



OXYGEN SENSOR TRAINING GUIDE



QUALITY • COVERAGE • SUPPORT



Oxygen Sensor Training and Certification Guide

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1.0 INTRODUCTION

About Walker Products



Walker Products began supplying the fuel system needs of the automotive industry in 1946. Today, Walker is one of the largest privately owned manufacturers of fuel system components and engine sensors.

We serve major Original Equipment Manufacturers, co-manufacturers, traditional aftermarket distributors, rebuilders, and retail customers in the automotive, Othermotive®, and heavy duty fuel, engine sensor, and exhaust markets worldwide.

We are committed to supplying products manufactured to meet or exceed OEM standards and specifications. This effort is backed by our in-house manufacturing, product management, and engineering staff to ensure precise accuracy in the production of the highest quality parts, vehicle applications, and technical support.

Our manufacturing facilities maintain and uphold ISO 9001/ IATF16949 standards.

We have sales and distribution centers in the U.S., Mexico, the UK, and China, as well as manufacturing facilities in Fruita and Grand Junction, CO; Pacific, MO; Palmetto, FL; and Changzhou, China.

Guidelines & Limitations of Manual

The Walker Products Oxygen Sensor Training and Certification program is a free resource for any industry professional or DIY user that wishes to expand his or her knowledge of oxygen sensor history, function, installation and repair. As an industry leader in the production and distribution of oxygen sensors, Walker is pleased to share its many decades of knowledge and experience with our valuable customers.

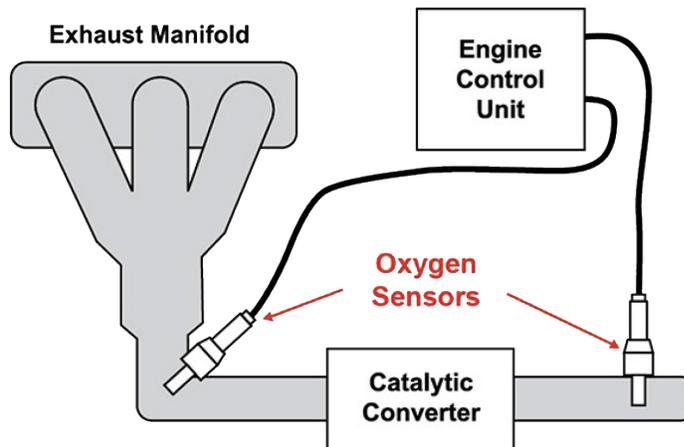
This training manual was drafted and edited exclusively by the trained staff of Walker Products. Its intent is for informational purposes only. The reading and completion of this course does not certify any individual to perform service work on automobiles in any professional capacity.

2.0 A BRIEF HISTORY OF OXYGEN SENSORS

Function

The oxygen or lambda sensor in a properly functioning exhaust system monitors the A/F ratio, as often as one hundred times per second, and reports this information to the vehicle's ECU or engine control unit (also referred to as the PCM or ECM). The proper adjustments are then made to ensure that this ratio is ideal or stoichiometric,

helping the automobile burn fuel more efficiently. Most oxygen sensors use the core material of zirconia, which produces voltage in relation to the amount of oxygen in the exhaust.



Evolution

Oxygen sensors were developed by the Robert Bosch Company and first used on Volvo applications in the late 1970's. Originally, automotive oxygen sensors had only one or two wires and were made from zirconia in a thimble shape. They relied upon the heat in the exhaust

system to warm them to their required operating temperature. The problem associated with this concept was that it took a very long time for the sensors to go from nonoperational (thus leaving the ECU in open loop mode) to operational (which is necessary for closed loop mode), typically over a minute. Some automobile manufacturers purposely retarded ignition timing to heat the exhaust to afford faster oxygen sensor and catalyst warm up. When located close to the engine (a requirement to warm the sensors to the adequate operating temperature) it was not possible to monitor the exhaust gases from both engine banks – another downfall of early sensor designs.

