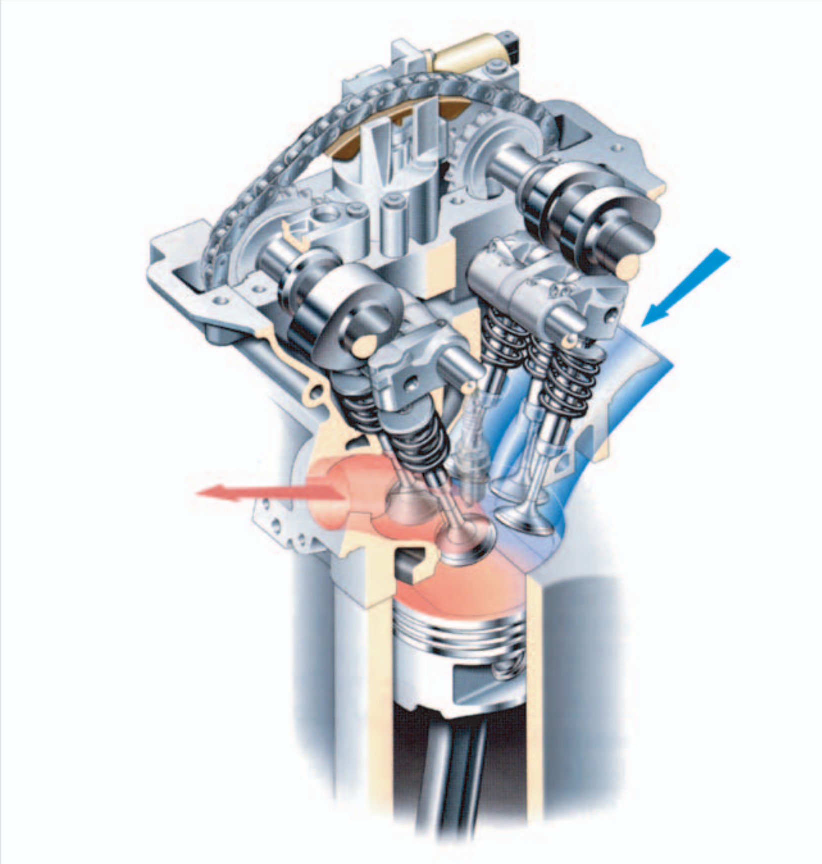
# Engine Management Systems



## Design and Function

Self-Study Program
Course Number 941003

Audi of America, Inc.
Service Training
Printed in U.S.A.
Printed 5/2000
Course Number 941003

Always check Technical Bulletins and the Audi Worldwide Repair Information System for information that may supersede any information included in this booklet.

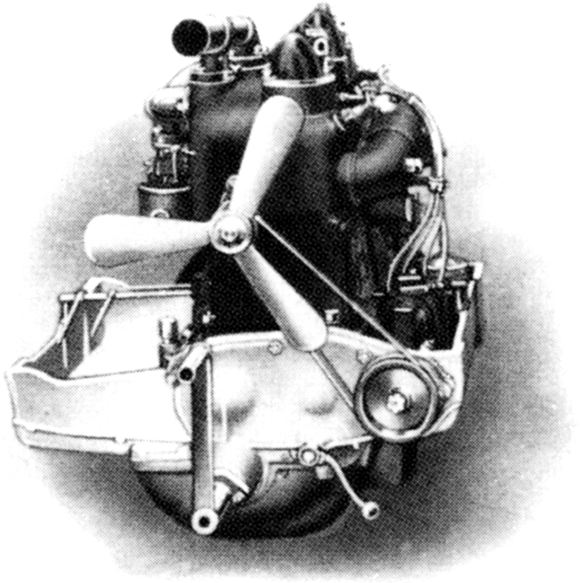
# Table of Contents

# Table of Contents

## Introduction

The origins of Audi engine development can be traced back to a 1913 4-cylinder liquid-cooled engine designed by August Horch (1868-1951) in Zwickau, Germany. This great-grandfather of the modern Audi engine shared the same operating principles as the most modern 5-valve per cylinder water-cooled automotive engine.

Both engines are four-stroke reciprocating internal combustion engines, and although a direct comparison cannot be made, the basic operating principles remain the same.



