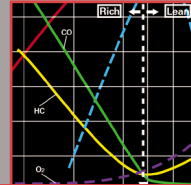


Motor Vehicle Exhaust Emissions

Emission Control and Standards

AUDI ACADEMY



Audi

Academy

Self-Study Program
Course Number 943003

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Course Goals

Course goals

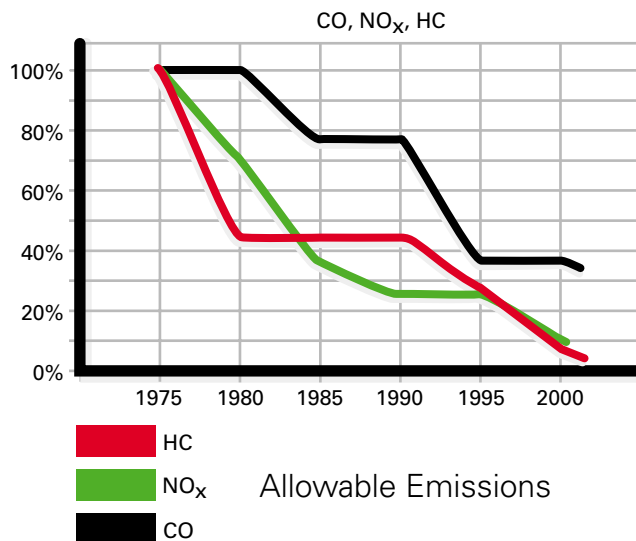
- Recognize the need for emissions controls
- Review the composition of exhaust gases
- Identify methods for reducing harmful pollutants
- Outline specific testing procedures

Introduction

The effects of the internal combustion engine on air quality have been an environmental concern for many years. The Environmental Protection Agency (EPA) raises the average fuel economy requirement yearly, and reduces allowable emissions every few years.

Emissions control efforts appear to be working. While the number of automobile registrations has risen sharply, fuel consumption has risen only slightly. Today, passenger vehicles account for less than 24 percent of smog in major cities, compared to 40 percent in 1970. These findings are more promising when we take into account that the number of miles driven per year has increased to 2 1/2 times the amount driven in 1970, and that light truck/SUV registrations have nearly doubled during the past 5 years.

It has been determined that half of all automobile pollution is generated by those 10 percent of the vehicles in the worst running condition. Modern emissions control standards ensure that today's automobiles run cleaner, but today's technicians ensure the percentage of gross polluters will continue to decline, ensuring that the quality of the environment will continue to increase in the future.

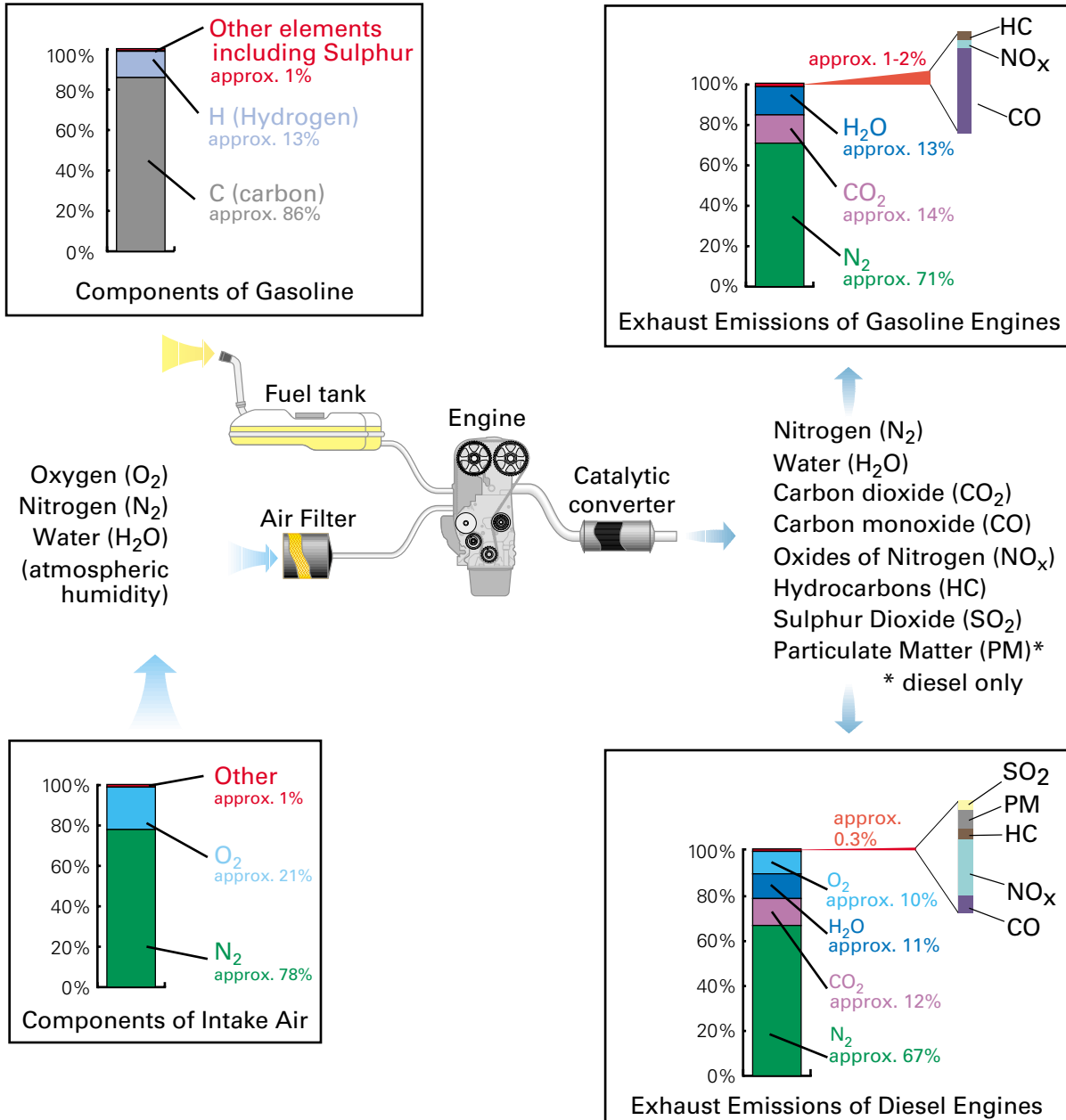


SSP 9430/01

Composition

Composition

The diagram below shows the intake and exhaust components of the internal combustion engine. Note that carbon monoxide and hydrocarbons make up only a small percentage of a vehicles exhaust gas emissions.



SSP 9430/02

Exhaust Gas Components

By-products of combustion	
Carbon dioxide (CO ₂)	Sulphur dioxide (SO ₂)
Carbon monoxide (CO)	Particulate matter (PM)*
Hydrocarbons (HC)	Nitrogen (N ₂) **
Oxides of nitrogen (NO _x)	Oxygen (O ₂) **
	Water (H ₂ O) **

* *diesel only*

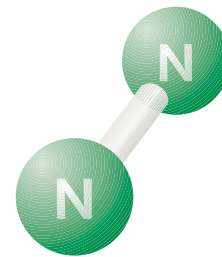
** *present as intake components*

SSP 9430/28

An internal combustion engine produces the following exhaust components:

Nitrogen (N₂)

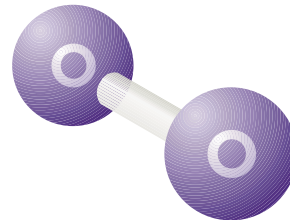
Nitrogen gas is non-flammable, colorless and odorless, and makes up 78% of the air we breathe. While most of the nitrogen drawn into the combustion chamber during the intake stroke is expelled during the exhaust stroke, a small portion of the nitrogen can combine with oxygen (O₂) to form oxides of nitrogen (NO_x).



SSP 9430/03

Oxygen (O₂)

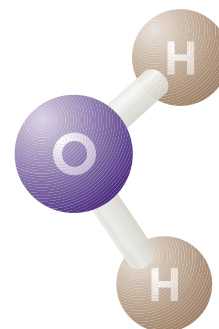
Oxygen gas is colorless, odorless, and tasteless. It comprises 21% of the air we breathe.



SSP 9430/04

Water (H₂O)

Water may be present in the combustion chamber in either gaseous (due to atmospheric humidity) or liquid (via the fuel injectors when low quality fuel is used) forms. Water is a normal by-product of combustion.



SSP 9430/05

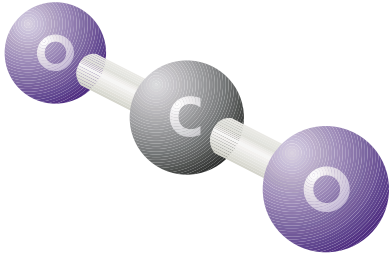
Composition

Carbon Dioxide (CO₂)

Carbon dioxide gas is colorless and non-flammable, and is a by-product of the combustion process. It is considered a "Greenhouse gas" due to its role in global warming.