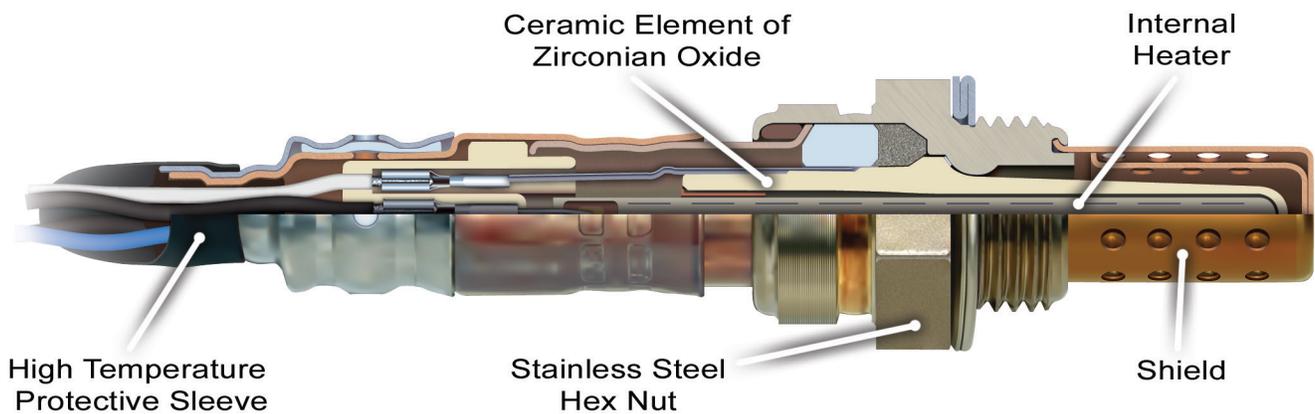
In the early 1980's, oxygen sensor manufacturers added a small rod type heater in the center of the thimble that warmed the ceramic thimble to its operating temperature much faster. The heated sensors could be mounted downstream next to the catalytic converter – a more desirable location because the exhaust gases were in a more homogenous state and the potential for sensor overheating was reduced dramatically. The first versions were three wire sensors that employed a case ground for the sensor signal. Later applications employed four wire versions with an isolated ground.

Starting in the early 1990's for California vehicles & 1996 for the other 49 states, OBDII controls were implemented. The requirements of the oxygen sensor increased dramatically. New technologies were developed and sensors were placed in more locations, thus increasing their feedback to the ECU. The current narrow band sensors, which only allowed for readings

of “rich” or “lean,” were replaced. The new generation of four and five wire wide band sensors are now being employed on many vehicle applications. These sensors allow for exact measurements of A/F ratio, allowing for true emission control.

While the first sensor equipped vehicles had a single sensor, today’s vehicles can have up to eight. The original one wire thimble sensor has been joined by heated, planar, titania, FLO (fast light off), UFLO (ultra-fast light off), wideband and A/F ratio sensors. The modern oxygen sensor, due to its sophistication and placement, is what allows for the fuel injected and low emission engines of the modern vehicle.

Typical Sensor Components



3.0 OXYGEN SENSOR TYPES & FUNCTION

Unheated



A one wire or two wire unheated oxygen sensor is the earliest and most basic type of sensor. One wire sensors employ only a signal wire, while two wire versions also have a wire going to ground. Unheated sensors require external heat and thus can only be located close to the engine's exhaust ports, which are not ideal locations in which to measure A/F ratio. Another limitation of the unheated sensor is that it can take a minute or longer to reach the temperature required for proper operation.

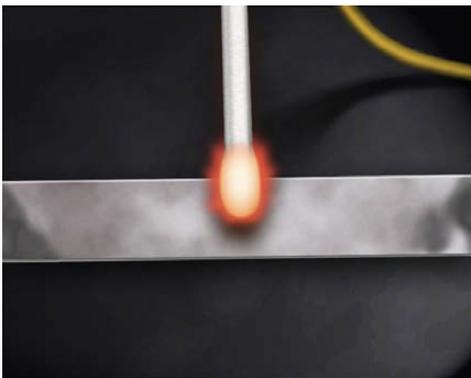
Heated



Three and four wire heated oxygen sensors evolved in order to reach operational temperature more rapidly.

The heater element is an internal resistor that heats up as via an electrical current that is passed through it. Heated sensors can be placed in downstream locations on the exhaust system and will stay at the proper temperature for a longer period of time than unheated sensors. All modern oxygen sensors employ a heater, though the type and heat-up times vary.

FLO & UFLO



Fast Light Off and Ultra-Fast Light Off sensors employ a low resistance, high watt density heater in order to expedite warm up time. These sensors can reach operating temperature in as little as twenty seconds. Since vehicle emissions are at their most harmful when a vehicle is cold, FLO and UFLO are able to help reduce pollution where other sensors cannot. Exposed heater element shown on left.