Audi 14/35 engine as installed in the 1913 Type C Austrian Alpine Run car featuring three main bearings and a fixed cylinder head.

| | |
|---|---|
| Displacement: | 3560 cc (217.1 cid) |
| Compression ratio: | NA |
| Maximum torque: | NA |
| Maximum power: | 35 hp @ 1800 rpm<br>(40 hp competition version) |
| Engine management: | Spray-jet carburetor<br>magneto ignition |
| Fuel requirement: | Gasoline |

Technology moved the four-stroke engine from magnetos and carburetors to ignition coils, points, distributors, mechanical fuel injection, hydraulic fuel injection, electronic ignition, electronic fuel injection, and finally to the combined fuel and ignition control of modern Motronic engine management systems.

Motronic engine management systems use electronics to precisely monitor and control every aspect of engine operation, thereby improving efficiency, power, and driveability, while at the same time reducing fuel consumption and tailpipe emissions.

Turbo-charged and intercooled TT engine with 5 valves per cylinder as installed from the 2000 model year.

| | |
|---|---|
| Displacement: | 1781 cc (108.6 cid) |
| Compression ratio: | 9.5:1 |
| Maximum torque: | 235 Nm @ 1950-4700 rpm<br>(173 LbFt @ 1950-4700 rpm) |
| Maximum power: | 132 Kw @ 5500 rpm<br>(180 hp @ 5500 rpm) |
| Engine management: | Bosch Motronic ME 7.5<br>OBD II |
| Fuel requirement: | 87 AKI unleaded (minimum)<br>91 AKI unleaded (best perf.) |

