Professional Technician Series  Part of Pearson Automotive’s Professional Technician Series, the seventh edition of *Automotive Steering, Suspension, and Alignment* represents the future of automotive textbooks. The series is a full-color, media-integrated solution for today’s students and instructors. The series includes textbooks that cover all eight areas of ASE certification, plus additional titles covering common courses.

The series is also peer reviewed for technical accuracy.

**UPDATES TO THE SEVENTH EDITION** Based on requests and suggestions from reviewers and users of the sixth edition, the following have been updated for the new edition:

- The content has been updated throughout to reflect the changes in the industry and to meet the latest NATEF/ASE standards.
- Many new full-color photos and line drawings have been added to this edition.
- The chapter on power steering has been split into two separate chapters—“Hydraulic Power Steering Systems” (Chapter 13) and “Electric Power Steering Systems” (Chapter 14)—making teaching and learning these topics easier.
- New Case Study elements which include the “three Cs” (Complaint, Cause, and Correction) have been added to many chapters.
- New content on tire selection, chrome clad wheels, and using a pin plate to balance wheels has been added in Chapter 3.
- Additional content on snap-in and clamp-on TPMS sensors plus updated relearn procedures has been added in Chapter 4.
- Additional content on various wheel weight materials plus wheel flange information has been added to the totally updated Chapter 5.
- New information on “Hi Per strut” has been included in Chapter 7.
- Two new Case Studies have been added to Chapter 8.
- Discussion related to resetting the steering angle sensor after an alignment has been added to Chapter 18.
- Unlike other textbooks, this book is written so that the theory, construction, diagnosis, and service of a particular component or system are presented in one location. There is no need to search through the entire book for other references to the same topic.

**ASE AND NATEF CORRELATED** NATEF-certified programs need to demonstrate that they use course material that covers NATEF and ASE tasks. All Professional Technician textbooks have been correlated to the appropriate ASE and NATEF task lists. These correlations can be found in two locations:

- As an appendix to each book.
- At the beginning of each chapter in the Annotated Instructor’s Guide.

**A COMPLETE INSTRUCTOR AND STUDENT SUPPLEMENTS PACKAGE** All Professional Technician textbooks are accompanied by a full set of instructor and student supplements. Please see page vi for a detailed list of supplements.

**A FOCUS ON DIAGNOSIS AND PROBLEM SOLVING** The Professional Technician Series has been developed to satisfy the need for a greater emphasis on problem diagnosis. Automotive instructors and service managers agree that students and beginning technicians need more training in diagnostic procedures and skill development. To meet this need and demonstrate how real-world problems are solved, “Case Study” features are included throughout and highlight how real-life problems are diagnosed and repaired.

The following pages highlight the unique core features that set the Professional Technician Series book apart from other automotive textbooks.
SAFEty TIPS

It Just Takes a Second
Whenever removing any automotive component, it is wise to screw the bolts back into the holes a couple of threads by hand. This ensures that the right bolt will be used in its original location when the component or part is put back on the vehicle.

learning objectives and Key terms

Learning objectives

After reading this chapter, the reader will be able to:
1. Locate and identify vehicle and part identification numbers and labels.
2. Locate vehicle warranty information from a variety of sources.
3. Identify the elements and purpose of safety related labels.
4. Identify the safety risks of hand tools and their uses.
5. Identify the safety risks of automotive tools and their uses.
6. Describe personal protective equipment and safety procedures to be used when servicing or repairing vehicles.

This chapter will help you understand the ASE content areas for vehicle identification and the proper use of tools and shop equipment.

key terms

Auto repair: (5) Service technician: (5) ASE certification (5) NATEF certification (5)

TECH TIPS

Safety Tips

Shop Cloth Disposal
Always dispose of oily shop cloths in an enclosed container to prevent a fire. SEE Figure 1-69. Whenever oily cloths are thrown together on the floor or workbench, a chemical reaction can occur, which can ignite the cloth even without an open flame. This process of ignition without an open flame is called spontaneous combustion.

CASE STUDY

The Rattle Story
A customer complained that a rattle was heard every time the vehicle hit a bump. The noise sounded as if it came from the rear. All parts of the exhaust system and suspension system were checked. Everything seemed okay until the vehicle was raised with a frame-type hoist instead of a drive-on type. Then, whenever the right rear wheel was lifted, the noise occurred. The problem was a worn (elongated) shock absorber mounting hole. A washer with the proper-size hole was welded over the worn lower frame mount and the shock absorber was bolted back into place.

Summary:
- Complaint—Vehicle owner complained of a rattle sound from the rear suspension at times.
- Cause—The lower shock mount was found to be worn (elongated) causing the noise.
- Correction—A steel washer was welded over the worn lower frame mount which restored the shock mount to the correct size and solved the noise issue.