Planar



Planar sensors use layers of zirconia and alumina bonded together. This technology allows for much faster warm up of the sensor because there is a much lower mass to heat and the heater is in direct contact with the sensing portion. Typical warm up time for planar sensors ranges from five to thirty seconds.

Titania



Titania sensors employ the use of titanium oxide instead of zirconia oxide. Unlike zirconia sensors, they require a base reference voltage to operate and

change resistance when the A/F ratio changes. Titania sensors were mainly used on Nissan vehicles from the mid 80's through the mid 90's and on some European applications. They are no longer used on new vehicles.

Air Fuel Ratio and Wideband



Five wire wideband sensors were introduced in 1994. Along with four wire air fuel ratio sensors, they represent the state of the art in sensor technology. They eliminate the lean-rich cycling inherent in narrow-band sensors, allowing the control unit to adjust the fuel delivery and ignition timing of the engine much more rapidly.

Universal vs. Direct Fit



Universal sensors can be made to fit a variety of applications providing that the sensor is the correct type for the vehicle in question. Connections must be made by splicing the correct wires into the corresponding wires on the existing harness. In the U.S. aftermarket, universal sensors are rarely used as the marketplace prefers the fit, form, and function that direct fit sensors provide.

As their name suggests, direct fit sensors are made to fit specific applications via a connector that fits directly into the existing connector on the vehicle. Direct fit connectors are often the preferred choice of installers.

This is because they offer ease of installation over the inherent risks of making multiple splices. The nature of the connector also helps ensure that the correct replacement part has been chosen.

OE vs. Aftermarket

Original Equipment sensors are the original sensors that were on a vehicle when it left the factory. There are several different providers of OE sensors that are chosen by vehicle manufacturers.

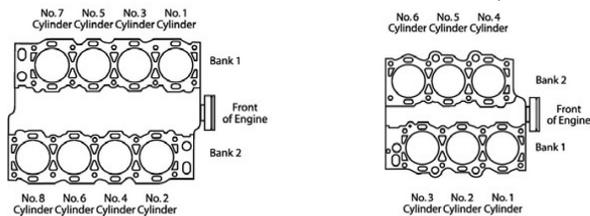
When OE sensors need to be replaced, an Aftermarket sensor can offer matched quality at a reduced cost. Therefore, aftermarket sensors are often the choice of installers and DIY individuals for replacement purposes.

4.0 INSTALLATION AND REMOVAL

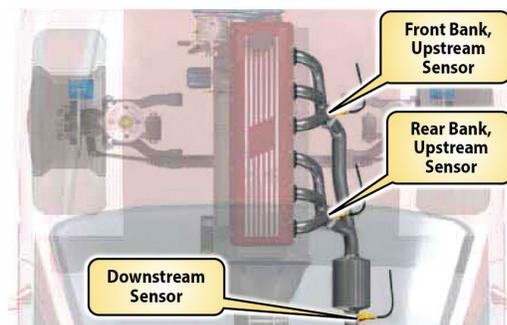
Basic Installation Guide

Once you have determined which sensor(s) need to be replaced (see section 5.0 Troubleshooting and OBDII Codes), the following is a general guide to replacing a direct fit oxygen sensor.

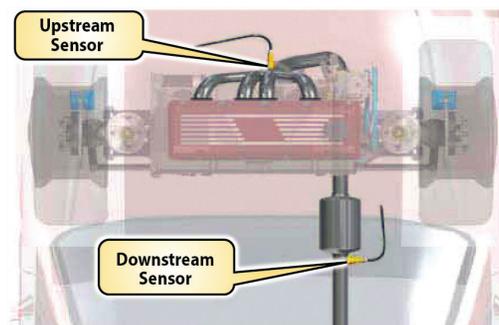
1. The following tools should be available: 7/8" or 22 mm oxygen sensor socket and corresponding ratchet (we would recommend Walker part # 823), 7/8" or 22 mm wrench, flat tip screwdriver, wire cutters, torque wrench, anti-seize compound, and replacement sensor. In some cases, your O2 sensor may require a smaller size tool than the standard 7/8" or 22 mm.
2. Locate the sensor along the vehicles exhaust system and pre-treat the area with a spray lubricant. The use of a bay lift can greatly aide in this process. If you are replacing a sensor due to an OBDII code reference, you must know how to read the codes. B1S1, for example, refers to Bank 1, Sensor 1. To locate a specific engine bank, remember that Bank 1 will always be the most forward sensor bank on the engine block, as shown below:



