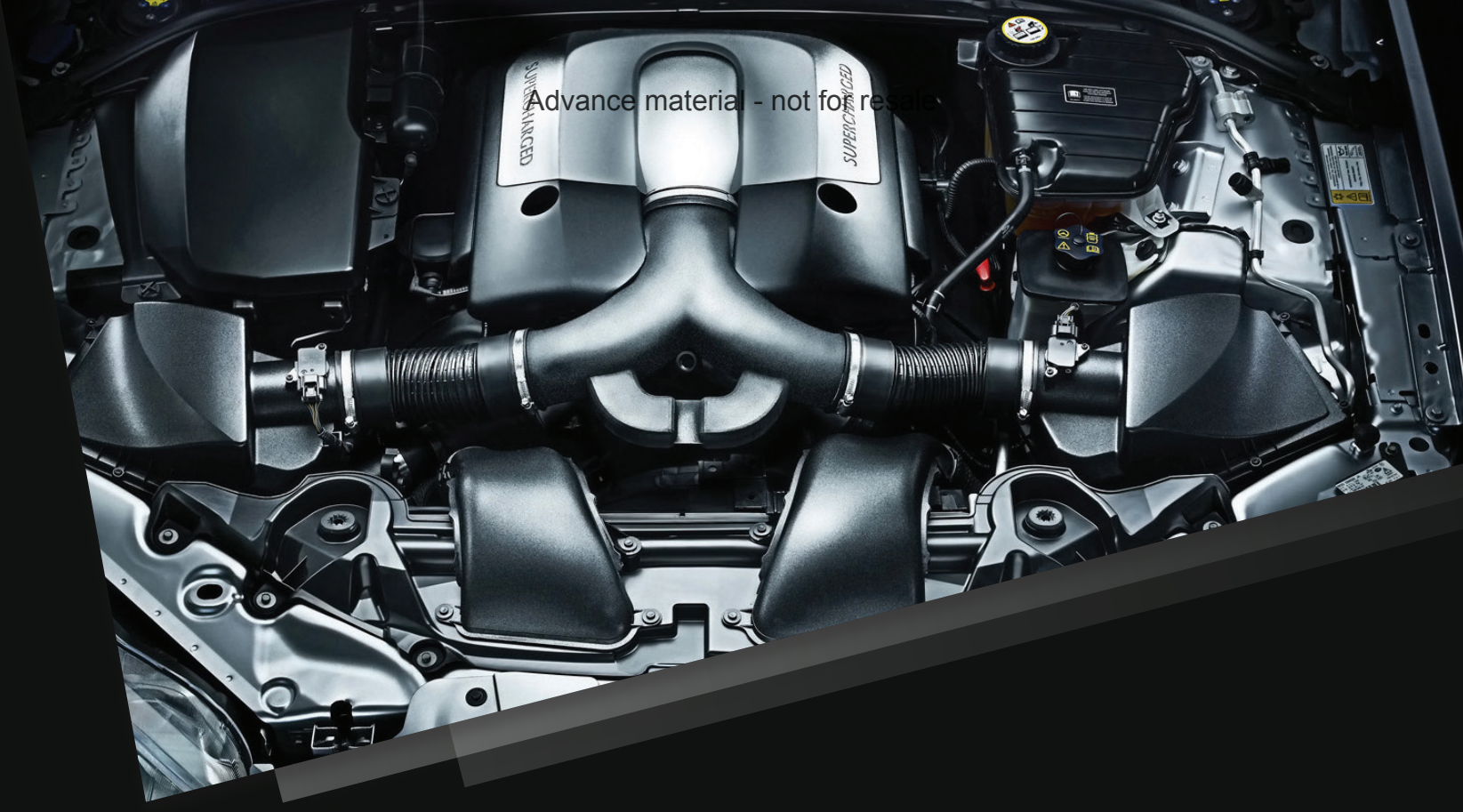

AUTOMOTIVE TECHNICIAN TRAINING

THEORY: LEVELS 1/2/3

IMI
THE INSTITUTE OF THE MOTOR INDUSTRY

ATT AutomotiveTT
Automotive Technician Training eLearning

Works alongside ATT Automotive VLE material

TOM DENTON

ROUTLEDGE

Contents

CHAPTER 1

ATT *interactive*

After successful completion of this chapter you will be able to show you have achieved these objectives:

- Understand the various icons and symbols and structure used in this book and online.
- Understand how to use the learning activities and other features.

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1.1 Introduction 1

This textbook should be used in conjunction with the ATT multimedia materials; it is not intended to be a stand-alone resource. But it is designed to help you learn . . .

. . . and the best way to learn anything new is to interact with it. In other words, be an active learner. Sitting back being passive and expecting your brain to remember stuff doesn't work!

You will find this button on all our multimedia learning screens – click it and see what happens!

As you work through this book you will see this symbol next to some paragraphs:

This means that there is a video or animation associated with the text. You can access this online or from the locally installed version of ATT. This is a good way to interact.

The other image you will see at the start of each chapter is a QR code (as on p. 1). If you have suitable software on your computer (and a camera) or a smartphone app, pointing at this image will link to some useful resources.

Note that the practical sections are not in this book (to save space) but they are all available in full multimedia online.

Online learning link: www.automotivett.org

Qualification levels This book contains all the theory/technology content for study at levels 1, 2 and 3. The materials are presented as chapters, subjects and then sections. Each section is marked as follows:

- 1 – study only these sections if working on a level 1 qualification
- 1 2 – read these sections if working on a level 1 qualification, study in detail on a level 2 qualification
- 2 – study these sections and those marked level 1 (unless done previously) if working on a level 2 qualification
- 2 3 – read these sections if working on a level 2 qualification, study in detail on a level 3 qualification
- 3 – study these sections and those marked level 1 and level 2 (unless done previously) if working on a level 3 qualification

Screen title Most of the paragraphs of text in this book start with a title in bold as shown here! This is the title that you will see on the multimedia learning screen. And to help you interact even more and make learning about automotive technology fun as well as interesting, we have developed ATT *interactive*. All of the activities in this book can be carried out using features on the interactive website. Paper and pencils will also work in most cases, so you can still work if you don't have internet access.

Visit: www.automotivett.org to access a demonstration of the amazing and unique features of ATT *interactive*:

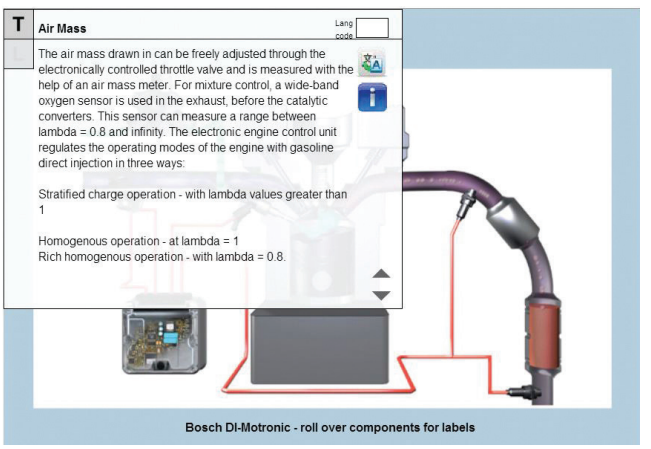

Figure 1.1 Example screen showing the interactive and translate buttons

The translate feature is available on all our learning screens. Enter the language code in the small box and then click the Google translate button. I used 'es' (Spanish) and the result is shown in Figure 1.2.

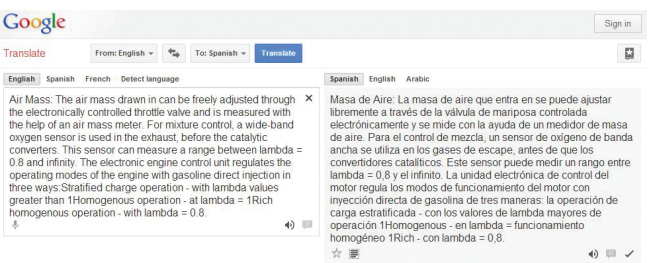

Figure 1.2 Google translate website

Now although this machine translation is very good it is not perfect and so fluent speakers will notice some amusing errors (filing metal and filing papers can be mixed up for example!). However, the feedback we have received is that it is a great help for people working in English as a second language.

Clicking the blue interactive button takes you to the website shown in Figure 1.3. We are working on this all the time so new options may become available but it will remain very similar.

You can also translate at this point and if you entered a language code then the search features will use that language. If not, it will default to English.

Figure 1.3 ATT interactive website

Clicking one of the buttons on the site may take you to an external website where, you will appreciate, we cannot be responsible for the content! There are currently 12 main headings and some of these have several associated buttons. Experiment as much as you like. These 12 options also relate to the different learning activities that are used in this book and are discussed in the next section.

Now complete the multiple-choice quiz associated with this topic/subject area.

1.2 Learning activities

Lots of learning activities are included in the ATT textbooks, and they provide a great way to interact and learn. In most cases the best option will be to follow the ATT *interactive* link from a learning screen. The answers to questions or notes/bullet/labels and other activities can be written directly in the textbook, on a separate notebook or perhaps even better as a computer document or in an electronic notebook.

Some activities will just show an icon (add labels to a diagram, for example) while others will give further instructions and maybe a space for the work to be completed. For all the activities in this section, I have included an example of what you could do. (Tip: Pressing PrtScr will copy the screen to the clipboard for pasting into your electronic notebook (Word document or whatever). Better still, use the annotator supplied as part of the ATT system or available from http://getgreenshot.org.

Note: The activities suggested in the text are recommended but you can do different types. Remember, the more you do the more you will learn!

Information search This activity will usually be something similar to this:

Use a library or the interactive web search tools to examine the subject in this section in more detail.
Here is the link I found useful after searching on the interactive site for one of the key words in the text: http://en.wikipedia.org/wiki/Catalytic_converters

Looking in other textbooks in a library is a good way to see the subject explained in a different way. Perhaps even better is to use the Info search option on the interactive site. Clicking any of the buttons in this row (see Figure 1.3) will search for the screen title, 'Air Mass' in this example, or you can select a word or phrase in the text and it will search for that instead.