CASE STUDIES

present students with actual automotive scenarios and shows how these common (and sometimes uncommon) problems were diagnosed and repaired.
How Many Types of Screw Heads Are Used in Automotive Applications?

There are many, including Torx, hex (also called Allen), plus many others used in custom vans and motor homes. ● SEE FIGURE 1–9.

FREQUENTLY ASKED QUESTIONS are based on the author’s own experience and provide answers to many of the most common questions asked by students and beginning service technicians.

NOTE: Most of these “locking nuts” are grouped together and are commonly referred to as prevailing torque nuts. This means that the nut will hold its tightness or torque and not loosen with movement or vibration.

NOTES provide students with additional technical information to give them a greater understanding of a specific task or procedure.

CAUTION: Never use hardware store (nongraded) bolts, studs, or nuts on any vehicle steering, suspension, or brake component. Always use the exact size and grade of hardware that is specified and used by the vehicle manufacturer.

CAUTIONS alert students about potential damage to the vehicle that can occur during a specific task or service procedure.

WARNING

Do not use incandescent trouble lights around gasoline or other flammable liquids. The liquids can cause the bulb to break and the hot filament can ignite the flammable liquid which can cause personal injury or even death.

WARNINGS alert students to potential dangers to themselves during a specific task or service procedure.
### SUPPLEMENTS

#### RESOURCES IN PRINT AND ONLINE

*Automotive Steering, Suspension, and Alignment*

<table>
<thead>
<tr>
<th>NAME OF SUPPLEMENT</th>
<th>PRINT</th>
<th>ONLINE</th>
<th>AUDIENCE</th>
<th>DESCRIPTION</th>
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<tr>
<td>Instructor Resource Manual 0134074939</td>
<td>✔</td>
<td></td>
<td>Instructors</td>
<td>NEW! The ultimate teaching aid: chapter summaries, key terms, chapter learning objectives, lecture resources discuss/demonstrate classroom activities. MyAutomotiveLab correlation, and answers to the in-text review and quiz questions.</td>
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<tr>
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<tr>
<td>NATEF Correlated Task Sheets – For Students 0134075072</td>
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<td></td>
<td>Students</td>
<td>Study activity manual that correlates NATEF Automobile Standards to chapters and page numbers in the text. Available to students at a discounted price when packaged with the text.</td>
</tr>
</tbody>
</table>

All online resources can be downloaded from the Instructor’s Resource Center: [www.pearsonhighered.com/irc](http://www.pearsonhighered.com/irc)

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**STEP-BY-STEP** photo sequences show in detail the steps involved in performing a specific task or service procedure.
chapter 4
TIRE-PRESSURE MONITORING SYSTEMS

LEARNING OBJECTIVES

After studying this chapter, the reader will be able to:

1. Explain why a tire-pressure monitoring system (TPMS) is used.
2. Discuss the TREAD Act.
3. Explain indirect and direct TPMS.
4. List the two types of TPMS pressure sensors.
5. Explain direct TPMS diagnosis and TPMS diagnostic tools.
6. Describe how to relearn TPMS sensors and the tools needed to service a TPMS.

This chapter will help you prepare for ASE Suspension and Steering (A4) certification content area “E” (Wheel and Tire Diagnosis and Repair).

KEY TERMS

Active mode 91
Alert mode 91
Delta pressure method 95
Placard cold inflation pressure 86
Sleep mode 91
Storage mode 92
Transmitter ID 95
TREAD Act 87
Tire-pressure monitoring system (TPMS) 86


**Chapter 4**

**Increases the number of tire-related faults, which have been estimated to be 90% of all vehicle faults.**

**Reduces handling and braking efficiency.**

**Hundreds of deaths and thousands of personal injuries are due to problems associated with low tire inflation pressure.**

**Placard Cold Inflation Pressure**

The term *placard cold inflation pressure* is used in service information to indicate the specified tire inflation pressure. The "placard" is the driver's side door jamb sticker that shows the tire size and the specified tire inflation pressure. It is also normal for a tire to lose one PSI per month just through normal leakage that occurs in any tire. Therefore, it is very important to check and correct inflation pressures regularly. The pressure stated is measured when the tires are cold or at room temperature, which is about 70°F (21°C). *See Figure 4–1.*

**Need for Tire Pressure Monitoring**

**Background**

A tire-pressure monitoring system (TPMS) is a system that detects a tire that has low inflation pressure and warns the driver. A tire-pressure monitoring system was first used when run-flat tires were introduced in the 1990s. A driver was often not aware that a tire had gone flat after a puncture. Because a run-flat tire is designed to be driven a limited distance and at limited speed after it loses air pressure, a method of alerting the driver had to be found. There were two systems used:

1. **Indirect**—Commonly used until the 2008 model year and then from 2010 on, there are some vehicles that use the indirect system.