Energy from the sun heats the Earth's surface, which in turn radiates energy back into space. Carbon dioxide traps a portion of this outgoing energy, retaining heat and contributing to the "Greenhouse effect".

The higher the concentration of carbon dioxide released into the atmosphere, the greater the impact on the world's climate. The emissions of carbon dioxide (CO₂), however, are directly proportional to fuel consumption.

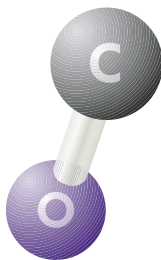


SSP 9430/06

Carbon Monoxide (CO)

Carbon monoxide is a colorless, odorless, tasteless, and extremely toxic gas produced by the incomplete combustion of intake components containing carbon. When released into the open, carbon monoxide quickly oxidizes to form carbon dioxide.

In very small concentrations, carbon monoxide can cause respiratory problems and impair visual perception, manual dexterity and learning function. In slightly greater concentrations, it can be lethal.

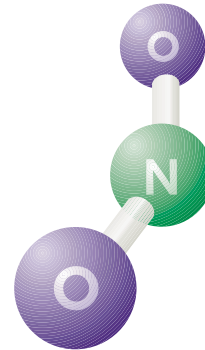


SSP 9430/08

Oxides of Nitrogen (NO_x)

Oxides of nitrogen are compounds of nitrogen (N₂) and oxygen (O₂) (e.g. NO, NO₂, N₂O, etc). Oxides of nitrogen are produced by high pressure, high temperature, and a surplus of oxygen in the engine during the combustion cycle.

Several oxides of nitrogen are harmful to health. Action taken to reduce fuel consumption has, unfortunately, often led to a rise in nitrogen oxide concentrations in exhaust emissions. This is because a more efficient combustion process generates higher temperatures.

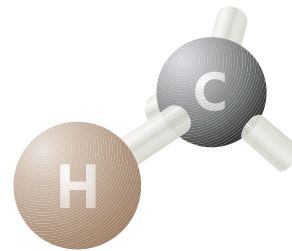


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Hydrocarbons (HC)

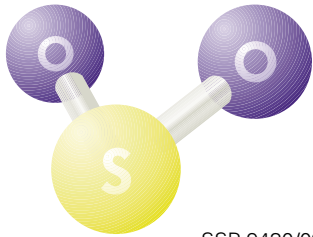
Hydrocarbons are unburned fuel components which occur in the exhaust emissions after incomplete combustion. Hydrocarbons occur in a variety of forms, including C₆H₆ (benzene) and C₈H₁₈ (octane). Each has different effects on humans; some irritate sensory organs, while others, such as benzene, are cancer causing.

Hydrocarbons mix with the oxides of nitrogen in sunlight to form ozone, which damages lung tissue, aggravates respiratory disease, and increases susceptibility to respiratory infections.



SSP 9430/10

Composition

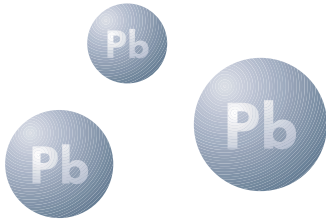


SSP 9430/09

Sulphur Dioxide (SO₂)

Sulphur dioxide gas is colorless, pungent and non-flammable. It is present in very low concentrations in exhaust gases, and can cause respiratory illness.

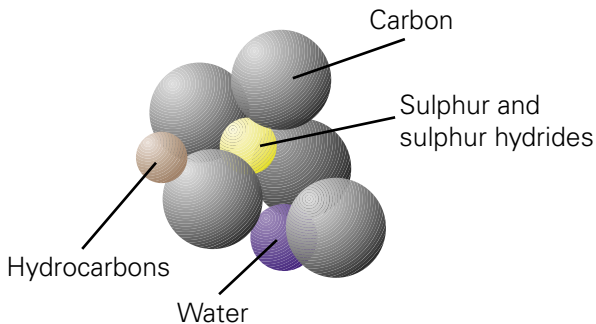
Sulphur dioxide emissions can only be reduced by lowering the sulphur content of fuel.



SSP 9430/11

Lead (Pb)

Lead is extremely toxic and was once used in gasoline to prevent knock. In 1985, 3000 tons of lead were released into the atmosphere. Today's gasolines substitute environmentally friendly additives in place of lead.



SSP 9430/29

Particulate Matter (PM)

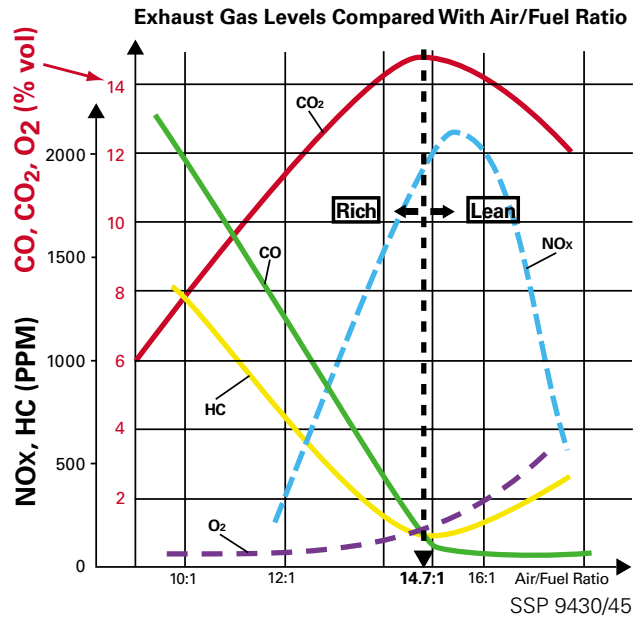
Particulate matter is mainly produced by diesel engines. It consists of a core and several attached components. One of the attached components, hydrocarbons, are oxidized in the catalytic converter. The remainder of the particulate matter can only be collected by specialized particulate filters.

Operating Conditions and the Effect on Exhaust Gas Composition

Operating conditions of the engine effect the composition of the exhaust gases produced. For example, a leaking injector will cause hydrocarbon emissions to rise.

Harmful exhaust emissions, with the exception of NO_x , are at their lowest levels when the air to fuel mixture is 14.7 parts air to 1 part fuel by weight. This is called the stoichiometric point, and is the same for all gasoline powered internal combustion engines.

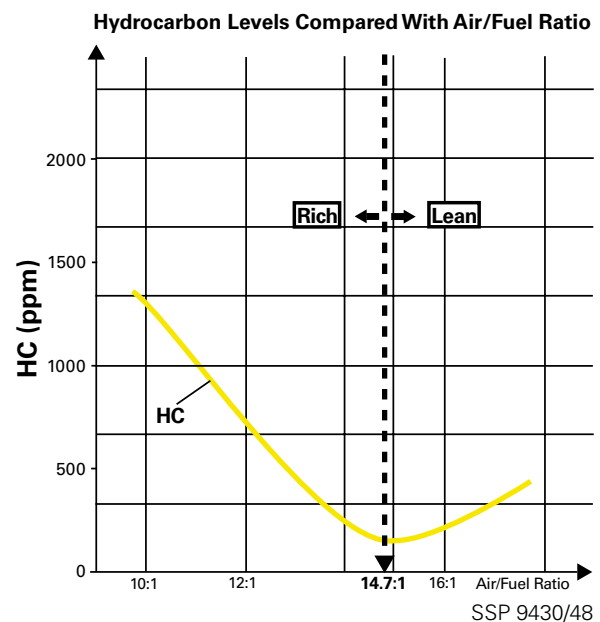
Note: All the charts show readings before the catalytic converter.



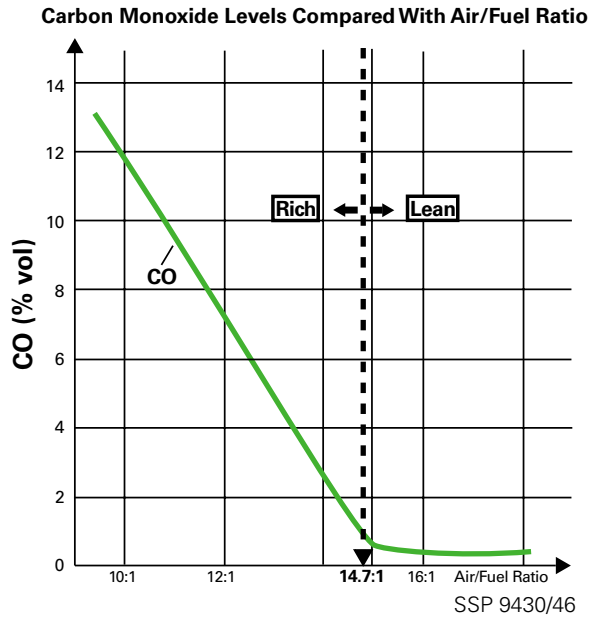
Hydrocarbons

Hydrocarbon emissions tend to remain fairly constant unless the mixture is very rich or very lean. HC tends to rise when the fuel mixture becomes so lean that the flame front in the combustion chamber cannot ignite all the fuel molecules. This is called a lean misfire. High HC often indicates incompletely atomized fuel (leaking injector), or an ignition problem.

