Tire Pressure Monitoring, Part 1

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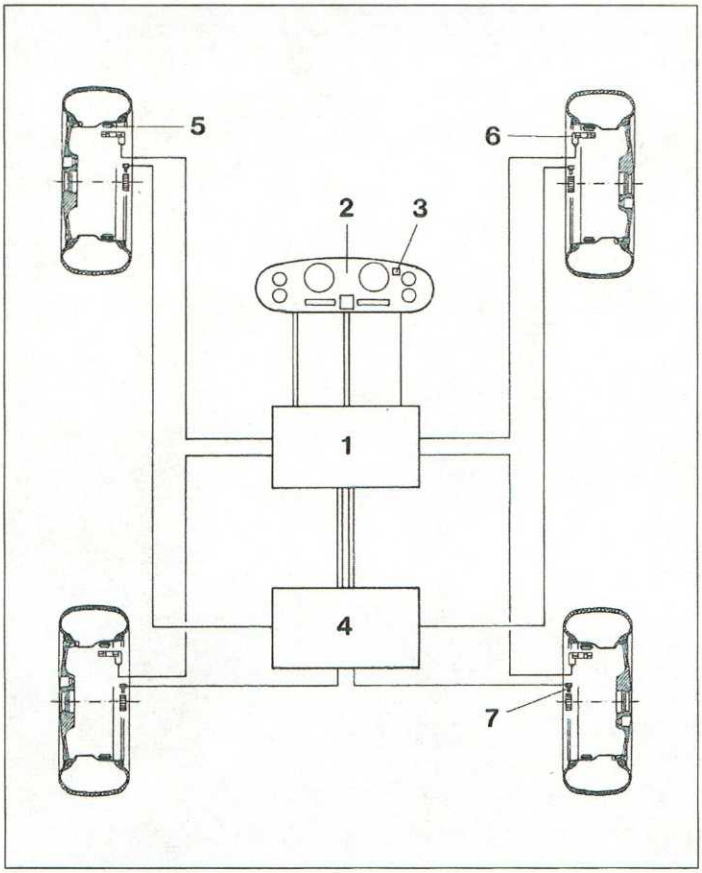
One of the most exciting jobs in the automotive world has to be a position in the research and development department at Porsche. The early 1980s, in particular, must have been an exceptional period. Development projects such as the 3.2-liter Carrera and the evolution of the 944 and 928 series would have been enough, but then there was racing and everything associated with it.

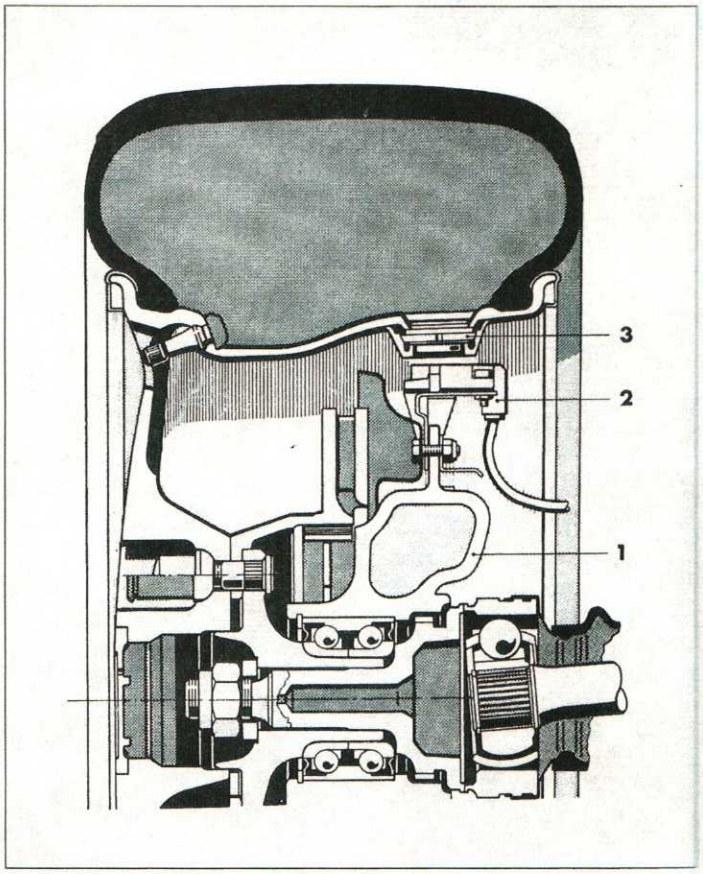
One project would have been particularly fascinating to have been involved with. It began after then head of engineering Dr. Helmuth Bott went to new managing director Peter Schultz with the idea of taking the development of the 911/Turbo further. A lot further. The result was a project originally called Gruppe B — a radical concept car that looked like a 911 in its headlight humps and roofline but little else. It was followed by rally, race, and street versions. The latter was introduced in 1985 and we know it today as Porsche's first supercar: the 959.