Media search This activity is very similar to the previous one except it asks you to search for images and videos.

Use the interactive media search tools to look for pictures and videos to examine the subject in this section in more detail.
Searching for Catalytic converter I found this rather nice image on Flickr:

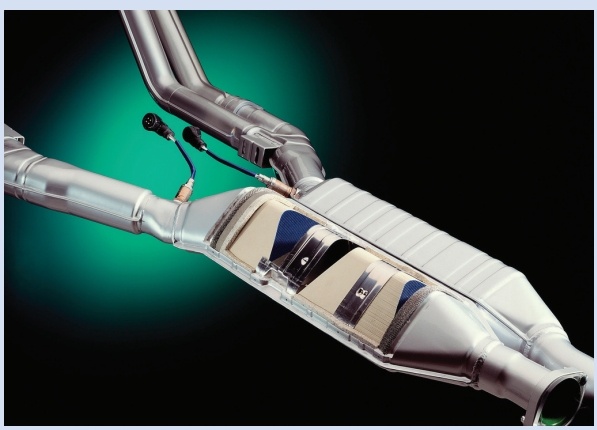

Figure 1.4 Daimler catalytic converter (Source: Flickr Creative Commons)

The buttons in this row search for the screen title or selected text in the same way as before.

Word cloud A word cloud shows the most common words in a block of text in a larger font. It is a great

way to focus in on the important aspects of a learning screen or paragraph of text. There are a few different options available on the interactive site. Here is an example of a word cloud I created based on the example screen shown earlier. Note that clicking the interactive button also copies the text onto the clipboard for pasting elsewhere.

Create a word cloud for one or more of the most important screens or blocks of text in this section.

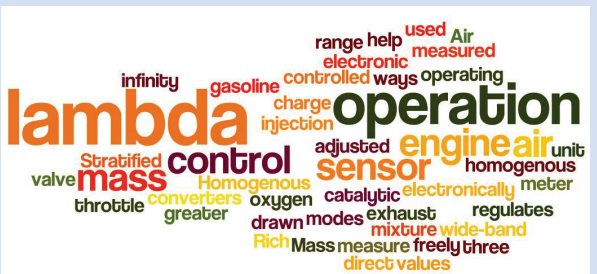

Figure 1.5 Example of a word cloud created by the amazing 'Wordle' website

Word puzzles Crossword and wordsearch puzzles are a great way to learn new important words and the associated technologies. A good method is to work in pairs so you each create a puzzle and then swap and try to complete the answers.

Construct a crossword puzzle using important words from this section. Hint: Use the ATT glossary where you can copy the words and definitions (clues!). About 20 words is a good puzzle.
OR
Construct a wordsearch grid using some key words from this section. About 10 words in a 12×12 grid is usually enough.

There is also an option for creating anagrams in this row of interactive features – I am not sure how useful that is, but it is fun! Here is a crossword I prepared earlier:

Across

3 To join in with an activity is to be. . .
5 Mode of transport
6 Technical reading material

Down

1 Look for connected letters in a grid
2 What you are doing now
4 Subject of this book

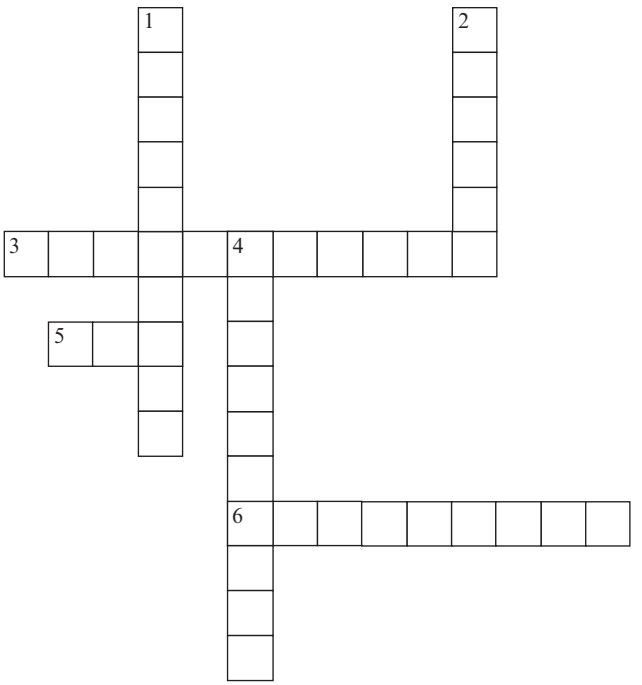

Figure 1.6 Crossword puzzle (Source: TeachersCorner.net)

Mind map/wall These activities work fine either with pen and paper or by using the online features. Figure 1.7 is an example of a simple mind map I created about brakes, using a link on the interactive site.

Create a mind map to illustrate the important features of a component or system in this section.

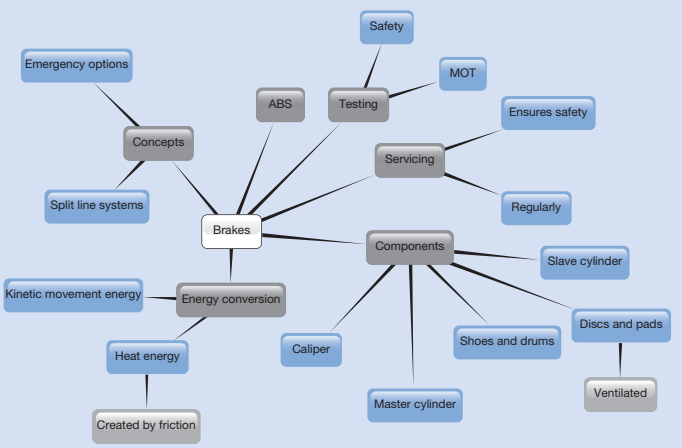

Figure 1.7 Brakes mind map (more work needed!)

OR
Create an information wall to illustrate the important features of a component or system in this section.

Notes/bullets Three great tools for keeping notes electronically are Evernote, Microsoft OneNote and Google Drive. My favourite at the moment is OneNote but I find all these tools easy to work with – they can be used online or offline and also synched to or from my smartphone. Of course, using any word processor is fine – as is using a pen. The following is an example of some key bullet points relating to an introduction to brakes:

Look back over the previous section and write out a list of the key bullet points.

- Brakes work by converting movement energy into heat.
- The foot brake acts on all wheels and the parking brake usually on two.
- Friction is used to create the heat.
- Main components are pads and discs or shoes and drums (pads most common).
- Hydraulic fluid is used to transfer the pressure from the accelerator pedal.

Labels Many of the diagrams in this book have numbers but no labels. Use the multimedia version to find out what they are and write them into the book (or copy the image and do it electronically).

Complete the labels on the diagram by referring to the appropriate ATT multimedia learning screen.

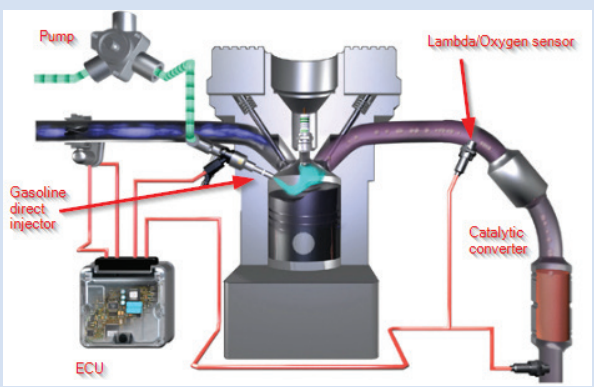

Figure 1.8 Labelled diagrams can be saved in your electronic notebook

OR: List the items separately.
The components on this diagram are:
1 Lambda sensor
2 Catalytic converter
3 High-pressure pump
4 Injector

I added labels and the arrows to the diagram above using the Greenshot annotator.

Social If you are working on a college or school network you may not be allowed to access these sites, but you certainly can in your own time. It is a great way to keep in touch, share ideas with your mates and communicate with us here at ATT.

Follow the tweets, Facebook, and blog posts from our automotive website linked from www.atttraining.com/auto. You could also set up a Facebook discussion group to talk about specific automotive technology subjects.

Questions Short-answer questions are used at the end of all the technology sections of this book. Write the answers in the box provided or keep them electronically and note the page number so you can refer back to them.

Answer the following questions either here in your book or electronically.

1 What is the address of the ATT interactive web site?
www.atttraining.com/auto
2 What is your favourite type of car?
One that starts every time and is comfortable and reliable (oh, and is ideally a Ferrari).

At the end of each main subject area you could carry out the associated multiple-choice test online or on the DVD/offline version. This box will show as a reminder:

Now complete the multiple-choice quiz associated with this topic/subject area.

Sketch Making a simple sketch to help you remember how a component or system works is a good way to learn. You can use a pencil or the online features or any drawing program – even word processors have quite good drawing tools now. The sketch here is my representation of a closed loop control system:

Make a simple sketch to show how one of the main components or systems in the section operates.

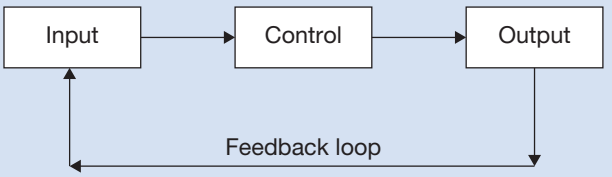

Figure 1.9 Simple sketch

Presentation Preparing and making a presentation to your mates is a great way to learn about something new because you have to study it in detail first! It can be a bit nerve-racking at first but is also good fun so don't worry.

There are some great online tools for this or you can use PowerPoint or a similar program to prepare some slides that you then explain in more detail.

Using images and text, put together a short presentation that you will deliver to your classmates to show how an important component of a system from this section works.