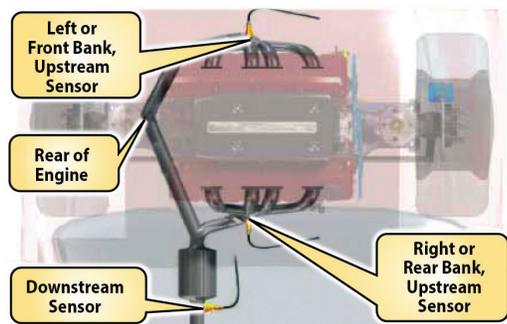
Sensor 1 will usually be in the upstream position and Sensor 2 the downstream. The illustration below shows typical sensor locations on common engine configurations. Regardless of the orientation of the engine in the vehicle, the left or right bank is determined by viewing from the rear of the engine (opposite the drive belts).



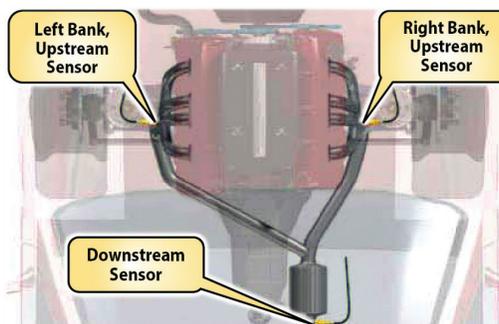
4 & 6 CYLINDER IN-LINE



4 & 6 CYLINDER TRANSVERSE



8 CYLINDER IN-LINE



8 CYLINDER TRANSVERSE

3. Remove the old sensor by first cutting away any zip ties that may be holding the unit in place. Then, unplug the connector. A small flat tip screwdriver may be helpful depressing the connector lock tab (FIGURE 1). Using your O2 socket, unscrew the existing sensor by turning it counterclockwise (FIGURE 2). Once the sensor has been loosened, you can finish removal by hand.

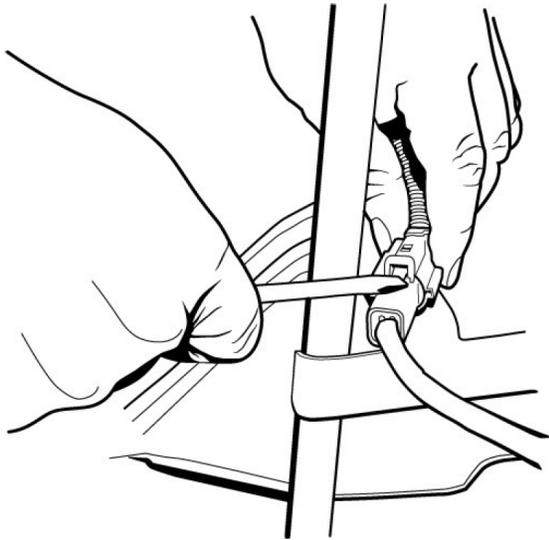


FIGURE 1



FIGURE 2

4. Inspect the replacement sensor to be certain that it has the correct number of wires, and that the connector end is correct. Note that sensor types are not interchangeable; an A/F ratio sensor will not work in place of a regular O2 sensor, and etc. However, sensor styles are interchangeable. The replacement sensor may not look precisely as the old one did.
5. Treat the threads of the new oxygen sensor by applying an even layer of anti-seize lubricant (FIGURE 3). Walker sensors include this component to insure a quality installation. Do not let the anti-seize come in contact with the head of the sensor.



FIGURE 3

6. Start the new sensor in the bung by hand, and tighten to specifications (often 35 ft lbs) with a torque wrench. Do not over tighten the sensor (FIGURE 4).

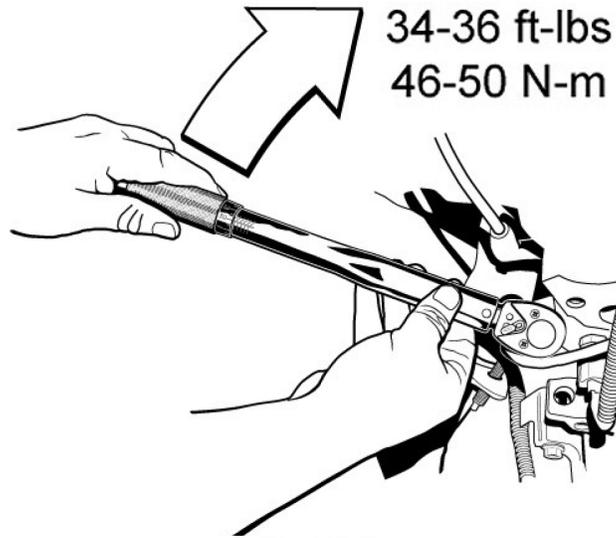


FIGURE 4

7. Connect the new sensor into the existing harness, making certain the connector halves line up properly (FIGURE 5). Finally, secure the sensor wire with a zip tie where necessary to avoid any chafes, snags, or burns. If the vehicle was producing a trouble code, make sure to clear it with a scanner (FIGURE 6).