The 959 was truly revolutionary, with water-cooled heads with four valves per cylinder, sequential turbochargers, lightweight aluminum and Kevlar body panels, advanced aerodynamics, and the Porsche-Steuer Kupplung (PSK) all-wheel-drive system — to name just a few of its extraordinary technical achievements. Even by today's standards, the 959 is a phenomenal car. And as you have probably guessed from the title of this Tech Forum, the 959 was the first passenger vehicle to be equipped with a tire pressure monitoring system.

This early tire pressure monitoring system was known as RDK, or *Reifen Druck Kontrolle*, which translates to Tire Pressure Control. The system was jointly developed by Bosch GmbH and Porsche AG. Porsche began to use RDK on its race cars in the early 1980s because the system provided drivers with an early warning of impending tire damage by identifying a tire that was losing air pressure. The driver could slow down before the tire deflation caused severe handling problems or a failure and, hopefully, get back to the pits for a tire change.

Road drivers might not perceive a tire-pressure loss of 4 to 8 psi or more caused by a slight leak or natural diffusion (the gradual loss of pressure over time as air permeates through the molecular pores





or gaps in a tire's material). However, the affect on a tire during consistent under-inflated usage is highly damaging. When a tire is under-inflated, the friction level with the road surface increases, resulting in higher-than-normal internal temperatures. Extended high-speed driving will cause severe heating. Sustained high heat from severe under inflation causes a tire's materials and structures to break down — to the point where the tire could literally come apart.

The 959's top speed of nearly 200 mph and the availability of the German autobahn, where ultra-high-speed driving could be explored regularly, prompted Porsche to include RDK technology in its 959. In 1989, it adapted the 959's RDK system to its 928 series. While U.S. and Canadian models were excluded, RDK was released in North America for the 1990 928 S4 and 928 GT.

Early RDK

The RDK tire pressure monitoring system for the 959 and 928 operates when the vehicle is moving at speeds above 3 mph. The driver will be notified if air pressure in any of the tires is below a predetermined set reference point. The driver is also notified if air pressure falls below that point while driving. The system is generally simple but operates effectively;

FIGURE 1 (above left): RDK control unit (1), instrument cluster (2), RDK warning light (3), ABS control unit (4), wheel sensor (5), high-frequency sender (6), ABS sensor (7).

FIGURE 2 (above, right): Wheel carrier (1), high-frequency sender (2), wheel sensor (3).

it is not hampered by water or dirt and it compensates for increases in tire pressure caused by ambient and frictional tire temperature changes.

The system consists of a control unit, a pictogram warning display on the instrument cluster, high-frequency senders, two wheel-mounted sensors per wheel, and special wheel rims with holes for mounting the sensors. The RDK control unit receives data on the rotational speed of each wheel from the anti-lock brake system (see Figure 1).

A high-frequency sender is mounted to the wheel carrier, or upright assembly, at each corner of the car. As the wheel rotates, the wheel-mounted sensors pass in close proximity to the high-frequency sender (see Figure 2). The high-frequency sender unit is basically a coil; it produces an electromagnetic field from current supplied by RDK's control unit. Through the process of electromagnetic induction, electrical energy is transferred wirelessly over the air gap into the wheel sensor's internal coil as the sensor passes through the electromagnetic field.

The wheel sensor is the most amazing part of this system; basically, it's a pressure switch. Each wheel sensor consists of an internal electrical circuit plus an air chamber pressurized to a set reference point; the air chamber is sealed by a flexible diaphragm. The wheel sensor is mounted through the rim so that air pressure within the tire is applied directly on the diaphragm. The diaphragm acts as the on/off switch for the electrical circuit within the sensor. Looking at Figure 3a, pressure within the tire (6) is greater than the sensor's (5) internal reference pressure. The diaphragm (7) is therefore pushed onto the contact pin (4), thus closing the switch and allowing current to flow within the sensor's circuit.