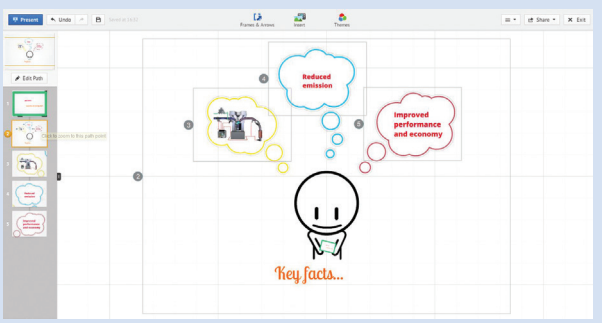

Figure 1.10 A basic presentation I started making using the online tool: Prezi

Practical Clearly practical work is the most important thing we do as automotive technicians.

Refer to the appropriate worksheets and carry out the practical task(s) related to this section – but only when directed by your teacher or instructor.

Summary In this chapter we have looked at some of the key features of this book that make learning more effective as well as more fun. As well as options to examine videos and more as part of the electronic learning screens, including translation features, there are lots of different learning activities in this book. Each one has an associated link on the online interactive site at www.automotivett.org

Good luck with your studies and I hope you find this book useful – remember, get involved in your learning and interact and it is much more interesting!

Now complete the multiple-choice quiz associated with this unit.

CHAPTER 6

Engine systems

After successful completion of this chapter you will be able to show you have achieved these objectives:

- Understand how the main light vehicle engine mechanical systems operate.
- Understand how light vehicle engine lubrication systems operate.
- Understand how light vehicle engine cooling, heating and ventilation systems operate.
- Understand how light vehicle engine fuel systems operate.
- Understand how light vehicle engine ignition systems operate.
- Understand how light vehicle engine air supply and exhaust systems operate.
- Understand how to check, replace and test light vehicle engine mechanical, lubrication, cooling, fuel, ignition, air and exhaust system units and components.
- Understand how to diagnose and rectify faults in light vehicle engine systems.

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Create an information wall to illustrate the important features of a component or system in this section.

Now complete the multiple-choice quiz associated with this topic/subject area.

6.5 Ignition

6.5.1 Ignition overview 1

Purpose The purpose of the ignition system is to supply a spark inside the cylinder, near the end of the compression stroke, to ignite the compressed charge of air/fuel vapour. For a spark to jump across an air gap of 1.0mm under normal atmospheric conditions, (1 bar) a voltage of 4 to 5kV is required. For a spark to jump across a similar gap in an engine cylinder, having a compression ratio of 8:1, approximately 10kV is required. For higher compression ratios and weaker mixtures, a voltage up to 20kV may be necessary. The ignition system has to transform the normal battery voltage of 12V to approximately 8 to 20kV and, in addition, has to deliver this high voltage to the right cylinder, at the right time. Some ignition systems will supply up to 40kV to the spark plugs.

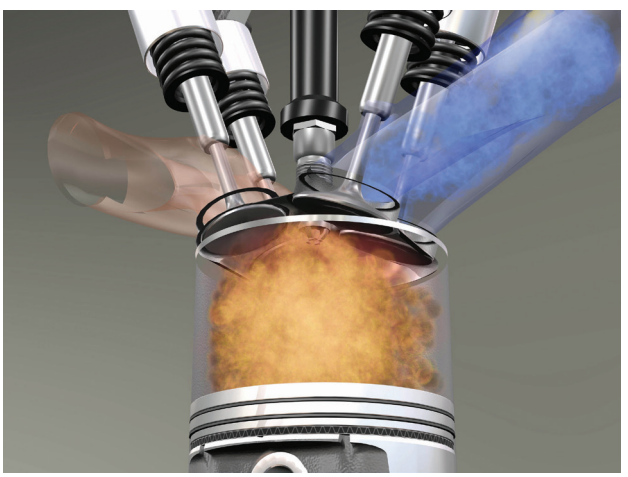


Figure 6.327 Combustion taking place (Source: Ford Media)

Conventional ignition is the forerunner of the more advanced systems controlled by electronics. It is worth mentioning at this stage, however, that the fundamental operation of most ignition systems is very similar. One winding of a coil is switched on and off causing a high voltage to be induced in a second winding. The basic types of ignition system can be classified as shown in the table.

Type	Conventional	Electronic	Programmed	Distributorless
Trigger	Mechanical	Electronic	Electronic	Electronic
Advance	Mechanical	Mechanical	Electronic	Electronic
Voltage source	Inductive	Inductive	Inductive	Inductive
Distribution	Mechanical	Mechanical	Mechanical	Electronic

Engine management Modern ignition systems now are part of the engine management, which controls fuel delivery, ignition, and other vehicle functions. These systems are under continuous development and reference to the manufacturer's workshop manual is essential when working on any vehicle. The main ignition components are the engine speed and load sensors, knock sensor, temperature sensor and the ignition coil. The ECU reads from the sensors, interprets and compares the data, and sends output signals to the actuators. The output component for ignition is the coil.

Developments Ignition systems continue to develop and will continue to improve. However, keep in mind that the simple purpose of an ignition system is to ignite the fuel/air mixture every time at the right time. And, no matter how complex the electronics may seem, the high voltage is produced by switching a coil on and off.

Generation of high voltage If two coils (known as the primary and secondary) are wound on to the same iron core, then any change in magnetism of one coil will induce a voltage in to the other (see Chapter 7 for more details). This happens when a current is switched on and off to the primary coil. If the number of turns of wire on the secondary coil is more than the primary, a higher voltage can be produced. This is called transformer action and is the principle of the ignition coil.

Value of this 'mutually induced' voltage depends upon:

- primary current
- turns ratio between primary and secondary coils
- the speed at which the magnetism changes.

The two windings are wound on a laminated iron core to concentrate the magnetism. This is how all types of ignition coil are constructed.

Ignition timing For optimum efficiency, the ignition timing (or advance angle) should be such as to cause the maximum combustion pressure to occur about 10° after TDC. The ideal ignition timing is dependent on two main factors, engine speed and engine load. An increase in engine speed requires the ignition timing to be advanced. The cylinder charge, of air/fuel mixture, requires a certain time to burn (something like 2ms). At higher engine speeds the time taken for the piston to travel the same distance reduces. Advancing the time of the spark ensures full burning is achieved.

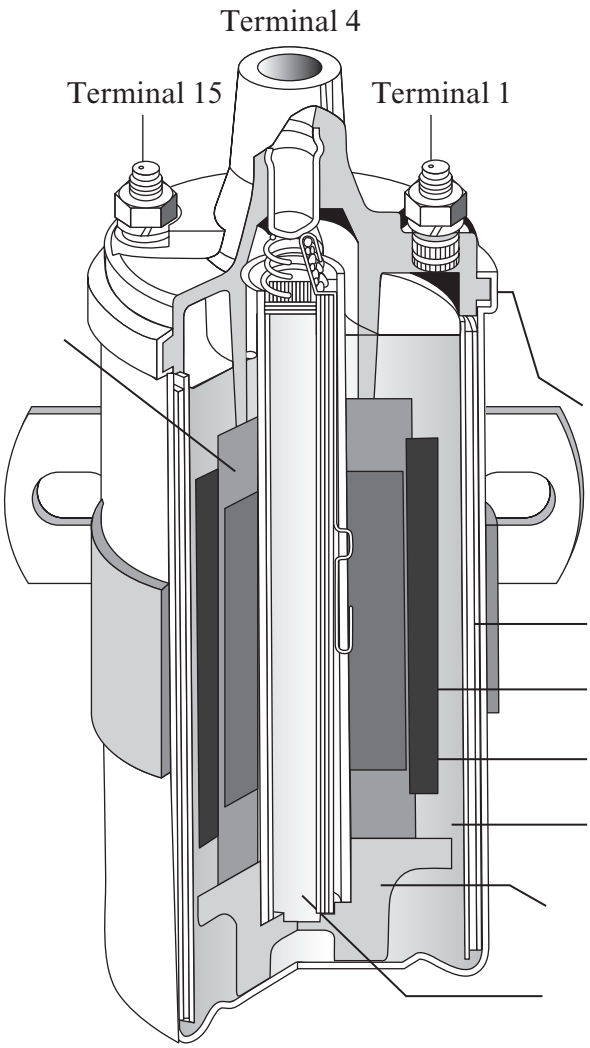


Figure 6.328 Traditional ignition coil

Engine load A change in timing due to engine load is also required as the weaker mixture used on low-load conditions burns at a slower rate. In this situation further ignition advance is necessary. Greater load on the engine requires a richer mixture, which burns more rapidly. In this case some retardation of timing is necessary. Overall, under any condition of engine speed and load an ideal advance angle is required to ensure maximum pressure is achieved in the cylinder just after top dead centre. The ideal advance angle may also be determined by engine temperature and any risk of detonation.

Spark advance is achieved in a number of ways, the simplest of these being the mechanical system comprising of a centrifugal advance mechanism and a vacuum (load sensitive) control unit. Manifold depression is almost inversely proportional to the engine load. However, I prefer to consider manifold pressure instead of vacuum or depression even though it is lower than atmospheric pressure. The manifold absolute pressure (MAP) is therefore proportional to engine load. Digital ignition systems adjust the timing in relation to the temperature as well as speed and load. The values of all ignition timing functions are combined either mechanically or electronically in order to determine the ideal ignition point.

Energy storage takes place in the ignition coil. The energy is stored in the form of a magnetic field. To ensure the coil is charged before the ignition point, a dwell period is required. Ignition timing is at the end of the dwell period as the coil is switched off.

Early ignition system Very early cars used something called a magneto, which is a story for another time, but here is a nice picture of one anyway!

Figure 6.329 First Bosch high-voltage magneto ignition system with spark plug in 1902 (Source: Bosch Media)

Mechanical switching For many years ignition systems were mechanically switched and distributed. The following table gives an overview of the components of this earlier system.