HC levels after the catalytic converter will be low, because the catalytic converter will convert most hydrocarbons to CO_2 and H_2O .



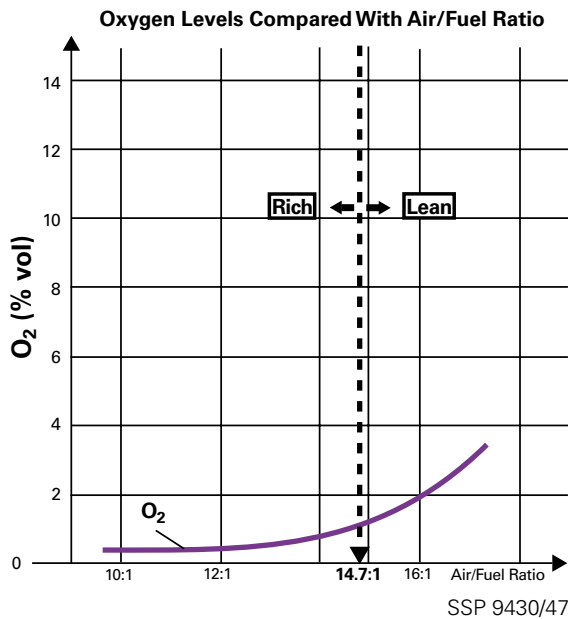
Composition



Carbon Monoxide

Carbon Monoxide levels are high when the air/fuel mixture is less than 14.7:1. There is not enough oxygen in the mixture to completely convert all the HC to CO_2 and H_2O . CO emissions drop sharply as the air/fuel mixture is increased, and levels off at approximately 14.7:1. High CO readings before the catalytic converter always indicate a rich mixture.

CO levels after the catalytic converter will tend to be low, because the catalytic converter will convert most CO to CO_2 .



Oxygen

Oxygen is low whenever the mixture is rich, because rich mixtures burn all the O_2 available. Just before the stoichiometric point, the O_2 level begins to rise. Once you cross over into the lean side, the O_2 curve climbs rapidly.

O_2 levels after the catalytic converter will be low due to the oxidation process, and the ability of the catalytic converter to store oxygen.

Carbon Monoxide and Oxygen

Carbon monoxide and oxygen values equalize at 14.7:1, the stoichiometric point. If the exhaust gases are measured before the catalytic converter, the following will always be true: If O_2 is higher than CO it is a lean mixture, and if CO is higher than O_2 it is a rich mixture.

Carbon Dioxide

Carbon dioxide indicates combustion efficiency. The more efficient the burn, the higher the CO_2 readings; the less efficient, the lower the CO_2 .

Adding CO_2 to the chart provides an efficiency indicator. As the mixture nears 14.7:1, CO_2 rises to its highest levels.

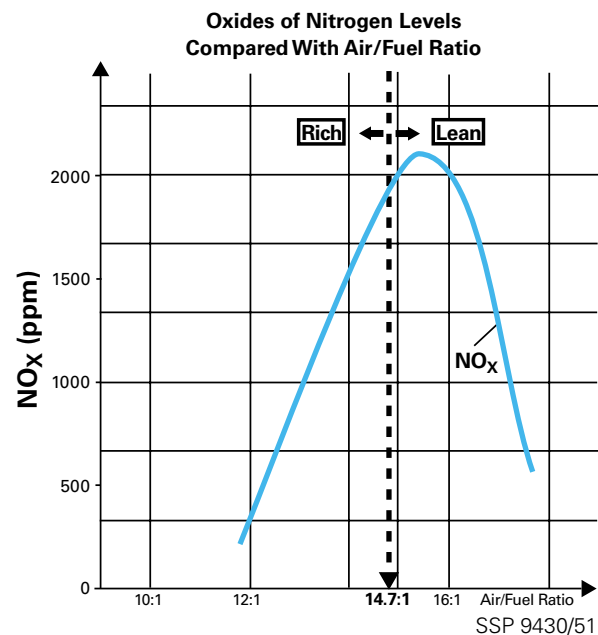
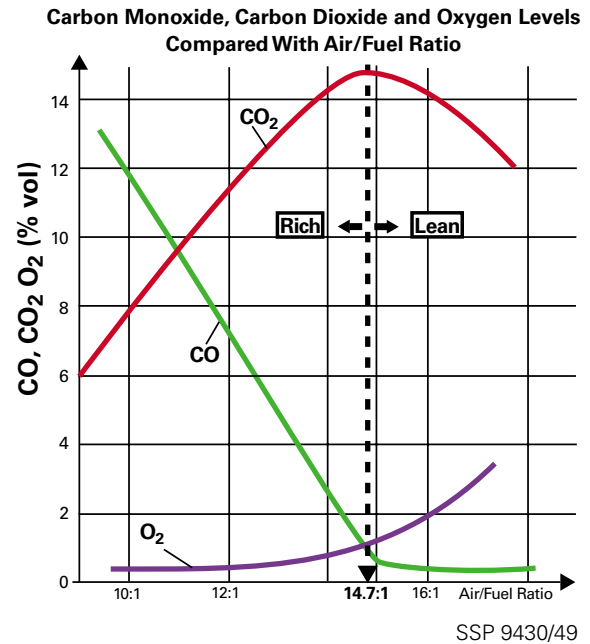
Oxides of Nitrogen

Oxides of nitrogen levels are at their highest when the mixture is near 14.7:1. NO_x production can be controlled both during pre-combustion and post-combustion.

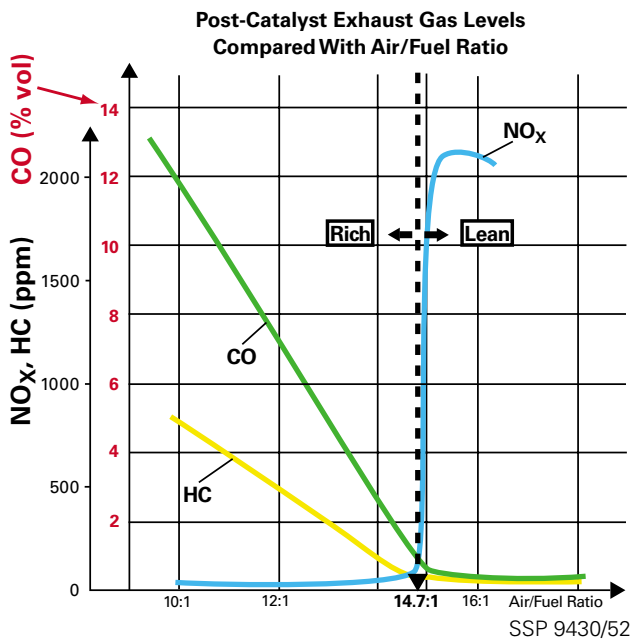
The primary method of controlling NO_x is by keeping the combustion temperatures and pressures low. Low compression, variable valve timing, and exhaust gas recirculation all help to reduce NO_x .

Post-combustion NO_x control is accomplished by the 3-way catalytic converter. However, a catalytic converter cannot overcome the emissions from an engine that is producing too much NO_x .

Comparing the relationship between HC, CO, O_2 , CO_2 and NO_x in this way provides a "window" into both the air/fuel mixture and the operating conditions within the engine.



Composition



Effect of the 3-way Catalytic Converter on Exhaust Gas Emissions

CO, HC and NO_x are all reduced to their lowest levels by the 3-way catalytic converter, as long as the engine operates close to 14.7:1 (stoichiometric range).

If the engine runs rich, there will not be enough free oxygen in the exhaust for the catalytic converter to oxidize the hydrocarbons into CO₂ and H₂O. This may cause overheating, damaging the catalytic converter.

If the engine runs lean, the excess oxygen in the exhaust will not allow the catalytic converter to effectively break the NO_x molecules into nitrogen and oxygen (reduction). This, combined with higher NO_x emissions caused by lean conditions in the combustion chamber, will cause high levels of NO_x to be emitted by the catalytic converter when the engine is under a load.

Methods of Reducing Emissions

Exhaust emissions standards adopted across Europe and the United States have prompted the automotive industry to develop new methods for reducing exhaust gas pollution.

Unfortunately, the development of individual automotive technologies is not sufficient. The vehicle must instead be looked at as an integral whole, matching all components to one another. Taking this holistic approach to vehicle development, four main exhaust emission control strategies can be defined:

- Reduction of fuel consumption
- Management of fuel vapor losses
- Treatment of exhaust gases before they are released into the atmosphere
- Emissions component performance monitoring (On Board Diagnostics)

Reduction of Fuel Consumption

Many recent engineering advancements have reduced fuel consumption, including improved aerodynamics, tires with lower rolling resistance, the use of lightweight materials, transmission optimization, and more accurate engine management.