SSP 9410/02

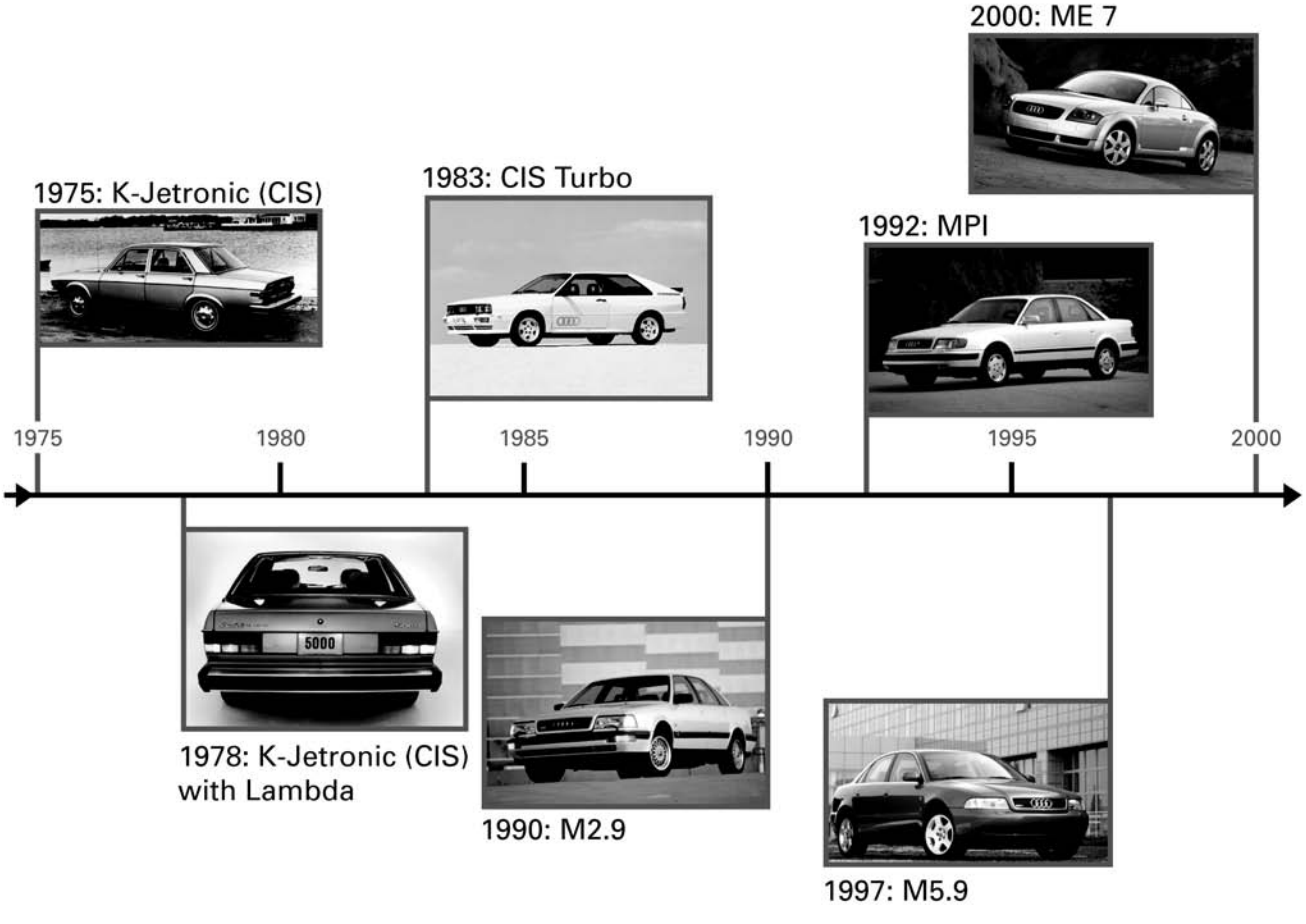
# Introduction

Motronic engine management systems control engine operation so precisely that it is no longer possible to identify a separate emissions system. All functions previously identified as emissions system functions are now components of Motronic engine management.

The intent of this program is to provide information that will yield a greater understanding of engine management systems commonly in use, and the progression leading to the newest Motronic ME 7 system.

**Course goals**

- review principles of engine operation
- explain the progression of engine management systems used by Audi
- provide an in-depth understanding of both previous engine management systems and the state-of-the-art engine management systems in use today



SSP 9410/03

## Principles of engine operation

### Basic four-stroke principle

An internal combustion engine requires the proper ratios of air and fuel, combined with a properly timed spark for efficient combustion.

Operation of most automotive engines is described in two upward and two downward movements of the piston, called strokes. These four strokes occur during two revolutions of the crankshaft and one revolution of the camshaft. The complete process of cyclic external spark ignition resulting in internal combustion is called the "Otto cycle."

All four-stroke engines operate in the same manner, regardless of the number of cylinders, although an engine with multiple cylinders has more firing pulses, resulting in a smoother running engine.

### Intake stroke (1)

The first phase of engine operation begins with the intake valve opening and the piston moving down into the cylinder. This draws air and atomized fuel into the cylinder.

### Compression stroke (2)

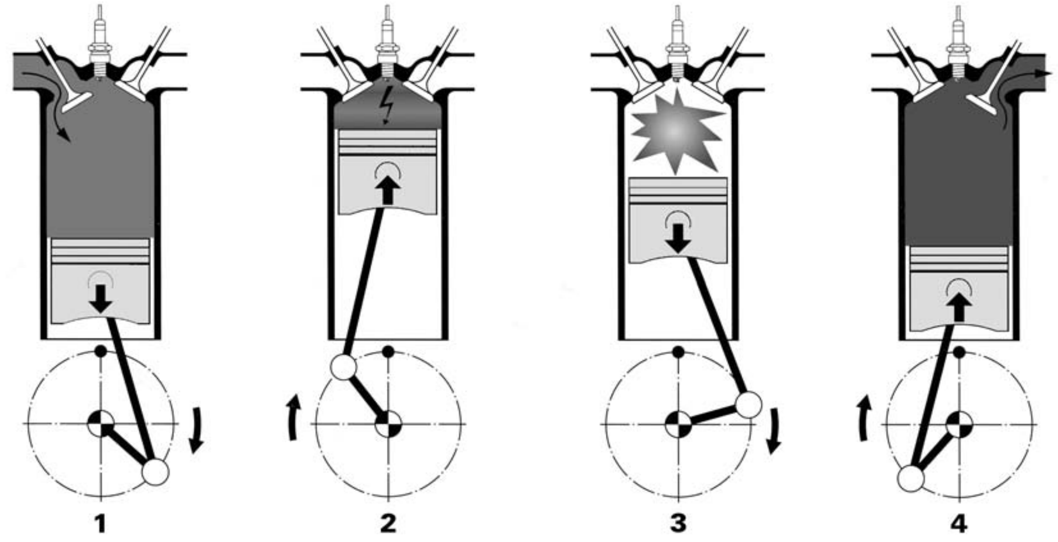
Operation continues with the piston at the bottom of its stroke, and the intake valve closing. The piston moves up in the cylinder, compressing the air/fuel mixture. Near the end of the stroke the air/fuel mixture is ignited by the ignition system.

### Combustion (power) stroke (3)

As the air/fuel mixture burns it expands, creating pressure within the cylinder, pushing the piston down. This provides the motion which turns the crankshaft.