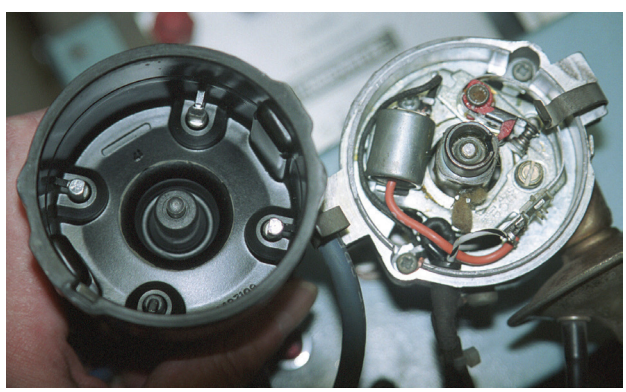


Figure 6.330 Contact breaker system

Spark plug	Seals electrodes for the spark to jump across in the cylinder. Must withstand very high voltages, pressures and temperatures
Ignition coil	Stores energy in the form of magnetism and delivers it to the distributor via the HT lead. Consists of primary and secondary windings
Ignition switch	Provides driver control of the ignition system and is usually also used to cause the starter to crank
Contact breakers (breaker points)	Switches the primary ignition circuit on and off to charge and discharge the coil. The contacts are operated by a rotating cam in the distributor
Capacitor (condenser)	Suppresses most of the arcing as the contact breakers open. This allows for a more rapid break of primary current and hence a more rapid collapse of coil magnetism which produces a higher voltage output
Distributor	Directs the spark from the coil to each cylinder in a preset sequence
Plug leads	Thickly insulated wires to connect the spark from the distributor to the plugs
Centrifugal advance	Changes the ignition timing with engine speed. As speed increases the timing is advanced
Vacuum advance	Changes timing depending on engine load. On conventional systems the vacuum advance is most important during cruise conditions

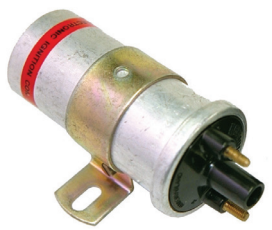


Figure 6.331 Traditional ignition coil

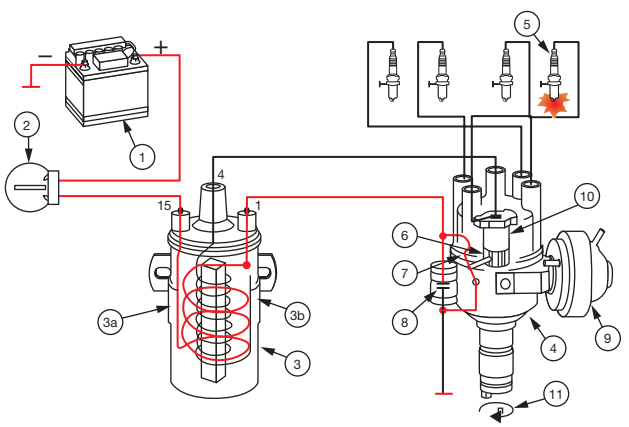


Figure 6.332 Ignition circuit of an early system: 1 Battery, 2 Ignition key switch, 3 Coil, a: primary, b: secondary winding, 4 Distributor body containing centrifugal (speed) advance/retard mechanism, 5 Spark plugs, 6 Cam (with a lobe for each cylinder), 7 Contact breakers (points), 8 Condenser (capacitor), 9 Vacuum (load) advance/retard mechanism

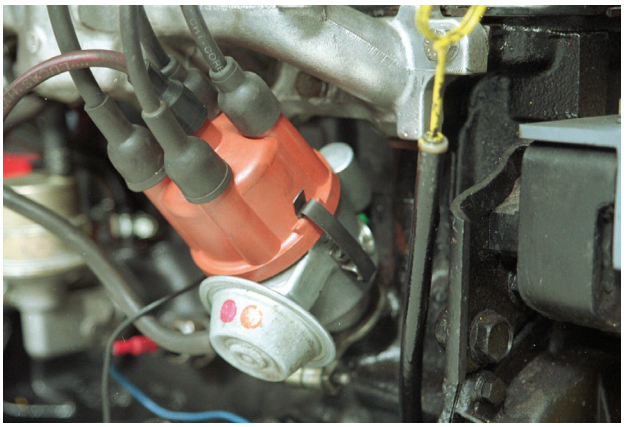


Figure 6.333 Traditional system using a distributor

Modern systems All current vehicle ignition systems are electronically switched and most are now digitally controlled as part of the engine management system. However, there are many vehicles out there still using conventional electronic ignition so the next main section will give an overview of these systems.

Look back over the previous section and write out a list of the key bullet points.

Construct a crossword puzzle using important words from this section. Hint: Use the online ATT glossary where you can copy the words and definitions (clues!). About 20 words is a good puzzle.

6.5.2 Electronic ignition 1 2

Early ignition systems had some major disadvantages:

- Mechanical problems with the contact breakers not least of which is the limited lifetime.
- Current flow in the primary circuit is limited to about 4A or damage will occur to the contacts – or at least the lifetime will be seriously reduced.
- Legislation requires stringent emission limits which means the ignition timing must stay in tune for a long period of time.
- Weaker mixtures require more energy from the spark to ensure successful ignition, even at very high engine speed.

These problems were overcome by using a power transistor to carry out the switching function and a pulse generator to provide the timing signal.

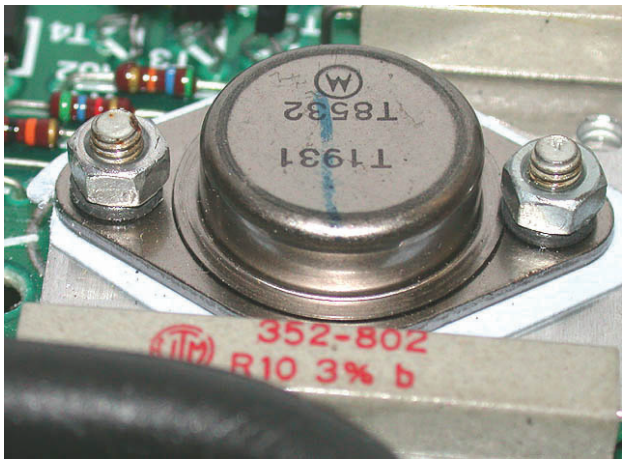


Figure 6.334 Power transistor

Dwell The term 'dwell' when applied to ignition is a measure of the time during which the ignition coil is charging, in other words when primary coil current is flowing. The dwell in traditional systems was simply the time during which the contact breakers were closed, and in these early electronic systems it is the time that the transistor is switched on. Whilst this was a very good system in its time, constant dwell still meant that, at very high engine speeds, the actual time available to charge the coil would only produce a lower power spark. Note that as engine speed increases dwell angle or dwell percentage remains the same but the actual time is reduced. All systems nowadays are known as constant energy, ensuring high performance ignition even at high engine speed.

Constant energy In order for a constant energy electronic ignition system to operate, the dwell must increase with engine speed. This will only be of benefit, however, if the ignition coil can be charged up to its full capacity in a very short time (the time available for maximum dwell at the highest expected engine speed). To this end, constant energy coils are very low resistance so a high current will flow quickly. Constant energy means that, within limits, the energy available to the spark plug remains constant under all operating conditions.

Pulse generator This was achieved by using a pulse generator in the distributor to 'tell' an ignition module the engine position and speed so that the module could determine the switch on (start of dwell) and switch off point (end of dwell and ignition timing spark). Two types of pulse generator (sensors) were most common:

1 Hall Effect
2 Inductive

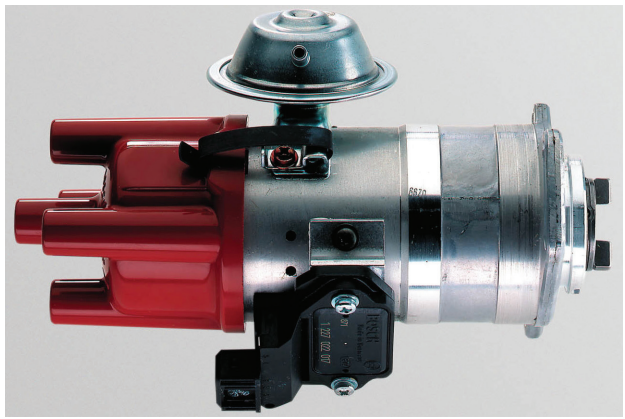


Figure 6.335 Distributor with ECU fitted (Source: Bosch Media)

Hall Effect As the central shaft of the Hall Effect distributor rotates, the chopper plate attached under the rotor arm alternately covers and uncovers the Hall chip. The number of vanes corresponds with the number of cylinders. In constant dwell systems, the dwell is determined by the width of the vanes. The vanes cause the Hall chip to be alternately in and out of a magnetic field. The result of this is that the device will produce almost a square wave output, which can then easily be used to switch further electronic circuits. The three terminals on the distributor are marked '+', '0' and '–'; the terminals + and – are for a voltage supply and terminal 0 is the output signal.