2. **Direct**—A direct-reading pressure system that uses a pressure sensor in each tire is the most commonly used system at this time.

**Low Tire Pressure Effects**

Low tire inflation pressures lead to the following:

- Increases the number of tire-related faults, which have been estimated to be 90% of all vehicle faults.

- Reduces handling and braking efficiency.

- Hundreds of deaths and thousands of personal injuries are due to problems associated with low tire inflation pressure.

**Placard Cold Inflation Pressure**

The term *placard cold inflation pressure* is used in service information to indicate the specified tire inflation pressure. The "placard" is the driver's side door jamb sticker that shows the tire size and the specified tire inflation pressure. It is also normal for a tire to lose one PSI per month just through normal leakage that occurs in any tire. Therefore, it is very important to check and correct inflation pressures regularly. The pressure stated is measured when the tires are cold or at room temperature, which is about 70°F (21°C). *See Figure 4–1.*

**Temperature and Inflation Pressure**

The tires become warmer while the vehicle is being driven, so tires should be checked before the vehicle has been driven or allowed to cool after being driven. Tire inflation pressure changes 1 PSI for every 10 degrees. *See Chart 4–1.*

---

**Chart 4–1**

<table>
<thead>
<tr>
<th>Temperature (°F)</th>
<th>Tire Pressure (PSI)</th>
<th>Change from Placard Cold Inflation Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>120°F (49°C)</td>
<td>37</td>
<td>+5</td>
</tr>
<tr>
<td>110°F (43°C)</td>
<td>36</td>
<td>+4</td>
</tr>
<tr>
<td>100°F (38°C)</td>
<td>35</td>
<td>+3</td>
</tr>
<tr>
<td>90°F (32°C)</td>
<td>34</td>
<td>+2</td>
</tr>
<tr>
<td>80°F (27°C)</td>
<td>33</td>
<td>+1</td>
</tr>
<tr>
<td>70°F (21°C)</td>
<td>32</td>
<td>0</td>
</tr>
<tr>
<td>60°F (16°C)</td>
<td>31</td>
<td>−1</td>
</tr>
<tr>
<td>50°F (10°C)</td>
<td>30</td>
<td>−2</td>
</tr>
<tr>
<td>40°F (4°C)</td>
<td>29</td>
<td>−3</td>
</tr>
<tr>
<td>30°F (−1°C)</td>
<td>28</td>
<td>−4</td>
</tr>
<tr>
<td>20°F (−7°C)</td>
<td>27</td>
<td>−5</td>
</tr>
<tr>
<td>10°F (−12°C)</td>
<td>26</td>
<td>−6</td>
</tr>
<tr>
<td>0°F (−18°C)</td>
<td>25</td>
<td>−7</td>
</tr>
<tr>
<td>−10°F (−23°C)</td>
<td>24</td>
<td>−8</td>
</tr>
<tr>
<td>−20°F (−29°C)</td>
<td>23</td>
<td>−9</td>
</tr>
</tbody>
</table>

*The effects of outside temperature on tire inflation, assuming a placard inflation pressure of 32 PSI. The tire inflation pressure changes 1 PSI for each 10 degrees change in temperature.*

---

**Figure 4–1**

The tire-pressure placard (sticker) on the driver's side door or door jamb indicates the specified tire pressure.
The Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act requires that all vehicles be equipped with a tire-pressure monitoring system that will warn the driver in the event of an underinflated tire. This act was passed due to many accidents that were caused at least in part to underinflated tires, which resulted in many deaths.

If the TPMS warning lamp is on at start-up, the system has detected a tire with low inflation pressure. If the TPMS warning lamp is flashing for 60 to 90 seconds, a system fault has been detected.

<table>
<thead>
<tr>
<th>Placard Cold Inflation Pressure (PSI)</th>
<th>Warning Light Pressure (~25%)</th>
<th>PSI Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>30.0</td>
<td>10.0</td>
</tr>
<tr>
<td>39</td>
<td>29.3</td>
<td>9.7</td>
</tr>
<tr>
<td>38</td>
<td>28.5</td>
<td>9.5</td>
</tr>
<tr>
<td>37</td>
<td>27.8</td>
<td>9.2</td>
</tr>
<tr>
<td>36</td>
<td>27.0</td>
<td>9.0</td>
</tr>
<tr>
<td>35</td>
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<td>8.7</td>
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<td>29</td>
<td>21.8</td>
<td>7.2</td>
</tr>
<tr>
<td>28</td>
<td>21.0</td>
<td>7.0</td>
</tr>
</tbody>
</table>

The NHTSA ruling is part one of a two-part final ruling.