### Exhaust stroke (4)

The exhaust valve opens near the end of the power stroke and the piston moves up. The burned gases are pushed up and out the exhaust port, and the cycle is repeated.



SSP 9410/04

## Mechanical systems

Several support systems are required to make the combustion process occur continuously. The valvetrain operates the valves, the lubrication system supplies the oil, the cooling system removes heat, and the electrical system supplies the voltage. The engine management system delivers fuel and spark to match the air demands of the engine.

Because of heat and drag, the thermal efficiency of a typical gasoline engine is around 25% (approximately one fourth of the heat energy of the fuel is converted into usable engine power).

## Mechanical Integrity

The mechanical condition of the cylinder directly influences the combustion process.

Conditions within the combustion chamber can also be influenced by other factors, including:

- Camshaft timing
- Oil pressure
- Restrictions in the intake or exhaust paths

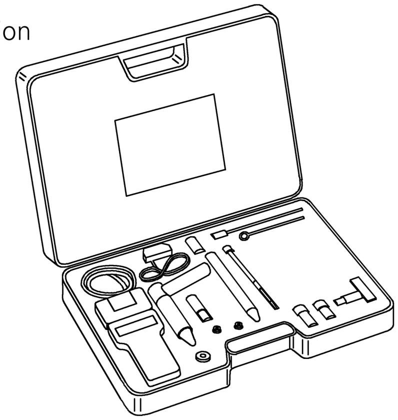
The following diagnostic tests are used to check cylinder condition:

- **Compression test:**

  This test can be useful in evaluating condition of the piston rings, head gasket and valve sealing ability when used in conjunction with other diagnostic tests.

  A compression test requires the removal of all the spark plugs. A pressure gauge is then threaded into the spark plug hole. The engine is cranked for a specified number of pulses using the starter, while applying Wide Open Throttle (WOT). Pressure gauge readings are then compared to factory specifications.

  To ensure the accuracy of the test, the engine should be at normal operating temperature.



VAG 1763
Compression
test kit

SSP 9410/05

- **Cylinder leakdown test**

  A cylinder leakdown test is especially useful to identify sources of cylinder leakage. As an example, a hissing sound heard at the tailpipe while the test is being performed indicates possible leaking exhaust valves.

  A cylinder leakdown test also requires the removal of the spark plugs, but necessitates that the crankshaft be turned so that the piston is at the top of the compression stroke (Top Dead Center or TDC) with both valves closed. A measured amount of compressed air is applied to the cylinder through the spark plug hole using a leakdown tester. The pressure of the air in the cylinder is compared to the pressure being applied. A "percentage of leakage reading" is given by the gauge. The reading is compared to adjacent cylinders to determine cylinder condition.

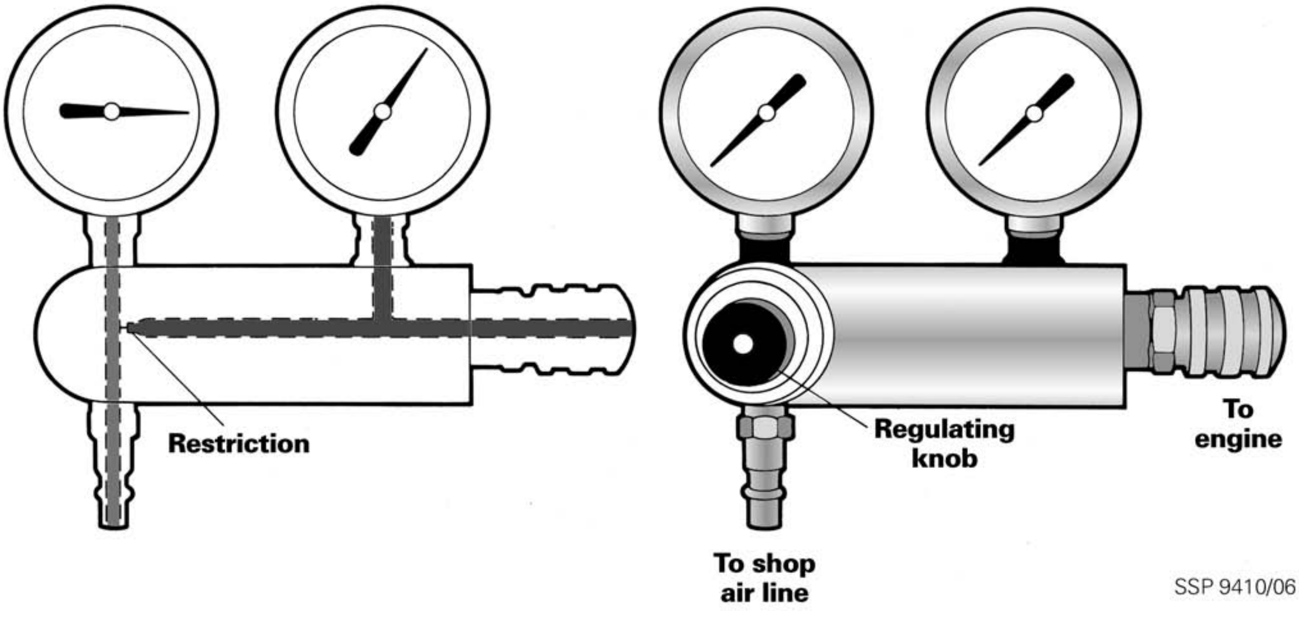
  As in the compression test, the engine should be at normal operating temperature to ensure the accuracy of the test.