Figure 3b shows what happens when tire pressure goes below the reference pressure. Because the sensor's internal pressure is now greater than the pressure in the tire, the diaphragm is pushed up, thus opening the connection between the diaphragm and the contact pin. The circuit is open and current no longer flows within the sensor. The recommended tire pressure is identified on each wheel sensor so that they can be distinguished; 2.5 bar (36.25 psi) for front tire sensors and 3.0 bar (43.5 psi) for rear tire sensors.

System operation is dependent on the wheel sensor's status. When tire pressure is correct, the wheel sensor's diaphragm pressure switch is closed so that the internal electrical circuit is working. The wheel sensor will absorb electrical energy as it passes through the electromagnetic field at the high-frequency sender. The RDK control unit senses this absorption, or current drop, as an electrical pulse signal. The control unit must receive two pulse signals per revolution of the wheel since there are two sensors per wheel. The ABS control unit confirms wheel rotation and the RDK control unit then concludes that tire pressure is adequate.

When tire air pressure falls below the wheel sensor's reference pressure and the diaphragm pressure switch "opens," there is no current flow in the sensor's internal circuit and the sensor no longer absorbs electrical current. When that happens, the RDK control unit does not receive a pulse signal — even though the ABS system says that the wheel is turning. RDK thus concludes that tire pressure is not adequate.

If, however, only one current pulse is received by the control unit per wheel revolution, RDK identifies this change and the tire warning display pictogram indicates a Stage 1 failure, changing to red with an arrow shown continuously next to the wheel exhibiting the problem. In a Stage 2 failure, the arrow flashes; either both wheel sensors indicate pressure loss or vehicle speed is above 32 mph.

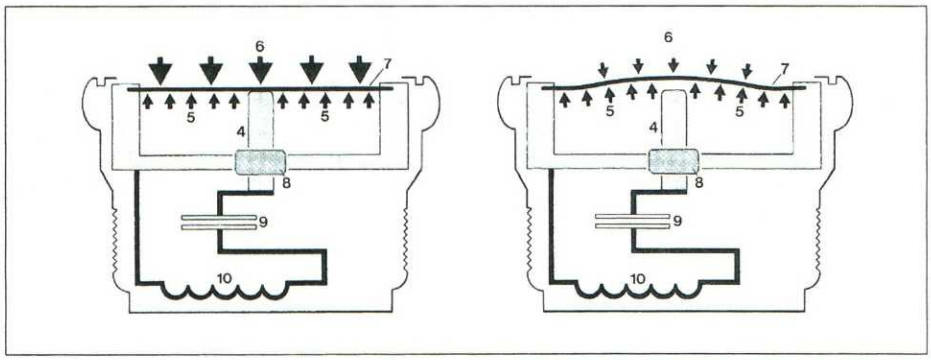
If a Stage 1 or 2 warning is displayed while driving, reduce your speed immediately and stop at the earliest opportunity to check for tire damage. If damage is found, the tire should be repaired or, if necessary, replaced. If no damage is found, the warning was likely caused by natural air diffusion. Porsche recommends air be added to the tire in 0.3-bar (or 4.3-psi) increments. After adding air, drive the car a minimum of 65 feet at a speed over 3 mph — this process should be repeated until the RDK warning turns off. Then match the pressure in the opposite tire on the same axle.

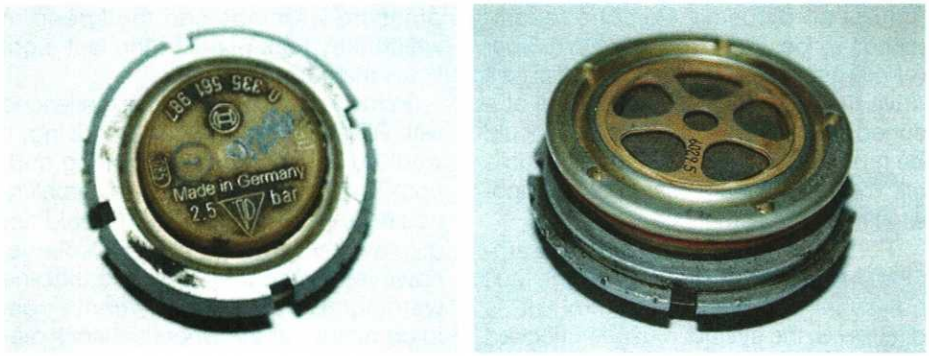
For a car with continuing RDK warnings that cannot be cleared or if the fault message "Tire Pressure Control Off" is displayed, the system must be checked with a Porsche System Tester according to factory procedures. If there is a stored fault in the RDK control unit, the system will no longer function.