- Part one establishes a new Federal Motor Vehicle Safety Standard (FMVSS) 138 that requires tire-pressure monitoring systems be installed in passenger vehicles and light trucks to warn the driver when a tire is 25% below the cold placard pressure.
- Part two includes the requirement to equip vehicles with a tire-pressure monitoring system that was phased-in starting in 2004 with 100% of the vehicles by September 1, 2007 (2008 model-year vehicles).

FMVSS 138 requires all cars, trucks, and vans with a gross vehicle weight rating (GVWR) of 10,000 pounds or less to illuminate a warning lamp within 10 minutes when the inflation pressure drops 25% or more from the vehicle manufacturer’s specified cold tire inflation pressure as printed on the door placard.

**WARNING LAMP** The FMVSS 138 specifies that the driver must be warned of a low tire inflation pressure by turning on an amber warning lamp. The warning lamp must also come on during a bulb check. The spare tire is not required to be monitored, but many vehicle manufacturers do equip full-size spare tires with a pressure sensor.

- If the TPMS warning lamp is on at start-up, the system has detected a tire with low inflation pressure.
- If the TPMS warning lamp is flashing for 60 to 90 seconds, a system fault has been detected.

**TWENTY-FIVE PERCENT RULE** The TREAD Act specifies that the driver be warned if any tire inflation pressure drops by 25% or more from the placard cold inflation pressure. ● SEE CHART 4–2.

**INDIRECT TPMS**

**FUNCTION** Indirect tire-pressure monitoring systems do not measure the actual tire pressure. Instead, the system uses the wheel speed sensors to detect differences in the speed of the wheels. If a tire is underinflated, the following occurs:

- A tire that is underinflated will have a smaller diameter than a properly inflated tire. ● SEE FIGURE 4–3.
- An underinflated tire will rotate faster than a properly inflated tire.

**CHART 4–2** Placard inflation pressure compared with the pressure when the TPMS triggers a warning light assuming a cold placard inflation pressure of 32 PSI.
**Indirect TPMS Relearn Procedures**

After checking that all four tires are the same size and condition, the system may require resetting, also called relearn or initialization. Check service information for the exact steps to follow, which could include driving the vehicle over an extended period of time. The procedure usually includes the following:

- Inflate all four tires to the placard inflation pressure.
- Depress and hold the reset switch for three seconds.

**Compensation for Cornering**

When a vehicle turns a corner, the outside wheels rotate faster than the inside wheels. To compensate for this normal change in wheel rotation speed, the indirect tire-pressure monitoring system checks the diagonally opposed wheels.  

*See Figure 4-4.*

If the calculation of the diagonal wheel speed indicates that one of the wheels is rotating faster than the other, the TPMS warning light is illuminated.

**Diagnosis of Indirect TPMS**

The diagnosis of an indirect tire-pressure monitoring system includes the following steps:

**STEP 1** Verify the fault.
- If the TPMS warning light is on but not flashing, this indicates that the system has detected a tire with low inflation pressure.
- If the TPMS warning light flashes, this indicates that the system has detected a fault. Check service information for the specified steps to follow.

**STEP 2** If the system has detected low tire pressure, check and adjust the tire pressure to that listed on the door pillar placard or factory specifications as stated in the owner’s manual or service information.

**STEP 3** Determine and correct the cause of the under-inflated tire.
FUNCTION Direct tire-pressure monitoring systems use individual pressure sensors located in each wheel to measure the inflation pressure.

IDENTIFYING THE SYSTEM All vehicles sold in the United States since the 2008 model year must be equipped with a tire-pressure monitoring system. Often because some vehicles use an indirect system, it is sometimes difficult to determine what type of system is being used by visual inspection only. Therefore, service information is needed to determine what type of system should be on the vehicle before service work is started.

- Many early (prior to 2008) and some newer vehicles (2010+) use indirect TPMS so there is no visual indication that the vehicle is equipped with a tire-pressure monitoring system.
- If the tire/wheel assembly has a TPMS valve-type sensor, it can usually be identified by the threaded portion of the valve stem. **SEE FIGURE 4–6.**

How Can an Indirect System Meet the TREAD Act Requirements?

Some newer vehicles such as 2009 and newer Audis, plus many models of Honda after 2013 and some Mazda models, use active wheel speed sensors to measure the slight change in vehicle speed compared to the speed in the internal memory of the TPMS module. Always check service information for the exact procedure to follow when a newer vehicle appears to not be equipped with a tire-pressure monitoring system because of no visible signs of a tire pressure sensor.