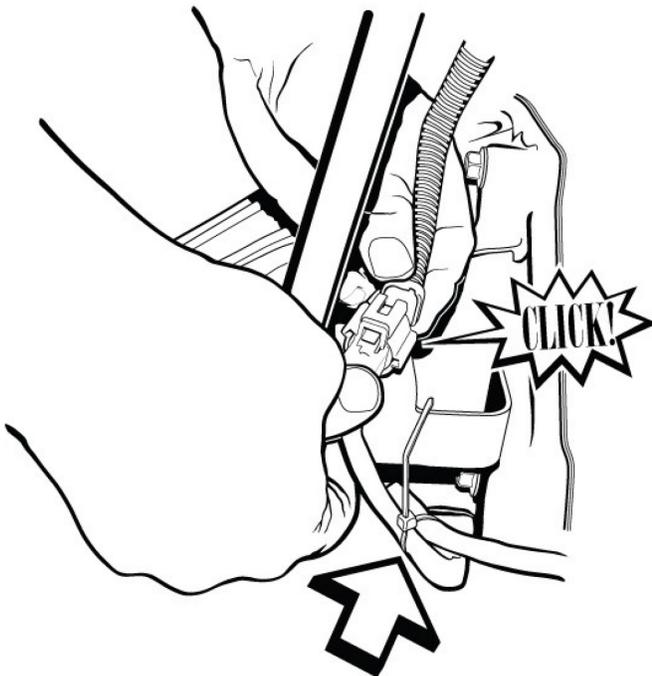


FIGURE 5

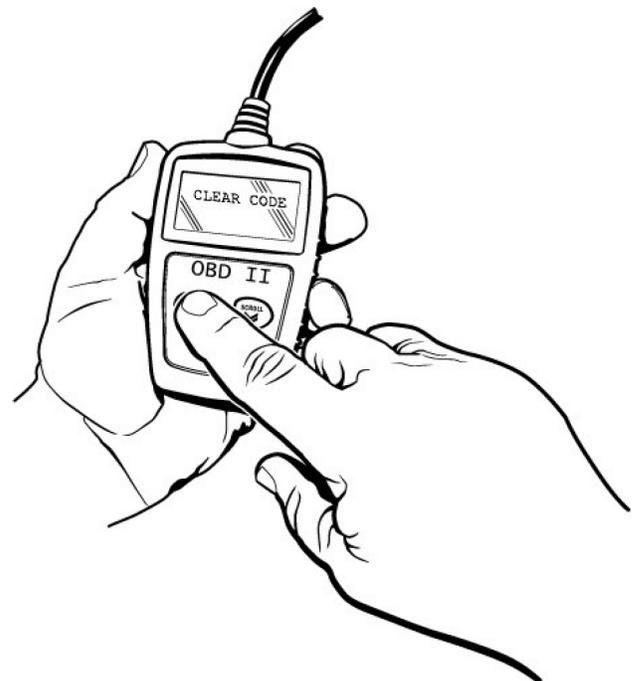


FIGURE 6

5.0 TROUBLESHOOTING

Symptoms of a Bad Oxygen Sensor

It is first important to understand that an OBDII code in itself is not indicative of a failed oxygen sensor. Sensors simply report information. An oxygen sensor that reports a lean fuel mixture, for example, will certainly set off a code. This sensor is doing its job and does not need to be replaced.

If a failing or dead sensor is the issue, there are several OBDII codes in particular that will be set off (more on this in the following section). In turn, the vehicle itself will often display physical symptoms due to a sensor that is not functioning properly.

A decrease in fuel efficiency can be a telltale sign that an O2 sensor is not performing as it should. This can happen because of a fuel mixture that is either too lean or too rich.

Such a swing in A/F ratio is a sign that an upstream or control sensor is faulty. The downstream or diagnostic sensors only monitor the exhaust leaving the catalytic converter and will not cause such an issue.