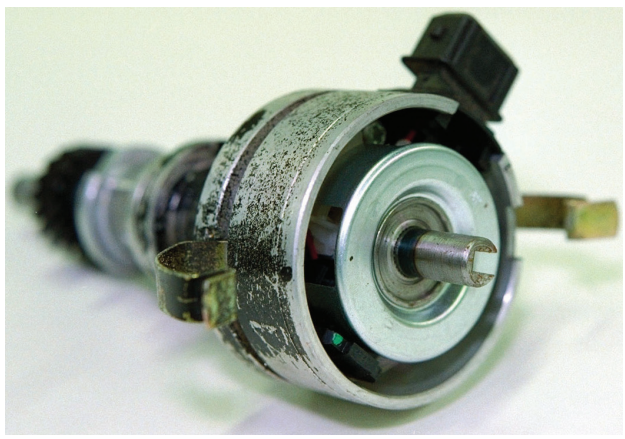


Figure 6.336 Hall effect distributor

Hall sensor output Typically the output from a Hall Effect sensor will switch between 0V and a few volts (systems vary). The supply voltage is taken from the ignition ECU and on some systems is stabilised at about 10V to prevent changes to the output of the sensor when the engine is being cranked. Hall Effect distributors are very common due to the accurate signal produced and their long

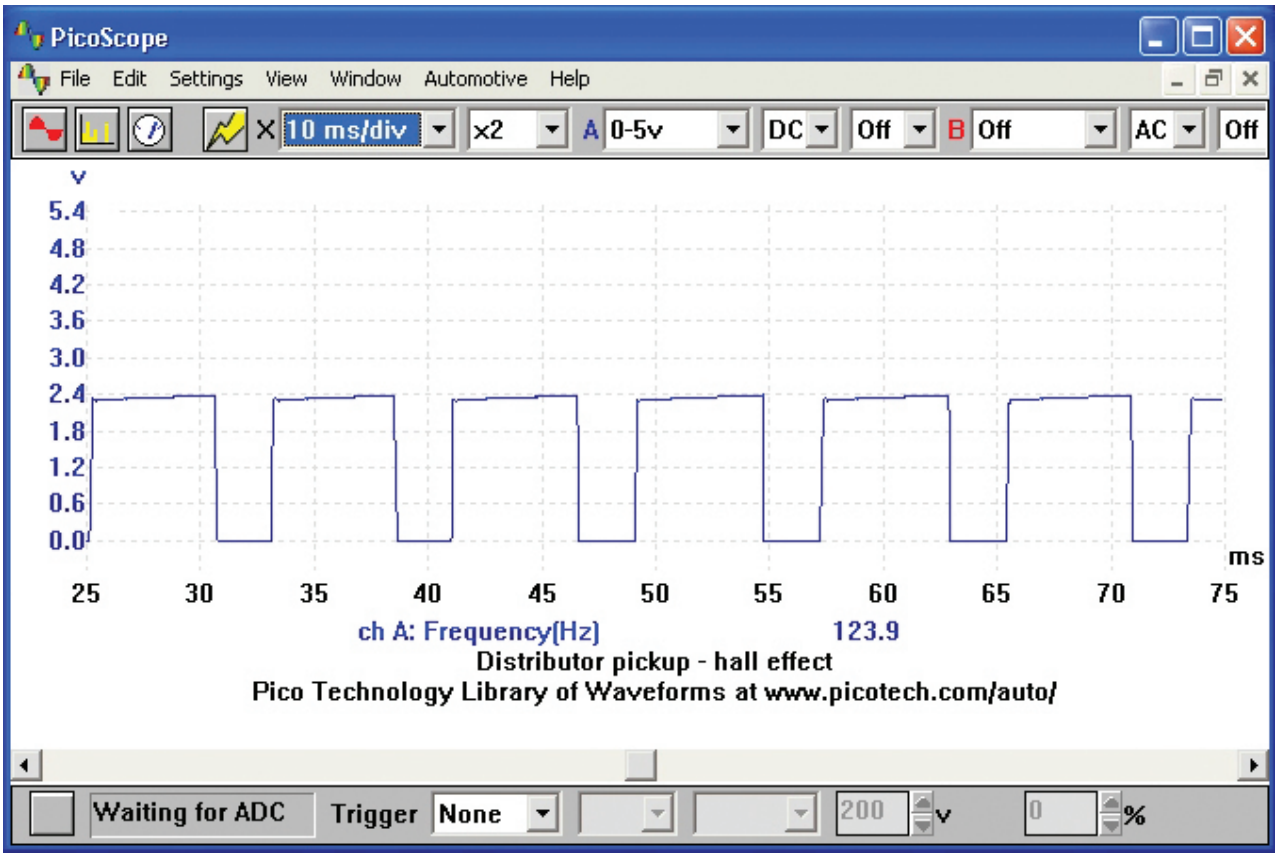


Figure 6.337 Hall sensor output

term reliability. They produced a kind of square wave output signal.

Inductive pulse generators use the basic principle of induction to produce a signal. Many forms exist but all are based around a coil of wire and a permanent magnet. The distributor shown in Figure 6.338 has the coil of wire wound on the pick-up and, as the reluctor rotates, the magnetic flux varies due to the peaks on the reluctor. The number of peaks or teeth on the reluctor corresponds to the number of engine cylinders. The gap between the reluctor and pick-up can be important and manufacturers have recommended settings. These systems produce a form of sinewave output.

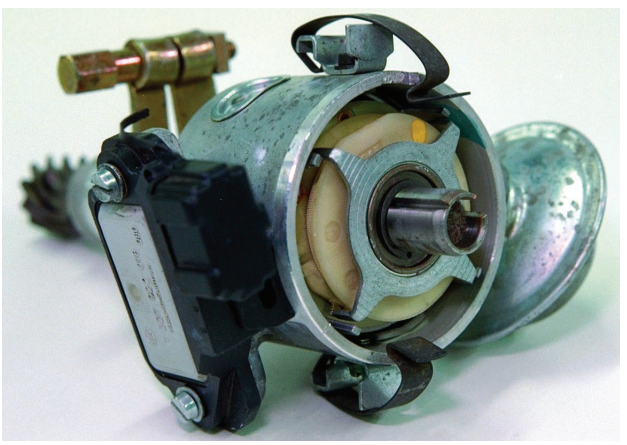


Figure 6.338 Inductive distributor

High energy Due to the high-energy nature of constant energy ignition coils, the coil cannot be allowed to remain switched on for more than a certain time. This is not a problem when the engine is running as the variable dwell or current limiting circuit prevents the coil overheating. Some form of protection must be provided for, however, when the ignition is switched on but the engine is not running. This is known as stationary engine primary current cut off.

Look back over the previous section and write out a list of the key bullet points.

Create an information wall to illustrate the important features of a component or system in this section.

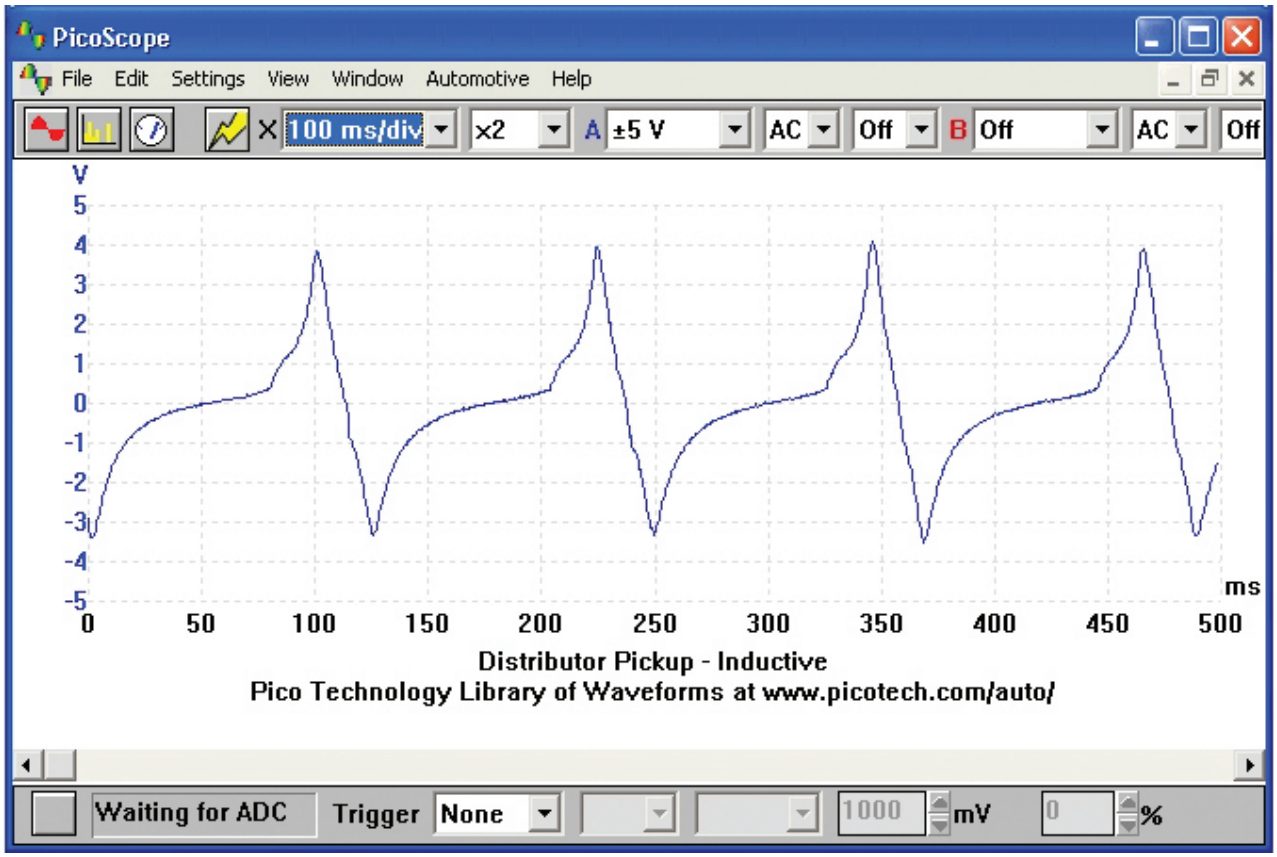


Figure 6.339 Inductive sensor output

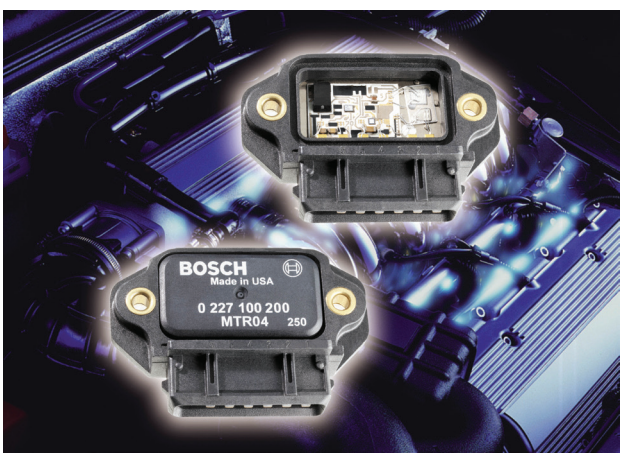


Figure 6.340 Electronic ignition module (Source: Bosch Media)

6.5.3 Electronic spark advance 2

Overview Constant energy electronic ignition was a major step forwards and is still used on most vehicles. However, limitations lie in having to rely upon mechanical components for speed and load advance characteristics. In many cases this does not ideally match the requirements of the engine.