FREQUENTLY ASKED QUESTION

MANUFACTURERS All direct TPMS sensors transmit tire inflation pressures to a module using a radio frequency (RF) signal. These sensors are manufactured by a variety of manufacturers, including:

- Beru
- Lear
- Pacific
- Schrader
- Siemens
- TRW

Each sensor uses a 3-volt lithium ion battery that has a service life of 7 to 10 years.

TYPES There are two basic types of pressure sensors used in direct pressure-sensing systems.

- **Valve-stem-mounted sensor**—This type of sensor uses the valve stem as the transmitter. The correct (nickel-plated) valve core must be used in the aluminum valve stem. If a conventional brass valve is used, moisture in the air will cause corrosion between the two different metals. There are two designs of stem-mounted sensors including:
  1. **Snap-in**—This design looks like a rubber valve stem but it uses a tapered brass section and a longer cap. **SEE FIGURE 4–7.**
If the cap is short then it does not have a stem-mounted tire pressure sensor. However, the wheel may be equipped with a wheel-mounted (banded) sensor, so care should still be taken to avoid damaging the sensor during service.  

2. Clamp–in—This design uses anodized aluminum housing and is held to the wheel using a threaded cap which must be properly tightened to the specified torque to provide the necessary clamping force. The valve stem itself is the antenna for the sensor. See Figure 4–8.

- Banded sensors—Banded sensors are installed in the drop well of the wheel and banded or clamped to keep them secure. Early banded sensors, such as those used in Corvettes equipped with run-flat tires, were piezoelectric and did not require a battery. All newer banded sensors include a battery. See Figure 4–9.

**MODES OF OPERATION**  Tire-pressure sensors have three modes of operation:

1. **Active mode**—When the sensor inside detects that the vehicle is traveling above 20 mph (32 km/h), the sensor transmits once every minute.

2. **Sleep mode**—When the vehicle is stopped, the sensor “goes to sleep” to help improve battery life. In this mode, the transmitter still will broadcast tire inflation information every hour or every six hours, depending on the sensor.

3. **Alert mode**—Alert mode is triggered if a rapid change in inflation pressure is detected. In alert (or rapid mode), the tire inflation pressure is sent about every second (every 800 milliseconds on some sensors).
Some vehicles display the actual measured tire pressure for each tire on a driver information display.

Depending on the type and manufacturer, tire-pressure monitoring sensors can be any of several different designs. The TREAD Act does not specify the type or operation of the pressure sensors, only that the system must be capable of measuring tire inflation pressure and light the TPMS warning lamp. The types of sensors include:

- **Continuous-wave-type sensor**—Designed to signal a tester when exposed to five to seven seconds of continuous 125 KHz wave signal.
- **Magnetically triggered-type sensor**—Designed to trigger a tester if exposed to a powerful magnetic force.
- **Pulse-width-modulated-type sensor**—Designed to be triggered when exposed to modulated wave 125 KHz signal.

The sensor can also vary according to the frequency at which it transmits tire-pressure information to the receiver in the vehicle. The two most commonly used frequencies are:

- 315 MHz
- 433.92 MHz (commonly listed as 434 MHz)

### DESIGNs

The wireless TPMS receiver is housed in one of the following locations, depending on the vehicle:

- Remote keyless entry (RKE) receiver
- Body control module (BCM)
- Door module
- Individual antennas near each wheel well. These individual antennas then transmit tire-pressure information to the driver information center. **SEE FIGURE 4–10.**

### LOCATIONs

**Does a TPMS Sensor Work Before Being Installed?**

No. New tire-pressure warning sensors (transmitters) are shipped in **storage mode**. This mode prevents the battery from becoming discharged while in storage. When the transmitter is installed in a wheel/tire assembly and the tire is inflated to more than 14 PSI (97 kPa), the transmitter automatically cancels storage mode. Once a transmitter has canceled storage mode, it cannot enter this mode again. Therefore, once a sensor has been installed and the tire inflated above 14 PSI, the clock is ticking on battery life.

**FREQUENTLY ASKED QUESTION**

FrequentLy AskEd QuEsTIon

An image of a digital display reading tire pressure. The text reads:**Some vehicles display the actual measured tire pressure for each tire on a driver information display.**

**TPMS SENSOR OPERATION**

**LOCATIONS**

The wireless TPMS receiver is housed in one of the following locations, depending on the vehicle:

- Remote keyless entry (RKE) receiver
- Body control module (BCM)
- Door module
- Individual antennas near each wheel well. These individual antennas then transmit tire-pressure information to the driver information center. **SEE FIGURE 4–10.**
The TPMS Warning Lamp

The owner of a six-year-old Honda Civic was concerned that the tire-pressure warning lamp was on even though all of the tires had the proper inflation pressure. The technician noted that the TPMS warning lamp was not the one that indicates a low tire, but it was the one that indicates that a fault with the system has been detected. ● SEE FIGURE 4–11.