It is important to consider that these engineering advancements are partially negated by the increase in new vehicle registrations and the current trend towards more powerful and heavier vehicles.

Improved aerodynamics

The styling of the modern automobile must strike a balance between space efficiency, aesthetics, and aerodynamics. By reducing drag, less power (and therefore less fuel) is needed to maintain a given speed.

Reduced rolling resistance

A portion of the power required to maintain a given speed is used to overcome the rolling resistance caused by the flexing of the tire's sidewall as the contact patch meets the road surface.

Because this flexing converts the energy provided by the engine into heat, fuel consumption can be reduced by specifying tires with a higher silica content and lower rolling resistance. As a general rule, rolling resistance decreases with increasing tire pressure, and increases with vehicle weight.

Methods of Reducing Emissions



SSP 9430/44

Reduction of vehicle mass

Each year, safety standards and standard equipment levels increase. This additional equipment adds mass, and unfortunately much of a vehicle's fuel consumption is used to accelerate a vehicle's mass up to speed. As a general rule, about 1.15 gallons of fuel is saved over 1000 miles of driving for each 100 lb. reduction in weight.

To offset the additional weight, Audi engineers have begun to utilize advanced materials with higher strength to weight ratios than conventional steel. Both the Audi A8 and Audi A2, for example, have aluminum structures and body panels, resulting in a weight savings of approximately 43% over conventional steel.

Due to cost and manufacturing constraints, aluminum is rarely used in high percentages. The trunklid of the Audi TT, for example, is formed from aluminum, as are the fenders of the A6 4.2.

High-strength steel is more common due to the material's lower cost and ease of manufacture when compared to aluminum. A high strength steel panel is thinner than a conventional steel panel of the same strength, which in turn reduces vehicle weight.

If you are using a rotary dial telephone, or have a rotary telephone at your test, please call **1-888-565-7366**, Monday

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Methods of Reducing Emissions

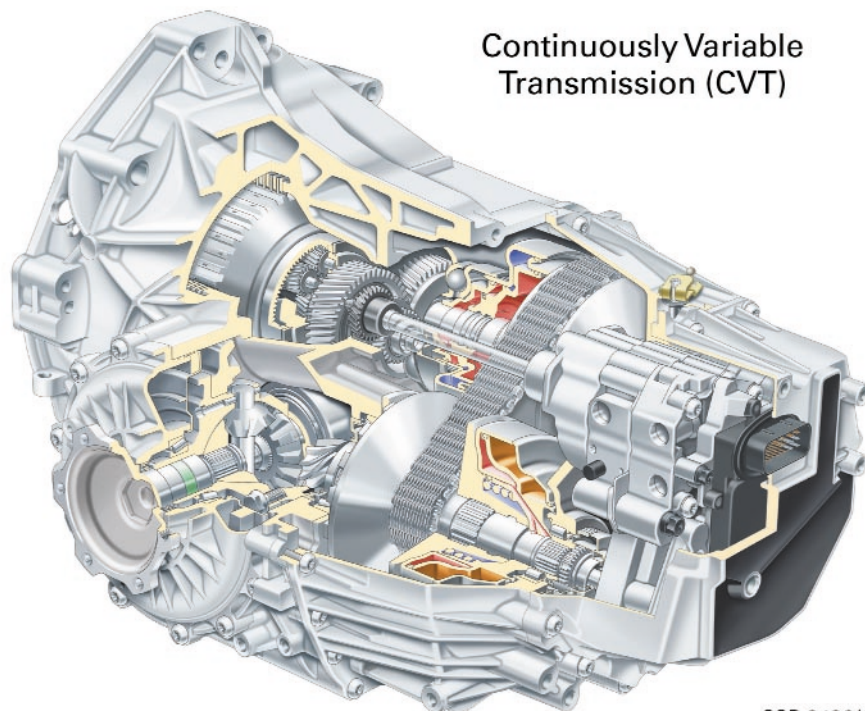
Transmission optimization

Fuel efficiency is strongly influenced by the design of a vehicle's transmission. Traditionally, there have been two types of transmission: manual and automatic. Automatic transmissions are less efficient due to the decoupling effect of the torque converter, and their fewer number of ratios. Having a greater number of ratios allows the engine to operate in its optimal RPM range more often, which results in better fuel economy.

Two transmission concepts recently introduced in some markets combine the performance and efficiency of the manual transmission design with the ease of use of an automatic transmission. The first of these concepts is the automated direct shift manual gearbox, essentially a conventional manual transmission with electro-hydraulic clutch engagement and gear selection. In the sys-

tem's driver-selectable "economy" driving mode, the transmission's control unit selects the most fuel efficient shift points based on the driving situation. The system also allows the engine to shut down when the car is stationary and the driver's foot is on the brake, and can disengage the clutch when the vehicle is coasting, reducing drag force and increasing fuel economy.

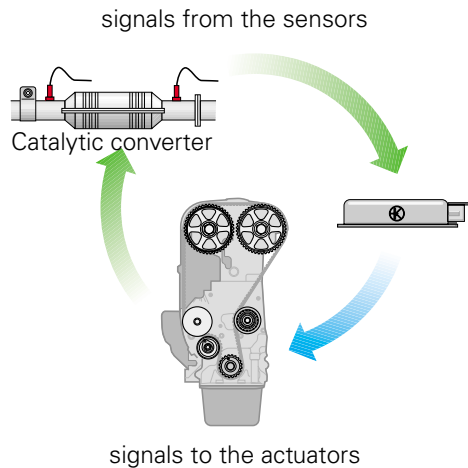
The second of these concepts is the Continuously Variable Transmission (CVT), which uses a chain drive mechanism to adjust reduction ratios continuously between the starting torque and final torque multiplication ratios. As a result, the engine can always operate in its optimum RPM range for performance or fuel economy, depending on driving conditions. The CVT uses an electro-hydraulically controlled wet plate clutch rather than a torque converter, further increasing efficiency.



SSP 9430/15

Methods of Reducing Emissions

Engine Management Control Loop



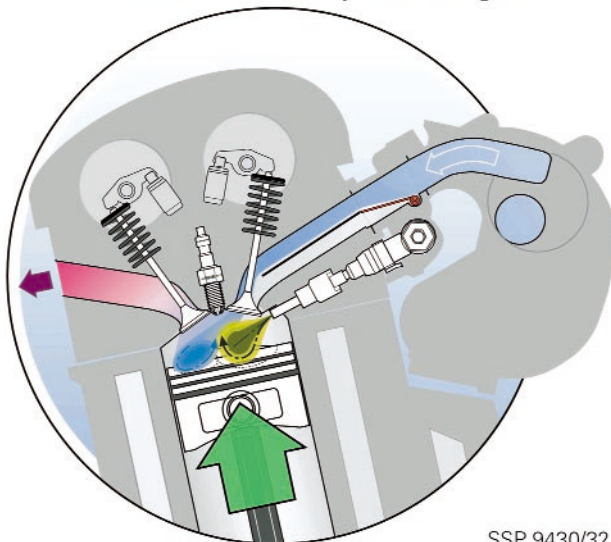
SSP 9430/16

More accurate engine management

Modern engine management systems use input signals from sensors (e.g. engine speed, throttle position, and mass air flow) to determine control values for the controllable components (e.g. spark advance and fuel injection quantity). This control loop allows the ECU to adapt to changes in atmospheric conditions, fuel quality or the engine's running condition.

The largest concentration of HC and CO is emitted just after a cold start, before the emissions equipment reaches operating temperature and while the ECU is still in "open loop" mode. Modern Audi vehicles use heated oxygen sensors and have their catalytic converters placed close to the engine, allowing both components to reach operating temperature (approx. 572°F/300°C in the case of the catalytic converter) more quickly. The heated planar oxygen sensor, for example, is operational as few as 10 seconds after engine start-up.

Gasoline Direct Injection Engine



SSP 9430/32

Engine optimization

Recently introduced in some markets, the Gasoline Direct Injection engine design increases power and efficiency by injecting the fuel directly into the combustion chamber under extremely high pressure. This direct injection improves swirl, while the high fuel system pressure results in finer atomization of the fuel. As an added benefit, the Gasoline Direct Injection engine uses mixtures as lean as 19:1 under light load conditions.

Methods of Reducing Emissions

Management of Fuel Vapor Losses

Evaporative Emissions (EVAP)

Fuel vapor escaping into the atmosphere contains more hydrocarbons than a vehicle's exhaust emissions. When these unburned hydrocarbons are exposed to sunlight, low-level ozone is created. Low-level ozone is the primary cause of smog, and has been linked to respiratory disorders.