Other symptoms of a bad oxygen sensor include a rough idle, a misfire, and/ or hesitation when trying to accelerate. Keep in mind, however, that these issues can also have other causes that have no relation to the health of a vehicle's oxygen sensors. Therefore, none of them alone is cause enough to replace one. A combination of an OBDII warning, engine performance issues, and a physical inspection of the sensor is often required to make a proper diagnosis.

Common O2 Failure Causes

Oxygen sensor failure can often be traced to one of three common factors: Age and high mileage, an internal contaminant (poisoning) or an electrical issue.

One or two wire unheated oxygen sensors should be inspected or replaced every 30,000 miles. These sensors must rely solely on hot exhaust gas to reach their operating temperature, and are designed to let a large amount of exhaust make contact with the active ceramic element.

Heated oxygen sensors are less prone to contamination, as their internal heat source allows them to be placed much farther downstream than unheated sensors. Heated sensors should be inspected or replaced every 60,000 miles. While heated oxygen sensors can be placed in safer locations than unheated models, they are made up of multiple circuits that can in turn allow for electrical issues. If the heater circuit in a sensor goes bad, the sensor will not function properly. Heater circuit issues are in fact a common source of OBDII codes.

In order to do their jobs, all oxygen sensors must be exposed to a constant stream of harmful exhaust gasses, extreme heat and high velocity particulates. Because of this, their efficiency will inevitably decrease over time.

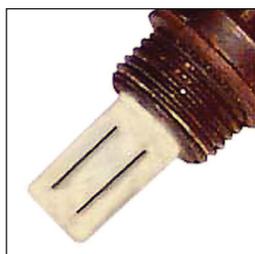
Sometimes, oxygen sensors can become contaminated by elements from within the engine. Exhaust from an overly rich fuel mixture can foul an O2 sensor, as will leaded fuel. Antifreeze or silicone residue resulting from faulty gaskets can have the same effect. The sensors pictured below have been poisoned and need to be replaced.



Carbon buildup from a rich fuel mixture is a frequent occurrence and causes many sensors to go bad. There are many possible causes of this, including a clogged air filter or a leaking or defective fuel injector.



Antifreeze can be very harmful to a sensor if it is allowed into the combustion chamber. This can happen in the case of a cracked or warped cylinder head, a leaking cylinder head gasket, or a leaking intake manifold gasket.



Silicone poisoning, as pictured to the left, can leave the head of an oxygen sensor appearing white in color. The most common cause of this condition is the use of an improper silicone gasket sealant on the engine.



Using improper (leaded) gasoline will harm an oxygen sensor. Although this is a rare occurrence, it is good to know what the effects of leaded gasoline look like on a sensor.

Oxygen Sensor Frequently Asked Questions

The oxygen sensor will not come out.

Soak the sensor thread area with a powerful penetrating lubricant. Starting and revving the engine should further aid in loosening the sensor by heating up the bung. If you are using an open end wrench, try an O2 socket. If this fails, try a long ratchet or breaker bar in conjunction with your socket to generate more torque. If you are still unsuccessful, heat the bung with a torch until cherry red and remove the sensor. After the sensor is removed, be sure to use a thread cleaner to clean up the bung threads. In some cases the threads will need to be repaired. This can be done with a thread repair kit (Walker Part # 88-832). Do not use an impact wrench to remove an O2 sensor, as you will most likely strip the threads in the bung. For any issues requiring the replacement or addition of a bung, Walker carries a full line of oxygen sensor bungs and plugs.

How many oxygen sensors does a particular vehicle have?

Our Find Your Part lookup at www.walkerproducts.com can give you specific sensor data for most applications. Modern cars can have up to 6 or more O2 sensors.

Are the rear oxygen sensors really necessary?

The role of the downstream sensors is to monitor the output and health of the catalytic converter. Removing them will take away this function, and produce a CEL (check engine light) or MIL (malfunction indicator light) on the vehicle.

I am getting a CEL/MIL and a . . . code. Do I need to replace the oxygen sensor?

Not necessarily. The oxygen sensor simply reports the data that it gathers. For example, if you are getting a lean mixture code, you may have a vacuum leak or a faulty fuel injector. Replacing the oxygen sensor will not fix this problem. You will just get the same code again.

Do I need to replace all of the sensors at once?

It is best to replace O2 sensors in pairs. For example, if you replace the downstream left sensor, you should also replace the downstream right.