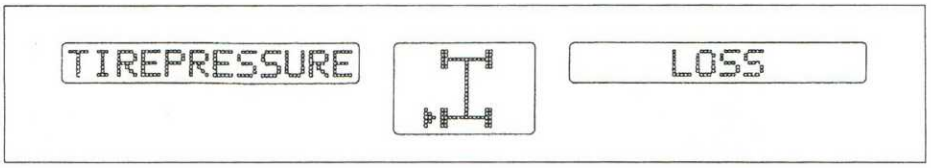
Wheel sensors often fail in the closed position. Thus, no warning will be displayed regardless of how low tire pressure goes. Additionally, when mounting a tire on a wheel rim, technicians sometimes inflate tire air pressure very high so the tire bead seals against the rim. With RDK, inflation pressure must not reach 6 bar (87 psi), as wheel sensor diaphragms can be permanently damaged.

Starting with model year 1991, both the 928 S4 and 928 GT received an update to the RDK control unit's software. Referred to as version R02, it provides an incident memory to record any tire-pressure warnings and the speed at which they took place in the last eight times the car was driven.

Porsche found a problem experienced with RDK during high-speed driving; it would display a Stage 2 warning and, upon inspection of the tires, no problem could be found. The system would not display any warnings at lower speeds, however. Porsche concluded that the warnings were caused by centrifugal force acting on the wheel sensor's diaphragm under the condition where air pressure in the tire was only slightly above the sensor's internal reference pressure or the threshold for the switch-over point from a closed circuit to an open circuit. Due to the sensor's dia-







phragm orientation in the wheel, centrifugal force could push the diaphragm away from the electrical circuit's contact pin if tire pressure against the diaphragm was not high enough to overcome the centrifugal force (see Figure 3b).

There are two important tests for early RDK systems: the RDK Short Test and the procedure for Correct Tire Pressure Adjustment. Both follow.

FIGURE 3a, 3b (top): Sensor contact pin (4), internal reference pressure (5), tire pressure (6), diaphragm (7), insulating glass (8), capacitor (9), coil (10). Switch is closed in 3a.

FIGURE 4a, 4b (middle): 2.5-bar RDK sensor. Note red sealing ring in 4b; this should be replaced whenever a sensor is installed. Use a light coat of Vaseline prior to installation.

FIGURE 5 (above): Sample 928 RDK readout.

RDK Short Test

This test is applicable to both the 959 and 928 and should be performed whenever a wheel, tire, or any component in the RDK system is replaced. The Short Test provides a relatively easy means to determine whether all components of the RDK system are operating as intended without the need for any special equipment other than a tire-pressure gauge.

Step 1. Reduce tire pressure for the front tires to 29 psi and the rears to 36 psi.

Step 2. At these tire-pressure settings, drive the car a minimum of 65 feet at a speed between 3 and 25 mph. A Stage 2 RDK warning for all tires should come on. The instrument cluster pictogram display should be illuminated in red while the arrows next to each wheel in the display should flash. This result confirms that all components of the system are operating correctly. If the display shows any arrows next to the wheels illuminated but not flashing, there is one bad wheel sensor in that specific wheel. If no display is seen — or other variations of the pictogram display are seen — the problem(s) must be diagnosed.

Step 3. Increase tire pressure for the front tires to 43 psi and the rear tires to 51 psi.

Step 4. At these tire-pressure settings, drive a minimum of 65 feet at 3–25 mph. There should be no RDK warning.

Step 5. Reduce tire pressures to the specified values or perform the tire pressure adjustment procedure described below.