EVAP systems prevent gasoline vapors that form above the surface of the fuel in the tank from being released into the atmosphere. When the vehicle is not in use, gasoline vapor is routed through the Breather Bottle and Roll-over valve to the EVAP Canister, where it is captured by activated charcoal. This vapor is reintroduced into the intake manifold when the engine is restarted.

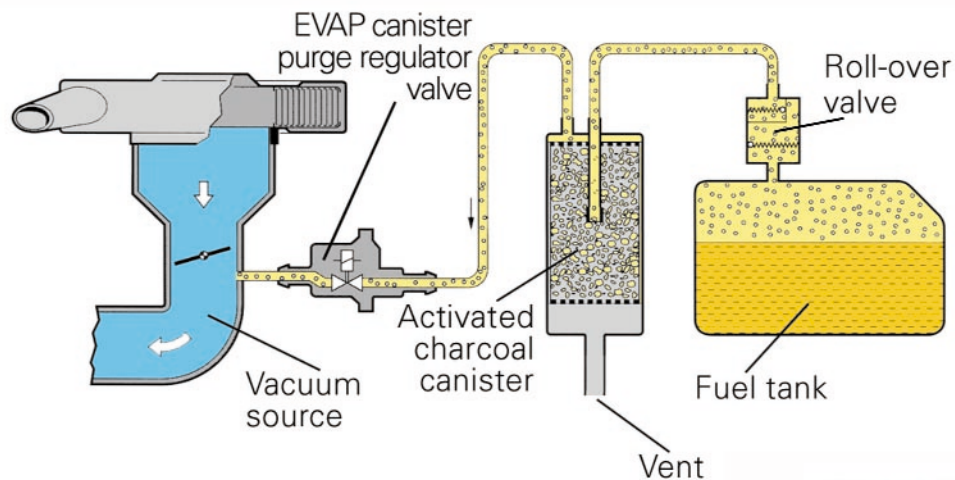
Leak Detection Pump (LDP)

The Leak Detection Pump (LDP) was added to the EVAP systems on 1999 model year and later Audi vehicles to satisfy the OBD II requirement of an automatic leak-check every drive cycle.

On Board Refueling Vapor Recovery (ORVR)

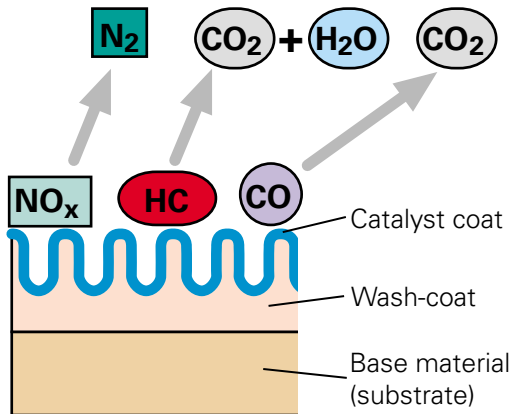
More hydrocarbons are released into the atmosphere during refueling than during the use of one tank of gasoline. Some states have attempted to combat this by requiring gas stations to fit vapor recovery nozzles that capture gasoline vapor for storage in an underground storage tank. All 1999 and later model year Audi vehicles are equipped with ORVR systems to meet Federal Emission standards.

For more information, refer to SSP 941903, *EVAP Systems, Operation and Diagnosis*.

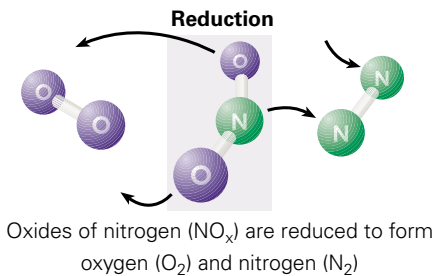


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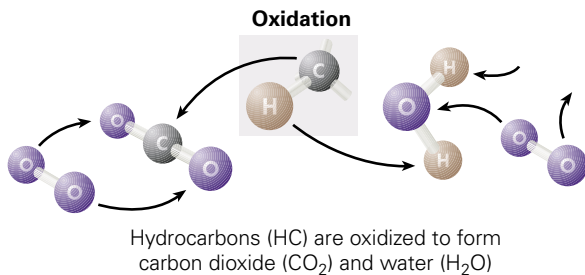
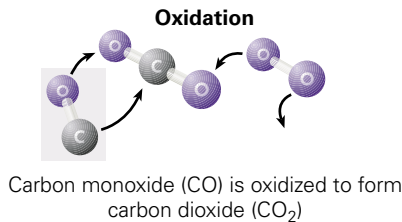
Methods of Reducing Emissions



SSP 9430/43



SSP 9430/18



SSP 9430/20

Treatment of Exhaust Gases

Before being released into the atmosphere, exhaust gases pass through the catalytic converter. The catalytic converter contains a ceramic or metallic monolith coated with a rough "wash coat" of platinum, rhodium and/or palladium. The wash coat maximizes the internal surface area exposed to exhaust flow, increasing efficiency. The metals within the wash coat act as a catalyst, facilitating two chemical reactions: reduction and oxidation.

In reduction, oxides of nitrogen (NO_x) are "reduced," leaving oxygen (O₂) and nitrogen (N₂) — both harmless, naturally occurring gases.

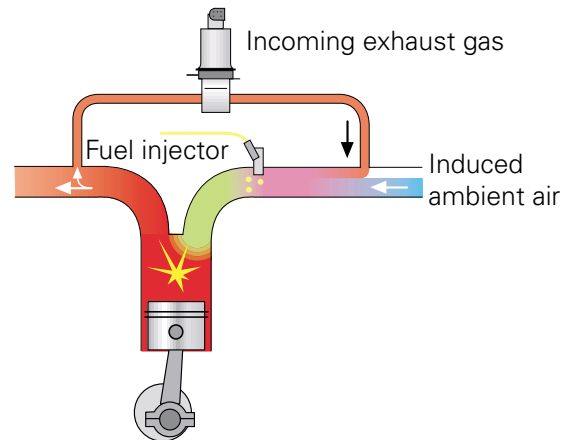
In oxidation, oxygen (O₂) oxidizes carbon monoxide (CO) to form carbon dioxide, and oxidizes hydrocarbons (HC) to form carbon dioxide (CO₂) and water (H₂O).

The reduction process is most efficient in a low O₂ environment, while the oxidation process is most efficient in a high O₂ environment.

Methods of Reducing Emissions

Exhaust Gas Recirculation (EGR)

Some vehicles are equipped with EGR systems, which inject a small amount of exhaust gas into the intake manifold. Since there is very little combustibility left in the injected gas, it simply occupies space. This lowers combustion chamber temperature, which reduces oxide of nitrogen (NO_x) emissions. The same effect can be accomplished through the use of variable valve timing.



Exhaust Gas Recirculation

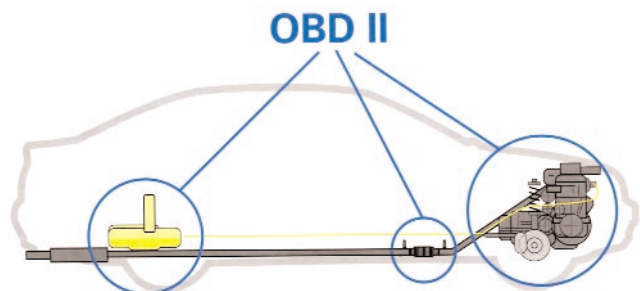
SSP 9430/21

Performance Monitoring (On Board Diagnostics)

The On Board Diagnostics system was designed to reduce pollution emitted by motor vehicles by monitoring the function of emissions-related components. If a malfunction is detected, a Diagnostic Trouble Code (DTC) is stored in DTC memory and the driver is alerted by the illumination of the Malfunction Indicator Lamp (MIL.)