Electronic spark advance (ESA) ignition systems have a major difference compared with earlier systems in that they operate digitally. Information about the operating requirements of a particular engine is programmed into the memory inside the electronic control unit. The data for storage in ROM are obtained from rigorous testing on an engine dynamometer and from further development work on the vehicle under various operating conditions. ESA ignition has several advantages.

- The ignition timing can be accurately matched to the individual application under a range of operating conditions.
- Other control inputs can be utilized such as coolant temperature and ambient air temperature.
- Starting is improved and fuel consumption is reduced, as are emissions, and idle control is better.
- Other inputs can be taken into account such as engine knock.
- The number of wearing components in the ignition system is considerably reduced.

ESA (also referred to as programmed ignition), can be a separate system but is now most likely to be included as part of the full engine management system.

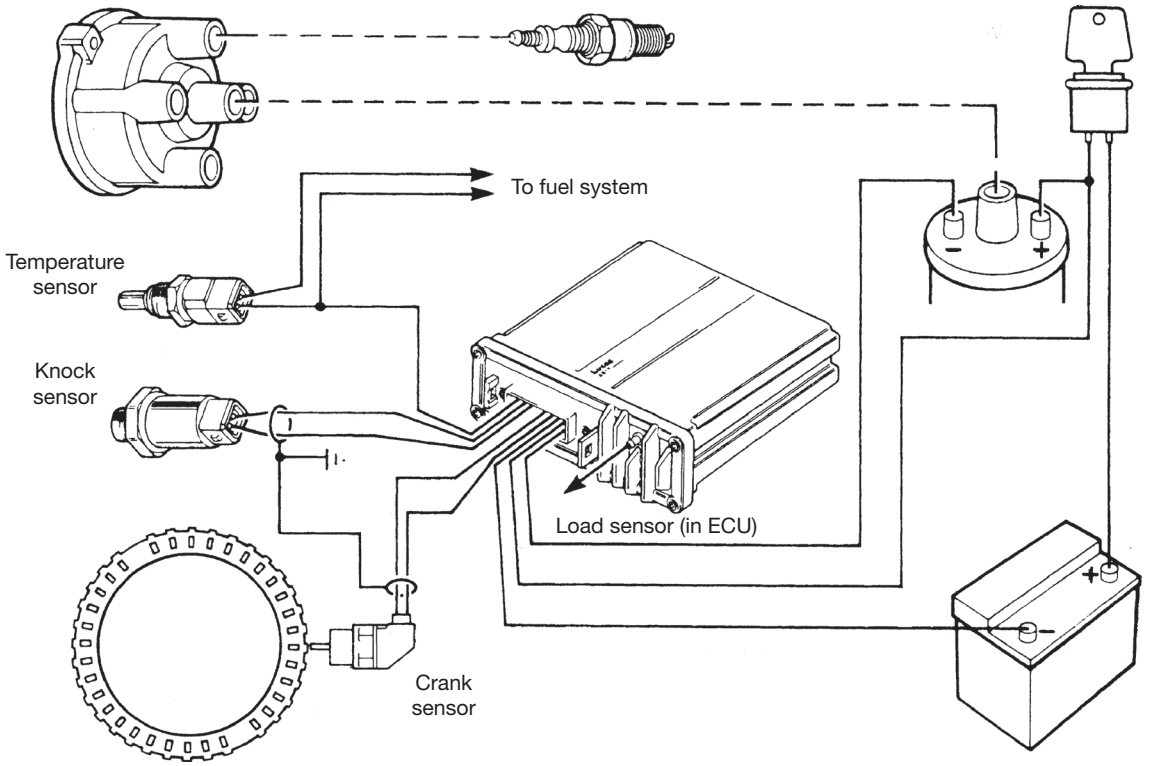


Figure 6.341 Programmed ignition or Electronic Spark Advance (ESA)

Sensors and input information A typical early ESA system is shown in Figure 6.341. In order for the ECU to calculate suitable timing and dwell outputs, certain input information is required.

Engine speed and position – crankshaft sensor This sensor is a reluctance sensor positioned as shown in Figure 6.342. The device consists of a permanent magnet, a winding and a soft iron core. It is mounted in proximity to a reluctor disc. The disc has 34 teeth, spaced at 10° intervals around the periphery of the disc. It has two teeth missing, 180° apart, at a known position before TDC (BTDC). Many manufacturers use this technique with minor differences. As a tooth from the reluctor disc passes the core of the sensor, the reluctance of the magnetic circuit is changed. This induces a voltage in the winding, the frequency of the waveform being proportional to the engine speed. The missing tooth causes a 'missed' output wave and hence the engine position can be determined.

Engine load – manifold absolute pressure sensor Engine load is proportional to manifold pressure in that high-load conditions produce high pressure and lower load conditions – such as cruise – produce lower pressure. Load sensors are therefore pressure transducers. They are either mounted in the ECU or as a separate unit and are connected to the inlet manifold with a pipe. The pipe often incorporates a restriction to damp out fluctuations and a vapour trap to prevent petrol fumes reaching the sensor.

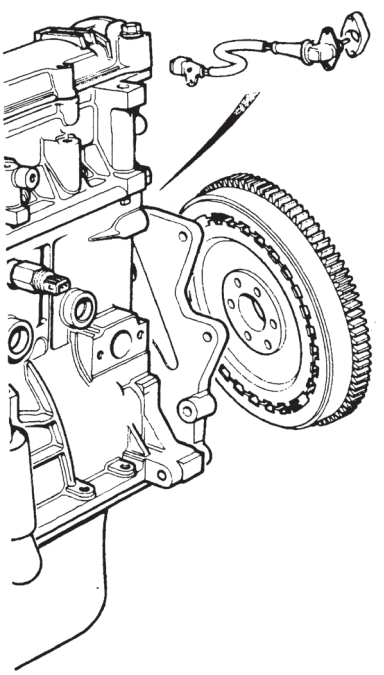


Figure 6.342 Position of a programmed ignition crankshaft sensor

Engine temperature – coolant sensor Coolant temperature measurement is carried out by a simple thermistor, and in many cases the same sensor is used for the operation of the temperature gauge and to provide information to the fuel control system. A separate memory map is used to correct the basic

timing settings. Timing may be retarded when the engine is cold to assist in more rapid warm-up.

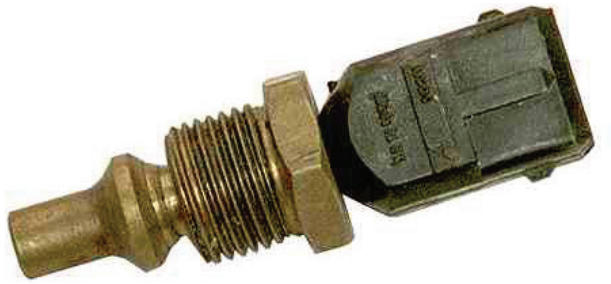


Figure 6.343 Temperature sensor

Detonation Combustion knock can cause serious damage to an engine if sustained for long periods. This knock, or detonation, is caused by over-advanced ignition timing. At variance with this is that an engine will, in general, run at its most efficient when the timing is advanced as far as possible. To achieve this, the data stored in the basic timing map will be as close to the knock limit of the engine as possible. The knock limit is also known as the detonation border line (DBL). The knock sensor provides a margin for error.

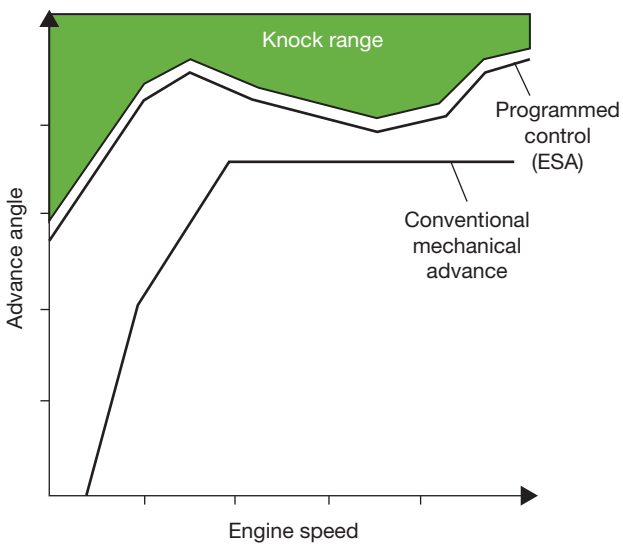


Figure 6.344 Ideal timing angle for an engine is close to the knock limit

Knock sensor The sensor itself is an accelerometer often of the piezoelectric type. It is fitted in the engine block between cylinders two and three on in-line four-cylinder engines. Vee engines require two sensors, one on each side. The ECU responds to signals from the knock sensor in the engine's knock window for each cylinder – this is often just a few degrees each side of TDC. This prevents clatter from the valve mechanism being interpreted as knock. The signal from the sensor is also filtered in the ECU to remove unwanted noise. If detonation is detected, the ignition timing is retarded on the fourth ignition pulse after detection (four-cylinder engine) in steps until knock is no longer detected. The steps vary between manufacturers, but about 2° is typical. The timing is then advanced slowly in steps of, say, 1° over a number of engine revolutions until the advance required by memory is restored. This fine control allows the engine to be run very close to the knock limit without risk of engine damage.