However, on most vehicles produced since 1996, replacing one sensor (especially the front engine monitoring sensor) will cause the ECU to set a code for the other sensors. This is because the new sensor switching activity is much faster than that of the older aged sensors. It is probable that on most vehicles, the code will be set within 30-60 days AFTER the first sensor replacement.

What is the life expectancy of an oxygen sensor?

Heated oxygen sensors should be checked or replaced every 60,000 miles, while unheated oxygen sensors should be checked or replaced every 30,000 miles.

How can I test an oxygen sensor?

You can test the O2 sensor on a vehicle by first identifying the signal wire on the sensor. Secondly, by using a voltmeter with the scale set to 1 volt, the voltage will fluctuate between 200 and 800 millivolts or .2 to .8 volts on your meter. If the sensor's reading is stalled in position, or switches abnormally high or low, your sensor has failed. If your results are inconclusive, it's best to have your vehicle checked at a professional shop. Note: This test will not work on Air Fuel or Wide Band sensors.

A second method is to connect some of the various testers available on the market directly to the oxygen sensor. This method is not as accurate, but can detect some of the sensor failures.

What is a California emissions sensor? How do I know if I need one?

A California emissions O2 sensor is meant for vehicles that are designed to meet California emission regulations. Such vehicles should have a sticker under the hood or on the driver's door jamb that identify them.

What are the symptoms of a failing oxygen sensor?

Typically, a failing sensor will produce poor gas mileage, hesitation or stalling, and a CEL/MIL. However, the oxygen sensor is not the only cause of these symptoms.

6.0 COMMON OBDII CODES

When an O2 sensor failure occurs, a DTC or diagnostic trouble code is recorded in the ECU and a check engine light appears on the vehicle's dash. The DTC must be retrieved using a scanning tool. There are generic or standard OBDII codes along with enhanced or OEM specific codes. Below is a list of the more common OBDII codes, along with the possible cause or causes of the code.

Code	Description	Location	Possible Causes
P0150	02 Sensor Circuit Malfunction	Bank 2 Sensor 1	Broken sensor element. Sensor disconnected. Shorted wiring. Catastrophic failure of sensor due to thermal shock.
P0151	02 Sensor Circuit Low Voltage	Bank 2 Sensor 1	Short in wiring between sensor ground & signal wire. Silicone or ethylene glycol poisoning of the air reference electrode.
P0152	02 Sensor Circuit High Voltage	Bank 2 Sensor 1	Short in wiring between heater circuit & signal wire. Sensor immersed in water. Silicone or ethylene glycol poisoning of the sensing electrode.
P0153	02 Sensor Circuit Slow Response	Bank 2 Sensor 1	Sensor electrode protective coated with carbon. Silicone poisoning. Ethylene glycol poisoning. Failed sensor heater. Heater circuit fuse.
P0154	02 Sensor Circuit No Activity Detected	Bank 2 Sensor 1	Short in wiring between sensor ground & signal wire. Silicone or ethylene glycol poisoning of the air reference electrode.
P0155	02 Sensor Heater Circuit Malfunction	Bank 2 Sensor 1	Sensor heater shorted or open. Replacement sensor installed with incorrect heater current values. Open or shorted electrical connections. Heater circuit fuse.
P0156	02 Sensor Circuit Malfunction	Bank 2 Sensor 2	Broken sensor element. Sensor disconnected. Shorted wiring. Catastrophic failure of sensor due to thermal shock.
P0157	02 Sensor Circuit Low Voltage	Bank 2 Sensor 2	Short in wiring between sensor ground & signal wire. Silicone or ethylene glycol poisoning of the air reference electrode.
P0158	02 Sensor Circuit High Voltage	Bank 2 Sensor 2	Short in wiring between heater circuit & signal wire. Sensor immersed in water. Silicone or ethylene glycol poisoning of the sensing electrode.
P0159	02 Sensor Circuit Slow Response	Bank 2 Sensor 2	Sensor electrode protective coated with carbon. Silicone poisoning. Ethylene glycol poisoning. Failed sensor heater. Heater circuit fuse.
P0160	02 Sensor Circuit No Activity Detected	Bank 2 Sensor 2	Short in wiring between sensor ground & signal wire. Silicone or ethylene glycol poisoning of the air reference electrode.