The second-generation version, OBD II, was introduced in the 1996 model year. OBD II retains the functions of OBD I, and adds the capability to:

- determine plausibility of signals received for emissions control components and related sensors
- monitor system functions (e.g. Secondary Air Injection system)
- monitor the entire drivetrain (e.g. automatic transmission emergency mode status)
- monitor catalytic converter efficiency



SSP 9430/22

Certification and Testing

Federal Emissions Certification

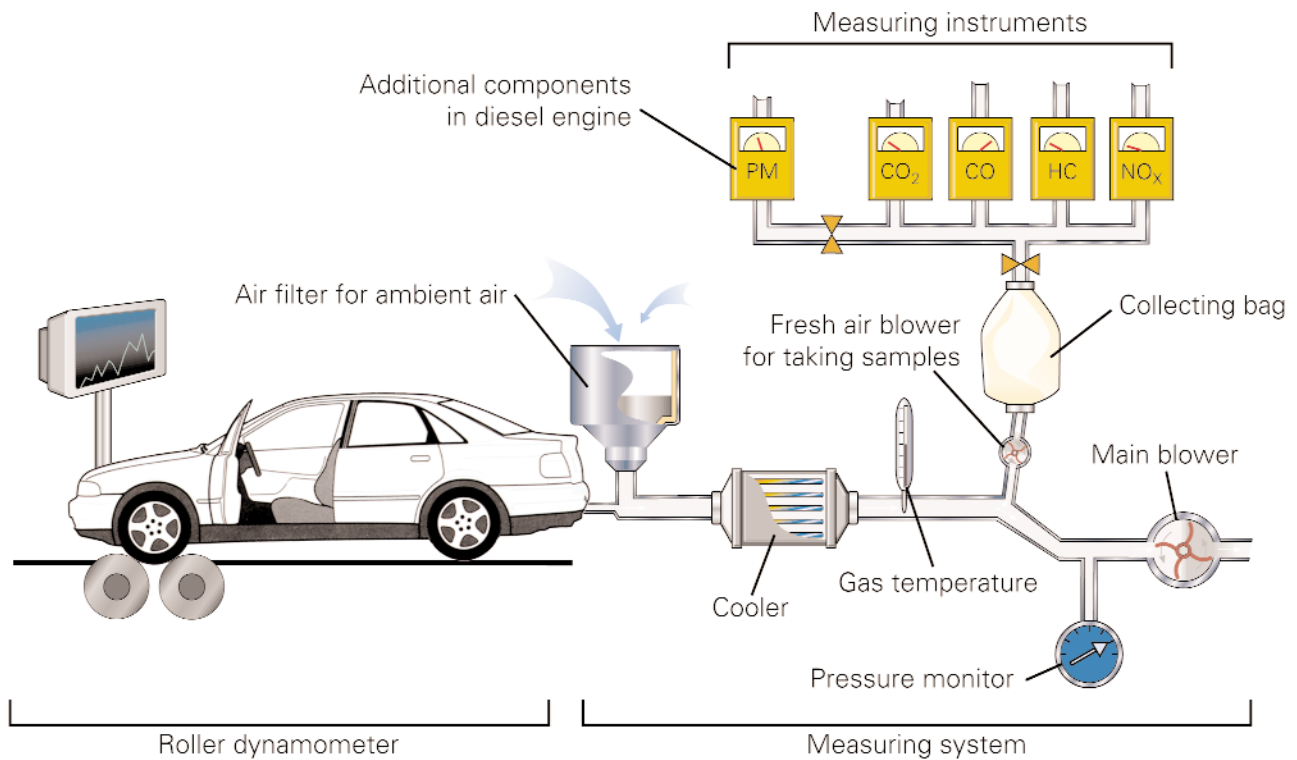
Before a vehicle intended for use on public roadways can be sold in the United States, it must be "certified" by the Environmental Protection Agency (EPA). In addition, manufacturers are required to meet specified sales-weighted fleet emissions averages.

The certification procedure requires the use of a chassis dynamometer as well as specialized equipment for exhaust gas collection and analysis.

The test vehicle is secured with the drive wheels on the measuring rollers of the dynamometer and a collecting tube over the exhaust pipe. A specially trained technician then modulates the accelerator and brake to "drive" the prescribed cycle.

Tailpipe emissions are collected for analysis of hydrocarbons, carbon monoxide and oxides of nitrogen while the vehicle is operated under varying engine loads.

Dynamometer used in Federal certification testing



FTP (Federal Test Procedure) 75 driving cycle

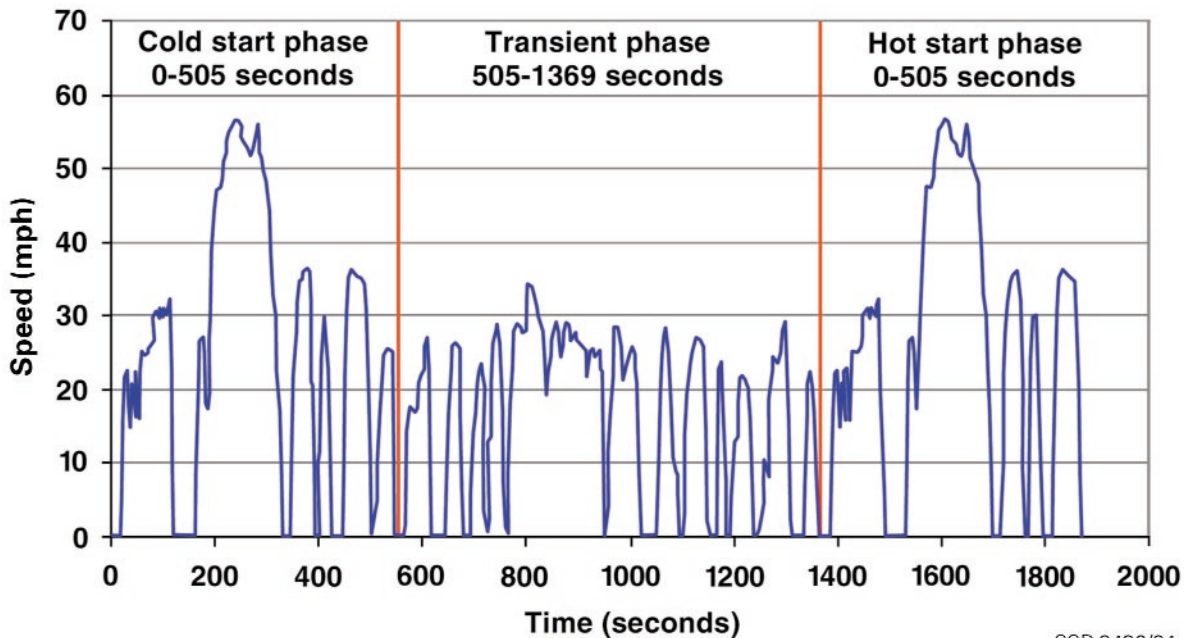
Vehicles certified for sale in the United States must pass the FTP75 emissions test. The total FTP75 cycle is 1874 seconds long and represents a 11.04 mile route with a 21.2 mile per hour average speed. It consists of three phases:

- the cold start phase
- the transient phase
- the hot start phase

The initial 505 seconds is referred to as the “cold start phase.” This phase of the FTP75 is especially stringent because of the high speeds and sudden acceleration/deceleration soon after startup, before the catalytic converter has reached operating temperature.

The second phase, known as the transient phase, simulates the speeds and stop and start driving conditions experienced while driving in heavy traffic.

Once the cold start and transient phases are completed, the vehicle is shut down. Ten minutes later, a hot start cycle is run, with a driving pattern similar to the cold start phase. Emissions are expressed in grams per mile (g/mi).



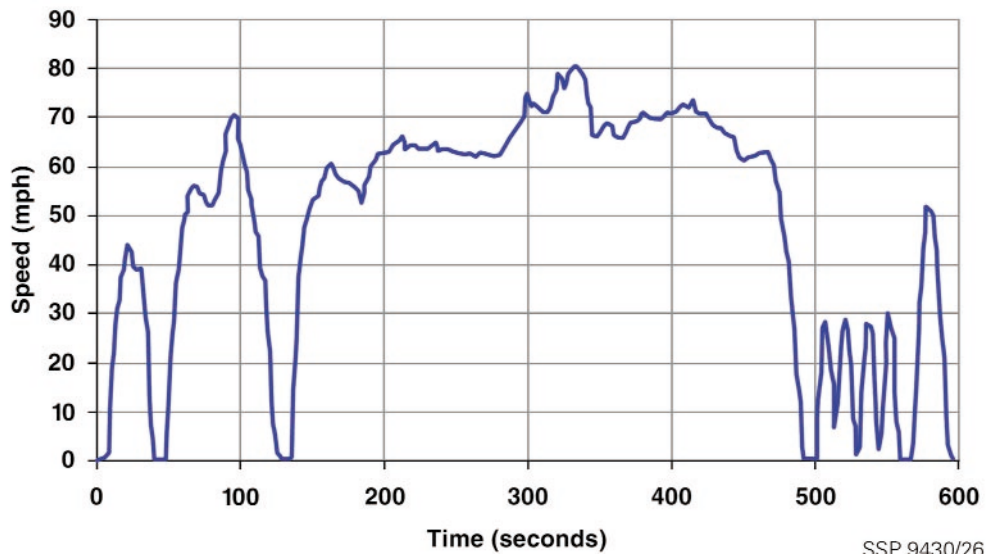
Certification and Testing

Supplemental Federal Test Procedures (SFTPs)

In addition to the FTP75 test, a Supplemental Federal Test procedure consisting of SFTP US06 and SFTP SC03 will be phased in between 2000 and 2004. Both procedures simulate driving conditions not covered by the FTP75 driving cycle.