Correct Tire Pressure Adjustment for RDK-equipped 928 Models

The procedure to Adjust Tire Pressure utilizes a Porsche System Tester 9288 (or later version Porsche System Tester) to determine the warning threshold or triggering point where the wheel sensor's internal diaphragm (7) closes and opens its electrical connection with the contact pin (4) seen in Figures 3a and 3b, then sets tire pressures at 0.3 bar (4.3 psi) above this point to minimize warnings caused by diffusion. This test is only applicable to RDK-equipped 928s, as the 959 cannot interface with the 9288 or later Porsche System Testers.

If possible, this adjustment should be performed on a cold tire, ideally at an ambient temperature of 68° F. This procedure is best performed after successfully completing the RDK Short Test and confirming the system is operating correctly. However, if you found a bad wheel sensor in the Short Test, this process can identify the bad sensor.

Step 1. Place the car on a lift if available. Raising one wheel at a time will work, but each wheel will need to be rotated.

Step 2. Connect the System Tester 9288 (or a later version) to the car, turn on the ignition, and proceed to the RDK control unit section on the tester.

Step 3. Go to the pressure switch display screen and choose Switch Inputs. The 928's screen should look like this:

PRESSURE SWITCH

FL: CLOSED	FR: OPEN
RL: OPEN	RR: OPEN
CONTINUE:	N

(Note: Switch position, whether closed or open, does not matter at this point.)

Step 4. Start with any wheel on the car; work with one wheel at a time until complete, then go to the other wheel on the same axle. Rotate the wheel until you have positioned one of its two sensors directly next to the high-frequency sender. As the sensor moves into position, you should see the Porsche tester's display identification for that wheel (such as FL, for Front Left) change from Open to Closed. The pressure switch will always show Open until it gets close enough for the high-frequency sender to read it. When the display changes from Open to Closed, tire pressure is above the wheel sensor's reference pressure and the switch is closed. Repeat this process for the second wheel

sensor on that same wheel.

If, however, the tester's display continues to show Open, check the tire's air pressure. If low, increase tire pressure in 4-psi increments until the display reads Closed, then move on to the next paragraph. *Note: If the Short Test exposed a bad wheel sensor on this wheel, the bad sensor is identified if it remains Open after tire pressure is raised clearly above specification.* Warning: Do not exceed 50 psi of pressure for a front sensor or 58 psi for a rear sensor! *If these pressures have been reached and the sensor is not responding, other problems exist that require diagnosis.*

Continuing with the same wheel, again move one of the sensors next to the high-frequency sender. Slowly reduce tire pressure until the display changes from Closed to Open; this is the switchover point for this sensor. Add about 4 psi back into the tire and slowly reduce air pressure again while monitoring the other wheel sensor's switchover from Closed to Open. Make a note of the air pressure at these switchover points.

Next, very slowly increase tire air pressure until the switch status display just changes from Open to Closed. We recommend that you take a pressure reading with a high-quality gauge and note the pressure at this sensor's switchover point for future reference. Now add slightly more than 4 psi to the tire.

Repeat the process every three to six months. Porsche recommends that you set the air pressure in the other tire on this axle to the same value, then move to the other axle. We recommend that you test all the sensors at least once.

Conclusions

Early versions of RDK, although somewhat basic, provide a driver with a timely warning of low tire pressure or a potential deflation problem. Taking an active role in maintaining the proper tire pressures once a month will stop obnoxious RDK warnings. The first step in keeping tire pressures above the warning threshold, however, is to invest in a high quality tire-pressure gauge.

RDK system components are expensive, which prompted some 928 owners experiencing problems to disconnect or remove the system rather than spend the money to repair the system and have a continuously active tire pressure warning display. For 928 owners wishing to update their wheels, custom fabrication and/or modifications to make the RDK system function correctly with modern, large-diameter wheels will require significant work and expenditures.

There have always been complaints about this version of RDK. Some say the tire pressures required by the system are too high for contemporary tires. The 928, however, is a heavy car and we see no unusual or premature tire wear when the 36-psi front and 44-psi rear inflation pressures are maintained — especially when owners include suspension alignment in their regular vehicle maintenance. There is no question that the newer RDK systems offer more information and ease of use, but the original system does exactly what it was intended to. It just requires a little more work and attention.

In Part 2, we will explore Porsche's newer Tire Pressure Monitoring Systems, starting with 2004's Cayenne and going through to the current 911.

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