The technician used a factory-level aftermarket scan tool and retrieved several diagnostic trouble codes for “pressure sensor signal failures.” ● SEE FIGURE 4–12.

The technician also noted that the tires were relatively new and recommended to the owner that all four TPMS sensors be replaced. The major reason why the technician recommended that all of them be replaced is that the battery life is normally 7 to 10 years so the life of the sensors is near the end of their useful life. Also, the technician thought that one or more of the sensors may have been damaged when the new tires were replaced. The vehicle owner approved the replacement of the sensors and the system was restored to normal operation.

Summary

- Complaint—TPMS warning lamp was on.
- Cause—Most of the tire-pressure warning system sensors had a stored diagnostic trouble code.
- Correction—All four tire-pressure sensors were replaced and the system relearned to the new sensors. The codes were cleared and the system was restored to normal operation.

Check the TPMS Sensors Before and After Service

It is wise to check that all of the tire-pressure monitoring system sensors are working before beginning service work. This is commonly called “test before you touch.” For example, if the tires need to be rotated, the sensors will have to be reprogrammed for their new location. If a tire-pressure monitoring sensor is defective, the procedure cannot be performed. Use an aftermarket or original equipment tire-pressure monitoring sensor tester to check that the sensors respond. ● SEE FIGURE 4–13.

Then the tire-pressure sensors should be checked again after the service to make sure that they are working correctly before returning the vehicle to the customer.
CHAPTER 4

TPMS DIAGNOSIS

WARNING LIGHT ON  If the TPMS warning light is on and not flashing, the system has detected a tire that has low inflation pressure. ● SEE FIGURE 4–14.

If the TPMS light is on, perform the following steps:

STEP 1  Check the door placard for the specified tire inflation pressure.

STEP 2  Check all tires using a known-accurate tire-pressure gauge.

STEP 3  Inflate all tires to the specified pressure.

NOTE: Some systems will trigger the TPMS warning light if a tire is overinflated. An overinflated tire is also a safety-related problem.

WARNING LIGHT FLASHING  If the TPMS warning lamp is flashing on and off or if a separate TPMS system warning light is on, the system has detected a fault. Faults could include:

- Defective wheel sensors, such as a sensor with a dead battery.
- A fault in the receiver, such as in the remote keyless entry module.

Check service information for the exact procedure to follow if the TPMS warning lamp is flashing. Always follow the specified diagnostic and service procedures.

CAUTION: Stop leak should never be used in a tire that is equipped with the TPMS sensor because the sensor can be damaged.

FIGURE 4–14  A tire-pressure warning light can vary depending on the vehicle, but includes a tire symbol.

FIGURE 4–15  A magnet is placed around the valve stem to reprogram some stem-mounted tire-pressure sensors.

Check the Spare

Many vehicles equipped with a full-size spare tire also have a TPMS sensor. If the inflation pressure decreases enough, the system will trigger the TPMS warning light. This is confusing to many vehicle owners who have checked all four tires and found them to be properly inflated. This fault often occurs during cold weather when the tire inflation pressure drops due to the temperature change. Most 2008 and newer vehicles with a full-size spare tire will come equipped with a TPMS sensor in the spare.

TPMS SENSOR ACTIVATIONS

ACTIVATING THE SENSOR  A tire-pressure monitoring system sensor needs to be activated to verify that the sensor actually works. This should be performed before any tire or wheel service is performed. There are three methods used to activate a TPMS sensor to cause it to send a signal that can be captured to verify proper operation. These activation methods include:

3. Monitor sensor values—TPMS transmitters send information to the controller including:
   - Sensor identification
   - Tire inflation pressure
   - Tire air temperature (some sensors)
   - Sensor battery voltage (some sensors)

**CASE STUDY**

### The Acura Dash Display Problem

The tires were rotated on an Acura equipped with a direct-type TPMS. The published relearn procedure included driving the vehicle above 15 MPH for at least 40 seconds. However, even after driving for over 10 miles, the pressures were not being displayed on the instrument panel cluster (IPC). The technician thought that maybe there was fault with the IPC. The owner decided to think it over what to do and drove the vehicle home. The next day, when the vehicle was driven, the tire pressure display worked as designed. Apparently the system needed to be powered down and allowed to go to sleep before it would start to transmit the new locations to the IPC.

**Summary**
- **Complaint**—The tire pressures for each wheel were not being displayed on the dash after the tires were rotated.
- **Cause**—The tire-pressure monitoring system apparently needed to go to sleep and then awaken before the tire pressure would be displayed on the dash.
- **Correction**—No action was required by the service technician because the system started to transmit after going to sleep, and the display operated as designed.