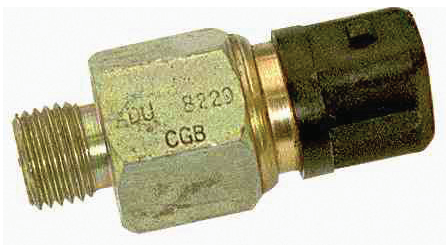


Figure 6.345 Knock sensor

Battery voltage Correction to dwell settings is required if the battery voltage falls, as a lower voltage supply to the coil will require a slightly larger dwell figure. This information is often stored in the form of a dwell correction map.

Electronic control unit As the sophistication of systems has increased, the information held in the memory chips of the ECU has also increased. The earlier versions of a programmed ignition system achieved accuracy in ignition timing of 1.8° whereas a mechanical distributor is 8°. The information, which is derived from dynamometer tests as well as running tests in the vehicle, is stored in ROM. The basic timing map consists of the correct ignition advance for a range of engine speeds and load conditions. This is shown using a cartographic representation. A separate three-dimensional map is used that has speed and temperature-related settings. This is used to add corrections for engine coolant temperature to the basic timing settings. This improves drivability and can be used to decrease the warm-up time of the engine.

Ignition output The output of a system, such as this programmed ignition, is very simple. The output stage, in common with most electronic ignitions, consists of a heavy-duty transistor that forms part of, or is driven by, a Darlington pair. This is simply to allow the high ignition primary current to be controlled. The switch off point of the coil will control ignition timing and the switch on point will control the dwell period.

Remember! There is a multimedia version of this textbook that includes additional images and interactive features: www.automotivett.org

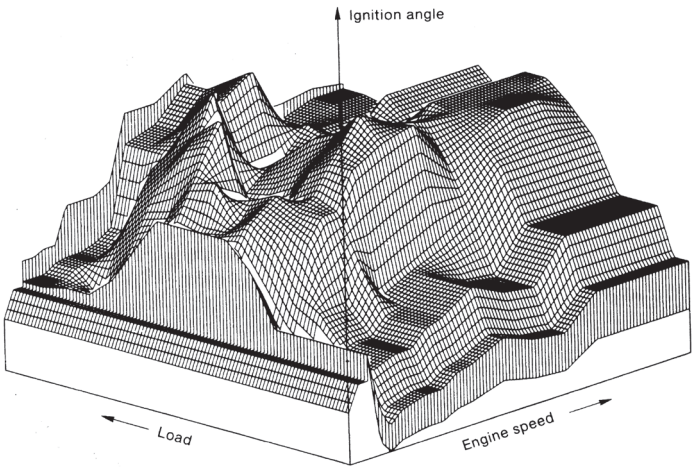


Figure 6.346 Cartographic map representing how ignition timing is stored in the ECU

HT distribution The high tension distribution is similar to a more conventional system. The rotor arm however is mounted on the end of the camshaft with the distributor cap positioned over the top.

Look back over the previous section and write out a list of the key bullet points.

Make a simple sketch to show how one of the main components or systems in this section operates.

6.5.4 Distributorless ignition 2

Distributorless ignition systems (DIS) use a special type of ignition coil, which outputs to the spark plugs without the need for an HT distributor.

Figure 6.347 Distributorless ignition coil in position

Lost spark The basic principle is that of the 'lost spark'. The distribution of the spark is achieved by using two double-ended coils, which are fired alternately by the ECU. The timing is determined from a crankshaft speed and position sensor as well as a load (MAP) sensor and other corrections such as engine temperature. When one of the coils is fired, a spark is delivered to two engine cylinders, either 1 and 4, or 2 and 3. The spark delivered to the cylinder on the compression stroke will ignite the mixture as normal. The spark produced in the other cylinder will have no effect as this cylinder will be just completing its exhaust stroke.

Operation Because of the low compression, and the exhaust gas in the 'lost spark' cylinder, the voltage used for the spark to jump the gap is only about 3kV. The spark produced in the compression cylinder is therefore not affected. An interesting point here is that the spark on one of the cylinders will jump from the earth electrode to the spark plug centre. Many years ago this would not have been acceptable as the spark quality when jumping this way would not have been as good as when it jumps from the hotter centre electrode. However, the energy available from modern constant energy systems will result in a spark of high quality regardless of its polarity.

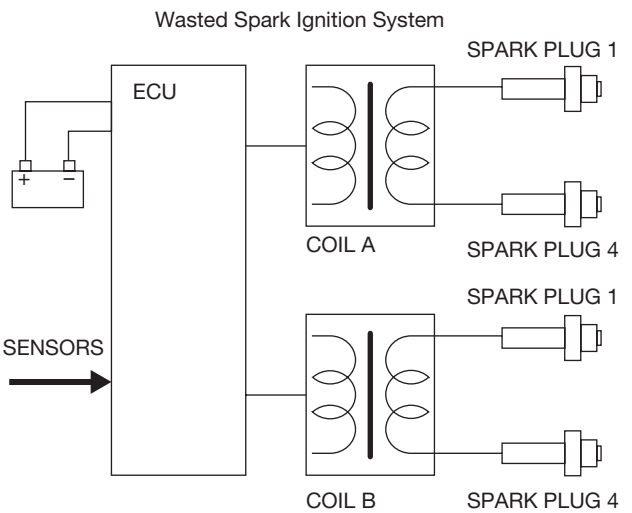


Figure 6.348 DIS simplified circuit (wasted spark ignition system)

DIS components The DIS system consists of three main components – the electronic control unit (ECU), a crankshaft position sensor and the DIS coil. A manifold absolute pressure sensor is integrated in the module or mounted separately. The module uses an electronic spark advance system. Data on ideal dwell and timing is held in memory maps for a wide range of speed, load and voltage conditions. This can be described as an electronic spark advance (ESA) system

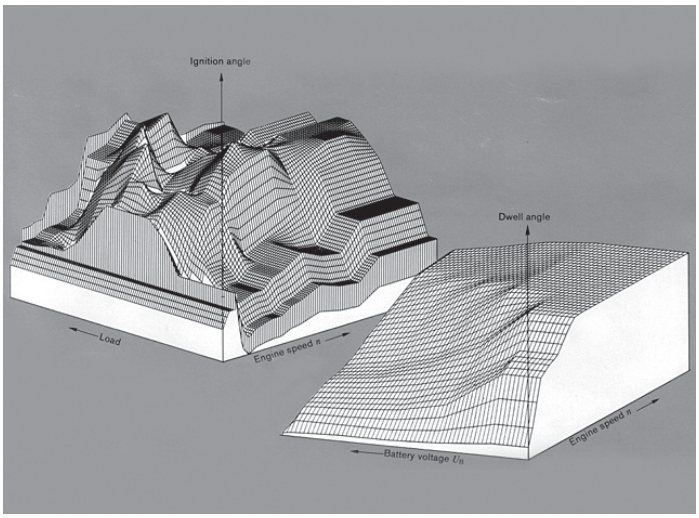


Figure 6.349 Timing and dwell maps

Crank position sensor (CPS) The crankshaft position sensor is similar in operation to the one described in the fuel section. It is an inductive sensor and is positioned against the front of the flywheel or against a reluctor wheel just behind the front crankshaft pulley. The tooth pattern usually consists of 35 teeth. These are spaced at 10° intervals with a gap where the 36th tooth would be. The missing tooth is positioned at 90° BTDC for numbers one and four cylinders. This reference position is placed a fixed number of degrees before top dead centre, in order to allow the timing or ignition point to be calculated as a fixed angle after the reference mark.

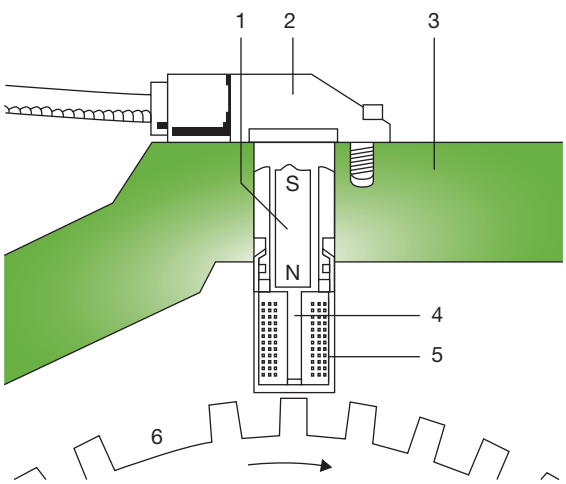


Figure 6.350 Inductive sensor: 1 Magnet, 2 Cover, 3 Engine, 4 Core, 5 Winding

Coil The primary winding is supplied with battery voltage to a centre terminal. The appropriate half of the winding is then switched to earth in the module. The high tension windings are separate and are specific to cylinders one and four, or two and three (or as appropriate if a six-cylinder engine). On most cars now the ignition system is combined with the fuel system so that even more accurate control of outputs is possible and input data from sensors can be shared.

Figure 6.351 DIS coil and plug leads

Look back over the previous section and write out a list of the key bullet points.

Use a library or the interactive web search tools to examine the subject in this section in more detail.

6.5.5 Coil on plug ignition 2

Coil on plug (COP) or direct ignition is a further improvement on distributorless ignition. This system utilises an inductive coil for each engine cylinder. These coils are mounted directly on the spark plugs. The use of an individual coil for each plug ensures that the charge time is very fast (full coil charge in a very small dwell angle). This ensures that a very high voltage, high-energy spark is produced. This voltage, which can be in excess of 40kV, provides efficient initiation of the combustion process under cold starting conditions and with weak mixtures.