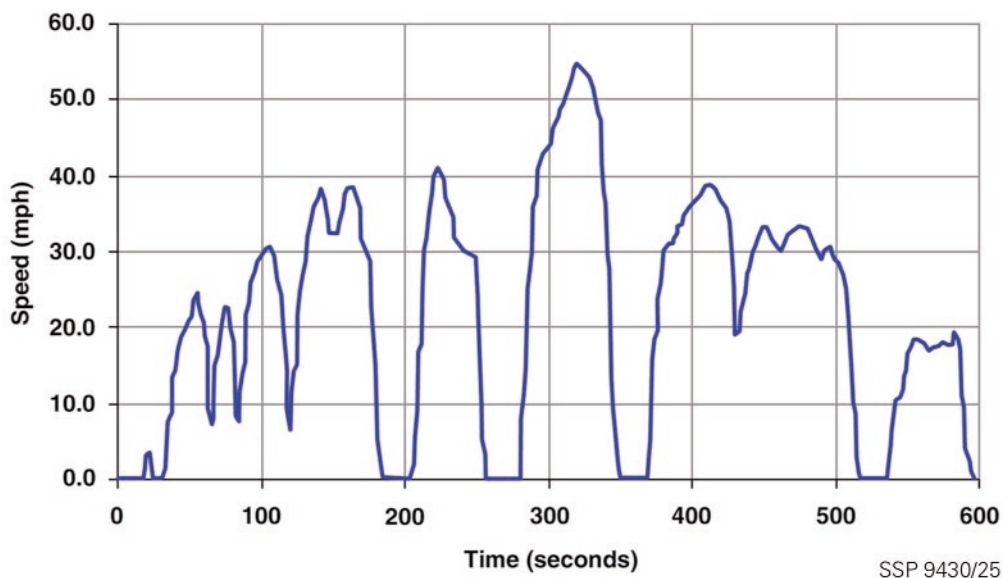
US06

SFTP US06 was designed to simulate aggressive, high speed driving (e.g. rapid speed fluctuations and acceleration).



SC03

SFTP SC03 was designed to simulate emissions performance while the air conditioner is operating.



Certification and Testing

Tier 1 and Tier 2 standards

The Tier 1 standard for light-duty vehicles was defined by the Clean Air Act Amendments of 1990. Vehicles must meet these standards over a 100,000 mile period, with an intermediate standard for the later 50,000 miles.

Tier 1 standards were published in 1991, and phased-in progressively between 1994 and 1997. The Tier 2 standards, adopted in 1999, are to be phased in beginning in 2004.

Unlike the Tier 1 standard, the Tier 2 standard holds all vehicles to the same emissions limits, regardless of fuel type. Tier 2 also requires fuel refiners and importers to progressively reduce the levels of sulphur in both gasoline and diesel fuels starting in 2004. Temporary, less stringent standards will apply to certain areas of the western U.S. between 2004 and 2006.

National Low Emission Vehicle (NLEV) program

NLEV is a voluntary agreement between northeastern states and automotive manufacturers. Starting with the northeastern states in model year 1999 and nationally in model year 2000, NLEV requires vehicles sold to meet more stringent emissions standards than the Federal Government can mandate before Tier 2 is enacted in 2004. The average emission level must meet LEV or better emission standards.

Emission Standard Programs

Tier 1	The least stringent Federal emission standards.
National Low Emissions Vehicle Program (NLEV)	An agreement between the Northeast states and automotive manufacturers. Average emissions must meet LEV or better emission standards.
California - Low Emission Vehicle Program (LEV I) and LEV II	Due to its unique air quality problems, California has special authority under the Clean Air Act to set its own emission standards.
Tier 2	New Federal standards for cars and trucks to replace the Federal Tier 1 standards in place since 1994. Tier 2 to be phased in from 2004 through 2009 and is optional from 2001 to 2003.

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California Air Resources Board (CARB) Emissions Classifications

TLEV	Transitional Low Emissions Vehicle
LEV	Low Emissions Vehicle
ULEV	Ultra Low Emissions Vehicle
SULEV	Super Ultra Low Emissions Vehicle
ZEV	Zero Emissions Vehicle

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Certification and Testing

California Emissions Standards

Although referred to as “California standards,” these standards are used for emissions classification throughout the U.S. and Canada. The following tables show maximum allowable limits.

California Emission Standards, FTP 75, grams/mile										
	50,000 miles/5 years					100,000 miles/10 years				
	NMOG	CO	NO_x	PM	HCHO	NMOG	CO	NO_x	PM	HCHO
Tier 1	0.25	3.4	0.4	0.08	-	0.31	4.2	0.6	-	-
TLEV	0.125	3.4	0.4	-	0.015	0.156	4.2	0.6	0.08	0.018
LEV	0.075	3.4	0.2	-	0.015	0.090	4.2	0.3	0.08	0.018
ULEV	0.040	1.7	0.2	-	0.008	0.055	2.1	0.3	0.04	0.011

NMOG - non-methane organic gases PM - particulate matter
 CO - carbon monoxide HCHO - formaldehyde
 NO_x - oxides of nitrogen

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LEV

LEV I requirements also include a sales mandate for ZEV (Zero Emission/Electric) vehicles beginning in the 2003 model year.

LEV II

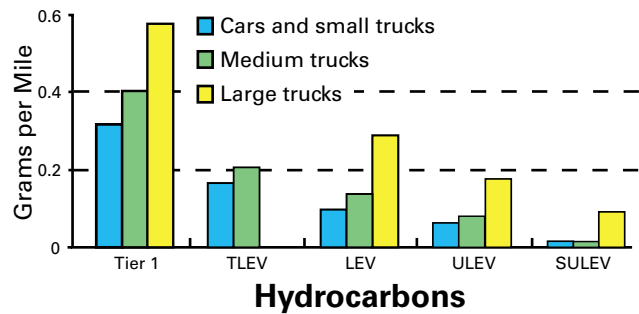
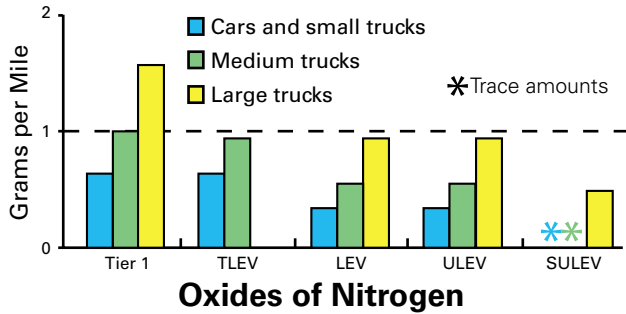
LEV II standards will be implemented from the year 2004 to 2010. Unlike original LEV standards, light-duty and medium duty trucks (under 8500 lbs. gross weight) will have to meet passenger car requirements. NO_x, PM, and evaporative emission standards are also much more strict, and the TLEV category will be eliminated. The same standards will apply to both gasoline and diesel vehicles, making it unlikely that light duty diesel vehicles will be certified without the use of advanced technologies such as particulate traps and NO_x catalysts.

California LEV II Emission Standards, grams/mile										
	50,000 miles/5 years					120,000 miles/11 years				
	NMOG	CO	NO_x	PM	HCHO	NMOG	CO	NO_x	PM	HCHO
LEV	0.075	3.4	0.05	-	0.015	0.090	4.2	0.07	0.01	0.018
ULEV	0.040	1.7	0.05	-	0.008	0.055	2.1	0.07	0.01	0.011
SULEV	-	-	-	-	-	0.010	1.0	0.02	0.01	0.004

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Certification and Testing

The following graphs highlight the difference in emissions levels between the various emissions standards.



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Regional Differences

The EPA allows states to individually determine the emissions limits required before a vehicle can be sold. As the following table demonstrates, California and certain Northeastern States have chosen to adopt more stringent standards than much of the rest of the country.

State	m.y. 1999	m.y. 2000	m.y. 2001
California	<u>CA LEV</u>	<u>CA LEV</u>	<u>CA LEV</u>
Vermont ²	<u>Federal Tier 1</u> NLEV CA LEV	<u>CA LEV</u>	<u>CA LEV</u>
Various other states	<u>Federal Tier 1</u> NLEV	<u>Federal Tier 1</u> NLEV	<u>Federal Tier 1</u> ¹ NLEV

Footnotes:

1. Tier 1 vehicles and TLEVs may be introduced only if also introduced in California.
2. CA LEV requirements in Vermont become effective for model year 1999 engine families that start production late in 1998.

Notes:

Underlined text indicates the minimum requirement, plain text indicates available alternatives.