### TPMS Diagnostic Tools

#### SCAN TOOLS
Scan tools can be used for TPMS service if the scan tool is an original equipment tool for the vehicle make or if an aftermarket scan tool has original equipment compatible software to access the chassis or body functions of the vehicle. A scan tool is used to perform the following functions:

1. **Register TPMS sensors**—A replacement TPMS transmitter has an 8-digit number, called the transmitter ID, on each valve/transmitter assembly. ![SEE FIGURE 4–16.]

2. **Perform initialization**—This step assigns a transmitter ID to the correct position on the vehicle, such as right front (RF).

#### HANDHELD TESTERS
Several manufacturers produce handheld testers to reset the sensors. These tools are used to perform the following functions:
- TPMS sensor activation
- TPMS sensor relearn
- To program a new TPMS sensor

Tools are available from the following companies:
- OTC (http://www.otctools.com)
- Bartec (http://www.bartecusa.com)
- Snap-on (http://www.snapon.com)
**SENSOR REPLACEMENT OPTIONS**

**ORIGINAL EQUIPMENT-BASED SENSORS**  These sensors are made by the original equipment (OE) manufacturer and usually are direct replacement for the factory unit.
- They are electronically identical to the original sensor
- The relearn procedure is the same
- May be a different color.

These sensors are usually tested and validated according to OE specifications but one part number may cover many factory part numbers.

**AFTERMARKET SENSORS**  There are many aftermarket TPMS sensors and these can be divided into several groups including:
- Original equipment (OE)-based replacement
- Multiple protocol sensors that can be programmed to match whatever the vehicle needs
- Fully programmable sensor—also called clones. This type needs a separate programming device.

If using aftermarket tire-pressure monitoring system pressure sensors, always check and follow the instructions that came with the sensors to properly program the vehicle being serviced.

**TPMS SENSOR RELEARN**

**TERMS USED**  Service information should always be checked when performing a relearn procedure. The relearn procedure may be called any of the following:
- Calibrate
- Recalibration
- Initialization
- Reprogramming
- Relearn
- Training

**CATEGORIES**  Most relearn procedures fall into four categories including:

1. **Auto relearn**—Install sensors, drive the vehicle for a prescribed amount of time and rate of speed. The vehicles that often can be automatically relearned usually include:
   - Chrysler
   - Dodge
   - Ram
   - Jeep
   - Jaguar
   - Land Rover

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**FREQUENTLY ASKED QUESTION**

**How Does a Vehicle Learn Where the Sensor Is Located?**

Vehicles that are capable of automatically learning their new position after a tire rotation or after being replaced can detect their location by:
- Some vehicles use an initiator located in each wheel well. The TPMS sensor broadcasts the pressure information which is detected by each initiator and then transmitted over a bus network to the TPMS or body control module. The module then will know where the sensor is located by its unique serial number.
- Include an accelerometer in the sensor which allows the sensor to “know” which side of the vehicle the sensor is located. When a tire revolves, it turns in an opposite direction than a wheel on the opposite side of the vehicle. By using the accelerometer, the TPMS controller can detect which side the sensor is located.
- Then the TPMS module checks for the relative strength of the signal being transmitted by the sensor. If the receiver is located at the rear of the vehicle, and two sensors are showing stronger signal, then these two must be the two rear wheels.
Always check service information for the exact procedures to follow on the vehicle being serviced.

**GENERAL MOTORS EXAMPLE** The following procedure will allow the service technician to reprogram the TPMS after tire rotation on a General Motors vehicle without using a scan tool.

**STEP 1** With KOEO (key on, engine off), the “lock” and “unlock” buttons on the key fob should be simultaneously pressed and held. The horn will chirp within 10 seconds, indicating the receiver is in programming mode. The programming procedure must now be completed within five minutes, with no more than one minute between programming.

**NOTE:** If the horn does not chirp at the start of this procedure, the TPMS option has not been enabled. A scan tool is needed to enable the system.

**STEP 2** At the left front wheel, the special magnet tool must be held over the valve stem to force the sensor to transmit its code. The horn will chirp once, indicating the system has recognized the sensor. The next sensor must be programmed within one minute.

**STEP 3** The remaining sensors should be programmed in the following order: RF, RR, LR. The horn will chirp once when each sensor has been detected. It will chirp twice to indicate completion of the programming process. ![See Figure 4–17](image)

**All Sensors Will Fail**

All TPMS pressure sensors will fail because they contain a battery that has a service life of 7 to 10 years. What does this mean to the service technician? This means that if new tires are being installed on a five or six-year-old vehicle equipped with tire-pressure sensors, then the customer should be notified that the TPMS sensors could fail almost anytime.
4. Tire valve nut torque wrench—Most are 11 or 12 mm in size and the torque ranges from 30 to 90 inch-pounds (4 to 10 N.m).