### Summary

For any combustion process to occur, proper air/fuel mixture and a source of ignition are required. For an internal combustion engine to operate, the air/fuel mixture must be compressed, and the spark must occur at the proper time to create the combustion that is the motive force used to drive the piston.

The mechanical systems must all work together to draw the combustible mixture into the cylinder, to compress it, to extract maximum power from combustion and to expel what remains after the combustion process. These systems work together to provide the support necessary to keep the engine running.

**Cylinder leakdown tester**



# Principles of engine operation

## Gasoline properties

For the engine management system to allow the engine to operate at peak efficiency and power, the octane rating of the gasoline must be within factory specifications as outlined in the owners manual.

Octane is a relative measure showing the gasoline’s ability to resist self-ignition due to heat and pressure within the cylinder. Self ignition of the fuel is known as knocking (detonation) or pinging (pre-ignition).

- Pinging:

  When the air/fuel mixture ignites before the spark occurs.
- Knock:

  When a pressure wave from spark igniting the fuel creates a secondary combustion, causing the two pressure waves to collide.

Gasoline with higher octane numbers resist temperature and pressure better, and therefore have less tendency to self-ignite.

Several methods of measuring octane are used worldwide. These include the following:

- Research Octane Number (RON); tests resistance to knock at lower engine speeds.
- Motor Octane Number (MON); tests resistance to knock at higher engine speeds.

In an effort to simplify a confusing array of octane numbers, the United States Government enacted legislation requiring the posting of a number on the dispensing pump reflecting the minimum octane number as determined by the Cost of Living Council (CLC).

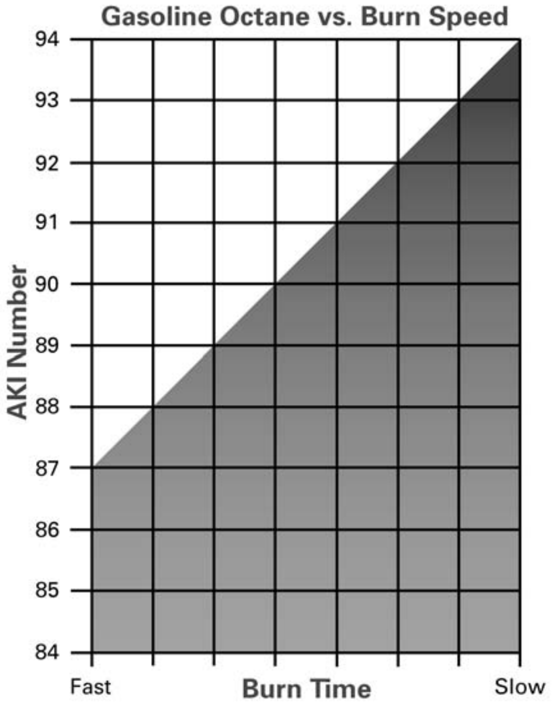
The CLC number is derived from both the RON and the MON as follows:

$$\frac{\text{RON} + \text{MON}}{2} = \text{CLC}$$

SSP 9410/118

The CLC number was later changed to the Anti-Knock Index (AKI) number. Gasolines identified as “regular” generally have an AKI number of around 87, while gasolines identified as “premium” generally have an AKI number around 92.

AKI numbers apply to gasoline that is freshly pumped. Gasoline that is exposed to the air for extended periods of time undergoes a decrease in AKI number due to evaporation and oxidation.



SSP 9410/100