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Certification and Testing

Emissions Inspection

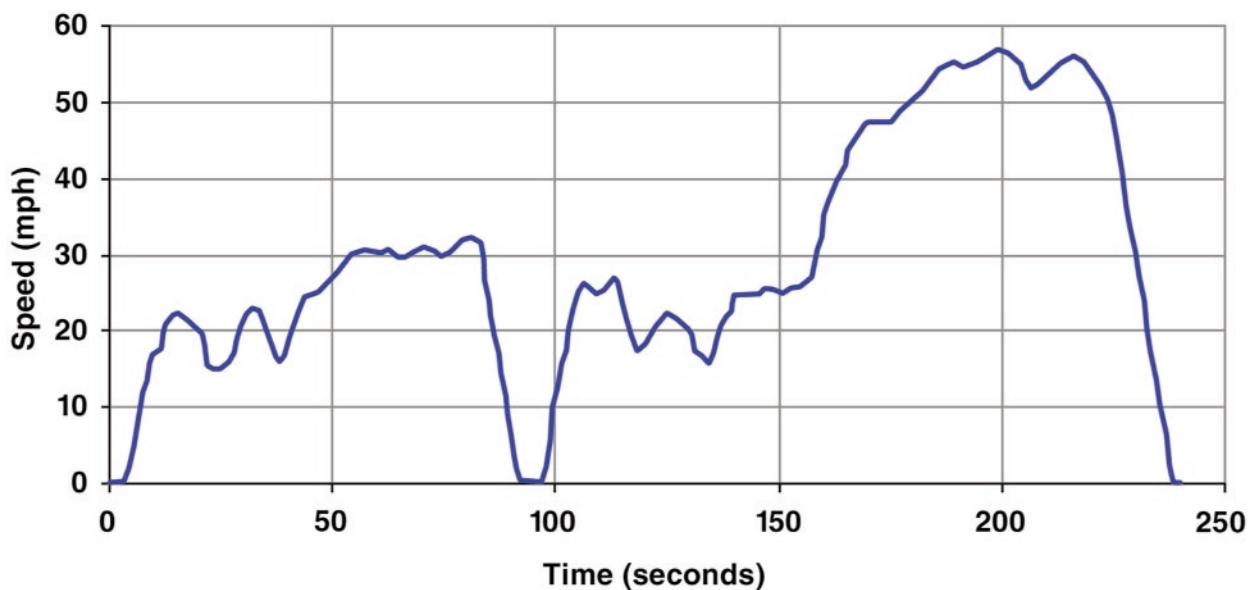
In the past, emissions inspections for vehicles registered in the United States sampled tailpipe emissions with the test vehicle at idle. This method allowed vehicles that were gross polluters on the road (i.e. while the engine is under load) to pass the emissions inspection. To reduce this risk, enhanced emission testing procedures have been implemented.

The Inspection/Maintenance (I/M) Flexibility Amendments, passed by the EPA in 1995, allow states options on how to meet enhanced emission program requirements. Pollution and population levels within the state are used to determine whether a state can use either a “high” or “low” enhanced emissions test. A Low Enhanced test allows the use of an idle test. A High Enhanced test, such as the IM240 driving cycle, requires the vehicle to be tested under load using a chassis dynamometer.

States are awarded emission reduction credit depending on the number of model years and vehicle weight classes included for tailpipe and evaporative emissions testing.

IM240 driving cycle

The IM240 driving cycle is a 240 second long test representing a 1.96 mile route with a 29.4 mile per hour average speed and a maximum speed of 56.7 miles per hour. The technician must modulate the accelerator and brake to maintain the appropriate speed. If the vehicle speed falls outside the specified range, the test must be restarted.



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Based on emissions sampling gathered during the test, a vehicle with very low emissions may receive a “fast pass” in as little as 31 seconds. Vehicles that fail but are within 200% of the pollution limit are allowed a second test. Vehicles that fail the test must be repaired. A waiver may be granted if the cost of these repairs exceeds approximately \$450 (may vary according to local regulations).

Summary

Additional vehicles are put into service each day, adding to the automobile's already considerable impact on the environment. Although Audi is extremely proactive in their efforts to minimize motor vehicle pollution, it is ultimately the responsibility of the technician to ensure that Audi vehicles continue to operate at peak efficiency.

In states that have recently moved from "static" inspections to "driving cycle" type inspections, an increasing number of vehicles are likely to fail and show up in service departments for diagnosis.

In this Self Study Program, we have:

- Recognized the need for emissions controls
- Reviewed the composition of exhaust gases
- Identified methods for reducing harmful pollutants
- Outlined current emissions testing procedures

Armed with this knowledge, the technician is able to diagnose emissions-related problems quickly and efficiently, reducing the impact of the automobile on our environment.

Notes

- 1. To which of the following is carbon dioxide (CO₂) emissions directly proportional?**
 - a) fuel octane
 - b) engine operating temperature
 - c) fuel consumption
 - d) fuel sulphur content
- 2. Which of the following measures reduces sulphur emissions?**
 - a) the use of oxygenated fuels
 - b) reduced sulphur in fuels
 - c) the use of particulate filters
 - d) primary catalysts
- 3. Under what operating conditions does the catalytic converter perform the reduction process most efficiently?**
 - a) high O₂
 - b) low O₂
 - c) high CO₂
 - d) low CO₂
- 4. Under what operating conditions does the catalytic converter perform the oxidation process most efficiently?**
 - a) high O₂
 - b) low O₂
 - c) high CO₂
 - d) low CO₂
- 5. Which of the following contributes to oxides of nitrogen production?**
 - a) high pressure
 - b) high temperature
 - c) a surplus of O₂ during combustion
 - d) all of the above
- 6. At what air to fuel ratio are harmful exhaust emissions (with the exception of NO_x) at their lowest levels?**
 - a) 10:1
 - b) 12:1
 - c) 14.7:1
 - d) 16:1
- 7. HC levels after the catalytic converter will usually remain _____, because the catalytic converter oxidizes hydrocarbons to CO₂ and H₂O.**
 - a) same
 - b) high
 - c) low
 - d) none of the above
- 8. A high CO₂ reading indicates which of the following?**
 - a) a rich mixture
 - b) a lean mixture
 - c) an inoperative EGR valve
 - d) combustion efficiency

Teletest

- 9. High O₂ levels in the exhaust before the catalytic converter indicate:**
- a) a rich mixture
 - b) a lean mixture
 - c) high fuel pressure
 - d) none of the above
- 10. High CO levels in the exhaust before the catalytic converter indicate:**
- a) a rich mixture
 - b) a lean mixture
 - c) an inoperative Secondary Air Injection system
 - d) none of the above
- 11. Which of the following is produced when unburned hydrocarbons are exposed to sunlight?**
- a) carbon monoxide
 - b) water
 - c) low level ozone
 - d) particulate matter
- 12. Water is present in the combustion chamber during combustion:**
- a) due to atmospheric humidity
 - b) due to low quality fuels
 - c) as a normal by-product of combustion
 - d) all of the above
- 13. The heated planar oxygen sensor can become operational in as little as:**
- a) 10 seconds
 - b) 15 seconds
 - c) 30 seconds
 - d) 60 seconds
- 14. Which of the following emissions do EGR systems reduce?**
- a) hydrocarbons
 - b) fuel vapor emissions
 - c) oxides of nitrogen
 - d) carbon monoxide
- 15. What percentage of smog in major cities is caused by passenger vehicles?**
- a) less than 15%
 - b) less than 18%
 - c) less than 24%
 - d) less than 35%
- 16. Which of the following is NOT a category used in California emissions standards?**
- a) Transitional Low Emission Vehicle (TLEV)
 - b) Super Ultra Low Emission Vehicle (SULEV)
 - c) Marginal Emission Vehicle (MEV)
 - d) Zero Emission Vehicle (ZEV)

- 17. Which of the following emissions tests requires the use of a dynamometer?**
- a) IM240
 - b) FTP75
 - c) SFTP US06
 - d) all of the above
- 18. By 2004, which of the following tests must a vehicle pass before it can be sold in the United States?**
- a) FTP75
 - b) SFTP SCO3
 - c) SFTP US06
 - d) all of the above
- 19. Which of the following systems or components reduce emissions during refueling?**
- a) LDP
 - b) EGR
 - c) ORVR
 - d) all of the above
- 20. What is the purpose of moving the catalytic converter and oxygen sensor closer to the exhaust manifold?**
- a) to reduce particulate matter emissions
 - b) to improve swirl in the combustion chamber
 - c) to shorten the warm-up phase and clean exhaust gases more quickly
 - d) to inject a small amount of exhaust gas into the intake manifold

Notes

ANSWER WORKSHEET

Automated Telephone Testing Instructions

Testing Times: 24 hours a day

To take an Automated Telephone test:

- Record your responses to test questions in the boxes below.
- Dial **1-800-928-2834**
- Enter your Social Security number, Social Insurance number, or Employee Identification Number.
- Enter the six-digit Course Number. The Course Number for this test is **943003**.
- Enter your test answers by pressing the corresponding numbers on the phone key pad when prompted by the Audio Response system — enter answers in groups of five.
- If you want to change your previous answers, press 8. You may change your answers at this time only. Failure to change incorrect answers could result in incorrect score.
- You will be given your results at the completion of the test.
- If you did not achieve a score of 80% you must wait 24 hours before retaking the exam.

If you are using a rotary dial telephone, or have difficulty with the Audio Response system while taking your test, please call **1-888-565-7366**, Monday-Friday, 7 a.m. to 7 p.m. (Central Time).

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