5. Sensor service kit—If a pressure sensor is going to be reused, the following service parts must be replaced:
   - Cap
   - Valve core (nickel-plated only)
   - Nut
   - Grommet

These parts are usually available individually or in an assortment package. Pressure sensor and kit information can be found at the following websites:

- [http://www.schrader-bridgeport.com](http://www.schrader-bridgeport.com)
- [http://www.myerstiresupply.com](http://www.myerstiresupply.com)
- [http://www.rubber-inc.com](http://www.rubber-inc.com)
FIGURE 4–20  An assortment of service parts that include all of the parts needed to service a stem-mounted TPMS sensor being installed after removal for a tire replacement or repair.

**FREQUENTLY ASKED QUESTION**

**Can TPMS Sensors Be Switched to New Wheels?**

Maybe. It depends on the style of the new or replacement wheels as to whether the sensors will fit or not. Some vehicles are designed to allow for a second set of sensors such as for winter tires. Many Lexus vehicles can be programmed to use set #1 or set #2. It is best to check before purchasing new wheels. Another set of TPMS sensors could be a major added expense.

**SUMMARY**

1. Low tire inflation pressure can cause a decrease in fuel economy, reduced tire life, and increase the chance of tire failure.
2. The designated tire inflation pressure is stated on the driver's side door jamb placard.
3. Tire inflation pressure drops 1 PSI for every 10 degrees drop in temperature.
4. The indirect tire-pressure monitoring system uses the wheel speed sensors to detect a low tire.
5. The TREAD Act, also called the Federal Motor Vehicle Safety Standard 138, specifies that all cars, trucks, and vans under 10,000 pounds gross vehicle weight rating (GVWR) must be equipped with a direct pressure-sending tire-pressure monitoring system after September 1, 2007 (2008 model-year vehicles).
6. The two basic types of TPMS sensors include:
   - Valve-stem-mounted (can be either snap-in or clamp-in design)
   - Banded
7. After a tire rotation, the sensors need to be reset or relearned.
8. Special tools are recommended to relearn, activate, or service a tire-pressure monitoring system.

**REVIEW QUESTIONS**

1. How does the use of wheel speed sensors detect a tire with low inflation pressure?
2. What is the difference between faults when the TPMS warning lamp is on compared with when it is flashing?
3. What is the difference between indirect and direct tire-pressure monitoring system?
4. TPMS pressure sensors can be made by what manufacturer?
5. What are the three modes of sensor operation?
6. What information is sent to the TPMS controller from the sensor?
7. After removing a stem-type pressure sensor to replace a tire or perform a tire repair, what should be replaced?
1. A tire with lower-than-specified inflation pressure could lead to what condition?
   a. Reduced fuel economy
   b. Reduced tire life
   c. Increased chances of roadside faults or accidents
   d. All of the above

2. Which tire inflation information should be checked to determine the proper tire inflation pressure?
   a. Cold placard inflation pressure
   b. The maximum pressure as stated on the sidewall of the tire
   c. 32 PSI in all tires
   d. Any of the above

3. Two technicians are discussing tire pressure and temperature. Technician A says that tire pressure will drop 1 PSI for every 10 degrees drop in temperature. Technician B says that the tire pressure will increase as the vehicle is being driven. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B

4. Two technicians are discussing the indirect tire-pressure monitoring system. Technician A says that it was used by some vehicle manufacturers. Technician B says that it uses the speeds of the RF and LR tires and compares the rotating speeds of the LF and RR tires to detect a low tire. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B

5. The FMVSS 138 law requires that the driver be notified if the tire inflation pressure drops how much?
   a. 30%
   b. 25%
   c. 20%
   d. 15%

6. The two basic types of direct TPMS sensors include.
   a. Rubber stem and aluminum stem
   b. Beru and Schrader
   c. Stem-mounted and banded
   d. Indirect and direct

7. What mode does a direct pressure sensor enter when the vehicle is stopped?
   a. Sleep mode
   b. Storage mode
   c. Alert mode
   d. Active mode

8. To activate or learn a direct pressure sensor, what does the service technician need to do?
   a. Enter learn mode and use a magnet
   b. Enter learn mode and decrease inflation pressure
   c. Use a handheld tester
   d. Any of the above depending on the vehicle and system

9. What does the “delta pressure method” mean?
   a. Change the inflation pressure
   b. Activate the sensor so it broadcasts the pressure to the scan tool
   c. Inflating the tire to the specified pressure
   d. Using a handheld tester to read the pressure as reported by the sensor

10. What type of valve core is used in stem-mounted sensors?
    a. Brass
    b. Nickel-plated
    c. Steel
    d. Aluminum