Code	Description	Location	Possible Causes
P0161	02 Sensor Heater Circuit Malfunction	Bank 2 Sensor 2	Sensor heater shorted or open. Replacement sensor installed with incorrect heater current values. Open or shorted electrical connections. Heater circuit fuse.
P0162	02 Sensor Circuit Malfunction	Bank 2 Sensor 3	Broken sensor element. Sensor disconnected. Shorted wiring. Catastrophic failure of sensor due to thermal shock.
P0163	02 Sensor Circuit low Voltage	Bank 2 Sensor 3	Short in wiring between sensor ground & signal wire. Silicone or ethylene glycol poisoning of reference electrode.
P0164	02 Sensor Circuit High Voltage	Bank 2 Sensor 3	Short in wiring between heater circuit & signal wire Sensor immersed i n water. Silicone or ethylene glycol poisoning of the sensing electrode.
P0165	02 Sensor Circuit Slow Response	Bank 2 Sensor 3	Sensor electrode protective coated with carbon. Silicone poisoning. Ethylene glycol poisoning. Failed sensor heater. Heater circuit fuse.
P0166	02 Sensor Circuit No Activity Detected	Bank 2 Sensor 3	Short in wiring between sensor ground & signal wire. Silicone or ethylene glycol poisoning of the air reference electrode.
P0167	02 Sensor Heater Circuit Malfunction	Bank 2 Sensor 3	Sensor heater shorted or open. Replacement sensor in stalled with incorrect heater current values. Open or shorted electrical connections. Heater circuit fuse.
P0170	Fuel Trim Malfunction	Bank 1	Vacuum leak. Gas in engine oil. Air lea ks. Bad 02 sensor.
P0171	System Too Lean	Bank 1	Leaking exhaust gaskets or vacuum lines. Defective fuel injectors. Damaged fuel pump. Clogged fuel filter.
P0172	System Too Rich	Bank 1	Vacuum leak. Fuel pressure or delivery problem. Faulty MAF sensor.
P0173	Fuel Trim Malfunction	Bank 2	Vacuum leak. Gas in engine oil. Air leaks. Bad 02 sensor.
P0174	System Too Lean	Bank 2	Leaking exhaust gaskets or vacuum lines. Defective fuel injectors. Damaged fuel pump. Clogged fuel filter.
P0175	System Too Rich	Bank 2	Vacuum leak. Fuel pressure or delivery problem. Faulty MAF sensor.

7.0 DEFINITIONS OF TERMINOLOGY

A/F Ratio	Air Fuel Ratio.
A/F Ratio Sensor	A four wire, heated oxygen sensor that more precisely measures A/F ratio than do traditional sensors.
Aftermarket Sensor	A sensor made to replace OE sensors.
CEL	Check Engine Light.
Closed Loop Mode	When the oxygen sensor(s) are operational in a vehicle's diagnostics.
DTC	Diagnostic Trouble Code
Direct Fit Sensor	A sensor with a connector that fits an existing connector directly.
DIY Installer	Do It Yourself. An individual that works on his or her own vehicle
Downstream	The sensor position after the catalytic converter. Also known as post-cat.
ECM	Engine Control Module
ECU	Engine Control Unit.
FLO Sensor	Fast Light Off Sensor. This design can reach operating temperature in as little as 10 seconds.
Heated Sensor	An oxygen sensor design that utilizes an internal heater.
Lean	A condition where there is an excess of oxygen in the exhaust stream.
MIL	Malfunction Indicator Lamp.
OBDII	The current onboard diagnostic language used by passenger vehicles.
OE Sensor	A sensor that is installed on a factory vehicle.
Open Loop Mode	When the oxygen sensor(s) are not engaged in a vehicle's diagnostics.
PCM	Powertrain Control Module
Planar Sensor	A sensor made of layers of zirconia & alumina bonded together, allowing for faster warm up of the sensor.
Rich	A condition where there is a shortage of oxygen in the exhaust stream.
Stoichiometric	The ideal air fuel ratio of 14.7:1 air: fuel by mass for gasoline engines.
Titania Sensor	A sensor design that employs the use of titanium instead of zirconia.
UFLO Sensor	Ultra Fast Light Off Sensor. The oxygen sensor design that will reach operating temperature in the least amount of time possible.
Universal Sensor	A sensor with no connector that must be installed through splices.
Unheated Sensor	An early, basic sensor design that relies on external heat.
Upstream	The sensor position before the catalytic converter. Also known as pre-cat.
Wideband	A five wire, heated oxygen sensor that utilizes patented technology to provide a better measurement of A/F ratio than do four wire sensors.
Zirconia	A white, crystalline compound that is used in oxygen sensors.