. The system retained impact sensors in the control unit and on each side of the car in the doorsills. The 997 was fitted with the two-stage front airbag system from the Cayenne, but the 987 retained a single-stage deployment system.

Due to the risk of serious or fatal injuries from a front airbag when a child seat is in use, Porsche made a dealer-installed key switch available to disable passenger-side front airbags in 997s and 987s. Since the airbag must be switched back on manually to protect a full-size passenger, a "Passenger Airbag Off" warning light illuminates on the center console — a message that is also displayed by the on-board computer.

The 997 and 987 featured a new generation of POSIP, with two airbags per side instead of one. An eight-liter thorax airbag was integrated into both front

seats and a separate, eight-liter curtain-type head airbag deployed upward from the upper door trim panel, making the system suitable for use in both coupes and convertibles, a world first. 997s and 987s still featured the seatbelts with pyrotechnic belt tensioners as used in later 996s, but the height of the shoulder strap was made adjustable at the B-pillar to ensure proper seatbelt fit.

Airbag System Aging

The airbag systems in 944 Turbos are now more than 20 years old, while most airbag-equipped 928S4/GTs and 964s are roughly that old. So what about continued functionality and component integrity? The good news is that Porsche's airbag systems are well engineered and supported by a sophisticated self-diagnostic capability. Even the early systems will detect minor changes within the system and return a fault code if specific electronic values are exceeded or operational issues detected.

Longterm exposure to high levels of moisture or corrosive conditions can be detrimental to components including wiring connections, but the system should recognize a change in resistance within the wiring and return a fault code.

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We've never seen documentation from Porsche stating that any airbag system component, including the airbags, must be replaced at a specific time interval to ensure operation.

That said, a passive approach to airbag maintenance is not a good idea. Porsche says airbag systems should be inspected per the factory repair manual recommendations four years after a car's build date. The system should again be inspected eight years after manufacture and then every two years thereafter for the life of the car. These inspections should be recorded in the maintenance manual, including a listing of any repairs or replacement of system components.

In addition to periodic inspections, the following components must be replaced after a deployment in the early cars: the control unit, both front impact sensors, the contact unit on the steering-column switch, and the airbag units. In later cars, check the repair manual carefully for what must be replaced in the event of a deployment. Porsche wants to learn from airbag deployments, asking that the parts be returned for inspection via a Porsche dealer. This includes any system components that malfunctioned.

Generally, airbag system inspections are not automatic; you must request one. Unfortunately, most owners rarely proactively pursue inspecting this system as part of their maintenance program. So what's involved in a periodic inspection? First, airbag warning light function is verified. If a fault is induced by interrupting power either to or within the system at a specific point (this varies by model), the control system must recognize, record, and playback the fault both on the airbag light and by outputting a fault code to a factory diagnostic tool.

Once the fault is corrected and a technician clears the fault, the system must accept the command, erase the fault memory, and return to normal operation. Next, a visual check of all system components ensures no physical damage or modifications have taken place that will hinder or prevent airbag deployment. All wiring must be in good condition and wiring connections must be tight and free of corrosion. No wiring that could induce electric current should be placed in the proximity of an airbag harness.

The best short-term insight into the operational condition of your airbag system is to monitor the airbag light on the dash. When you start your car, the airbag

light should illuminate for about three to five seconds and then go off. If the airbag light does not come on or turn off (at all) and/or the light illuminates after the initial startup sequence, there is a problem/fault in the system that must be diagnosed and repaired.

When troubleshooting the system, the use of a factory diagnostic tool is recommended — or at least one designed to interface with the systems of the Porsche in question. Similarly, a technician experienced with the system will be best able to ensure that an accurate diagnosis is obtained. The problem may be simple (like a bad sensor in a seatbelt buckle) or complex (like wiring or a control unit that has failed).

While it's easy to ignore the airbags as a Porsche ages, we believe the proactive approach recommended by Porsche is the best way to maintain longterm functionality. Your life may depend on it. ■

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