Ignition timing and dwell are controlled in a manner similar to the previously described electronic spark advance (ESA) system. The one important addition to this on most systems is a camshaft sensor to provide information as to which cylinder is on the compression stroke. A system which does not require a sensor to determine which cylinder is on compression (engine position is known from a crank sensor) determines the information by initially firing all of the coils. The voltage

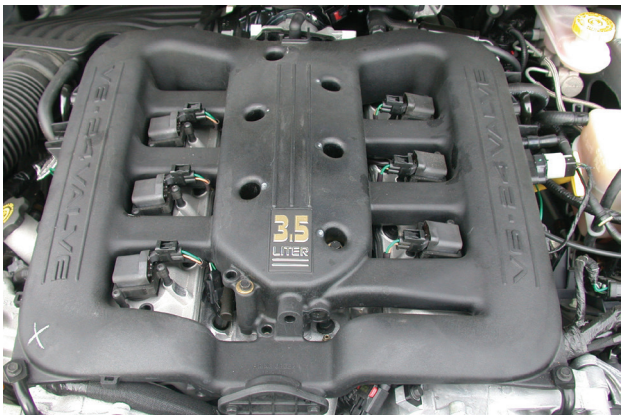


Figure 6.352 Six direct ignition coils in position

across the plugs allows measurement of the current for each spark and will indicate which cylinder is on its combustion stroke. This works because a burning mixture has a lower resistance. The cylinder with the highest current at this point will be the cylinder on the combustion stroke.

Flooding A further feature of some systems is the case when the engine is cranked over for an excessive time making flooding likely. The plugs can all fire with multi-sparks for a period of time after the ignition is left on to burn away any excess fuel. During difficult starting conditions, multi-sparking is also used by some systems during 70° of crank rotation before TDC. This assists with starting and then, once the engine is running, the timing will return to its normal calculated position.

Look back over the previous section and write out a list of the key bullet points.

Create a word cloud for one or more of the most important screens or blocks of text in this section.

6.5.6 Spark plugs and leads 1 2

Overview The simple requirement of a spark plug is that it must allow a spark to form within the combustion chamber to initiate combustion. In order to do this, the plug has to withstand a number of severe conditions. It must withstand severe vibration and a harsh chemical environment. Finally, but perhaps most importantly, the insulation properties must withstand voltage pressures up to 40kV.

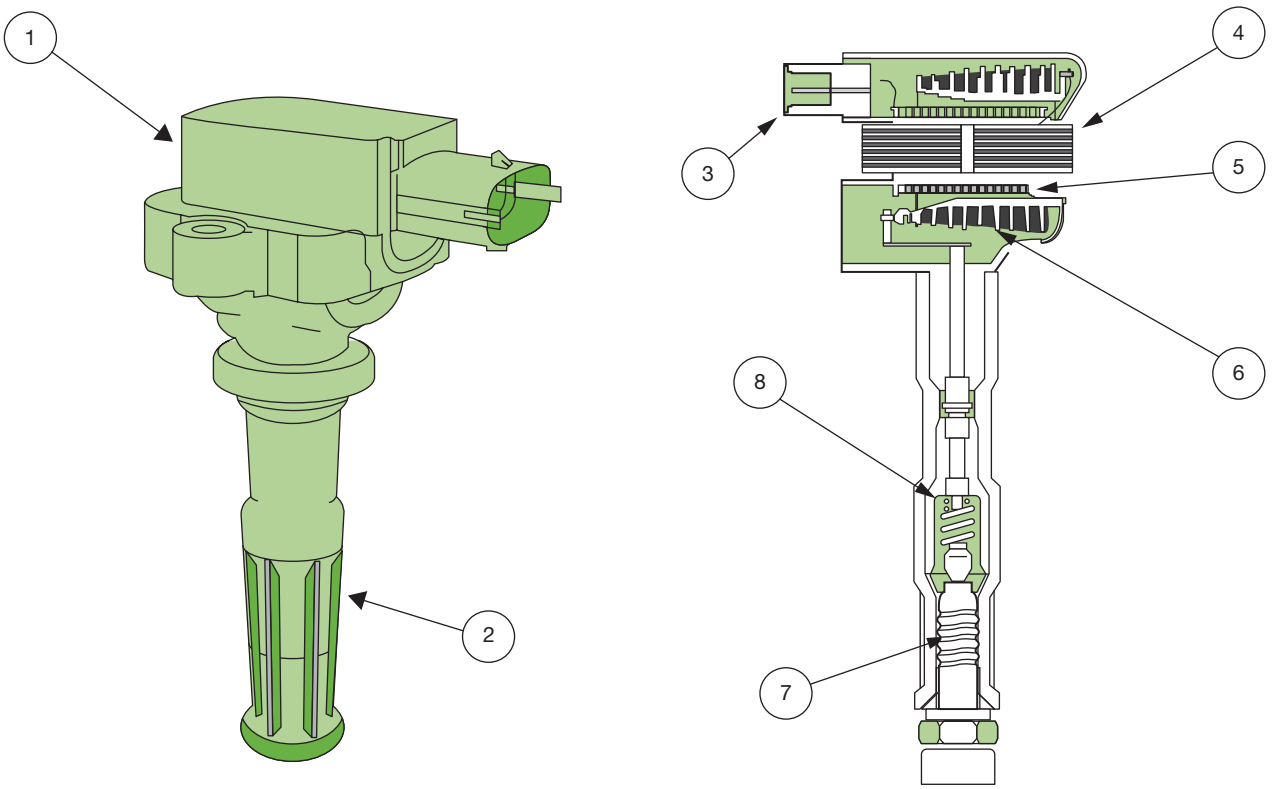


Figure 6.353 Direct ignition coil features: 1 Direct ignition coil, 2 Spark plug connector, 3 Low voltage connection, outer, 4 Laminated iron core, 5 Primary winding, 6 Secondary winding, 7 Spark plug, 8 High voltage connection, inner, via spring contact

Figure 6.354 Modern high-performance spark plug

Standard spark plug The centre electrode is connected to the top terminal by a stud. The electrode is constructed of a nickel-based alloy. Silver and platinum are also used for some applications. If a copper core is used in the electrode this improves the thermal conduction properties. The insulating material is ceramic based and of a very high grade. Flash over or tracking down the outside of the plug insulation is prevented by ribs which effectively increase the surface distance from the terminal to the metal fixing bolt, which is of course earthed to the engine.

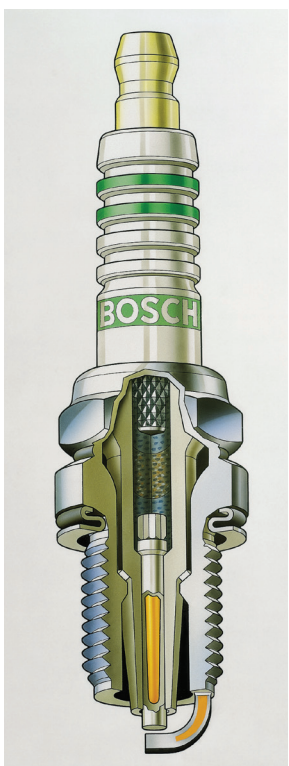


Figure 6.355 Cutaway section of a spark plug

Temperature Due to many and varied constructional features involved in the design of an engine, the range of temperatures a spark plug is exposed to can vary significantly. The operating temperature of the centre electrode of a spark plug is critical. If the temperature becomes too high then pre-ignition may occur where the fuel/air mixture may be ignited due to the incandescence of the plug electrode. If the electrode temperature is too low, then carbon and oil fouling can occur as deposits are not burnt off. The ideal operating temperature of the plug electrode is between 400 and 900°C.

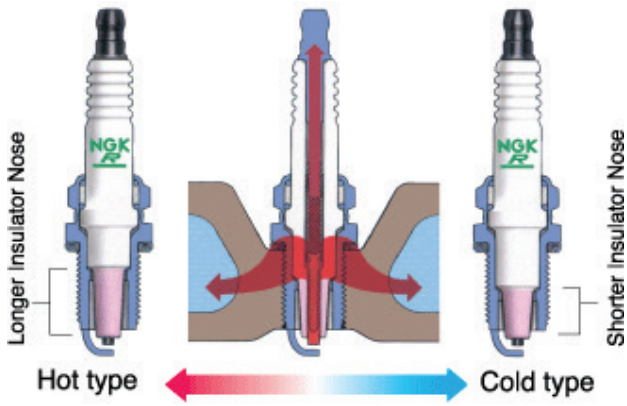


Figure 6.356 Heat-loss paths: the cold plug is able to transfer heat more easily so is suitable for a hot engine

The **heat range** of a spark plug is a measure of its ability to transfer heat away from the centre electrode. A hot running engine will require plugs with a higher thermal ability than a colder running engine. Note that hot and cold running of an engine in this sense refers to the combustion temperature, not to the cooling system.

Spark plug **electrode gaps**, in general, have increased as the power of the ignition systems driving the spark has increased. The simple relationship between plug gap and voltage required is that as the gap increases so must the voltage (leaving aside engine operating conditions). Further, the energy available to form a spark at a fixed engine speed is constant, which means that a larger gap using higher voltage will result in a shorter duration spark. A smaller gap will allow a longer duration spark. For cold starting an engine and for igniting weak mixtures, the duration of the spark is critical. Likewise the plug gap must be as large as possible to allow easy access for the mixture to prevent quenching of the flame. The final choice is therefore a compromise reached through testing and development of a particular application. Plug gaps in the region of 0.6 to 1.2mm seem to be the norm at present.

Figure 6.357 A range of spark plugs (Source: Bosch Media)

High tension (HT) is just an old fashioned way of saying high voltage. HT components, such as plug leads, must meet or exceed stringent ignition product requirements, such as:

- insulation to withstand 50 000V
- temperatures from 40°C to 260°C (40°F to 500°F)
- radio frequency interference suppression
- 160 000km (100 000 mile) product life
- resistance to ozone, corona, and fluids
- ten-year durability.

HT cables must meet the increased energy needs of lean-burn engines without emitting electromagnetic interference (EMI). The cables shown in Figure 6.358 offer metallic and non-metallic cores, including composite, high-temperature resistive and wire-wound inductive cores. Conductor construction includes copper, stainless steel, Delcore, CHT, and wire-wound. Jacketing materials include silicone.

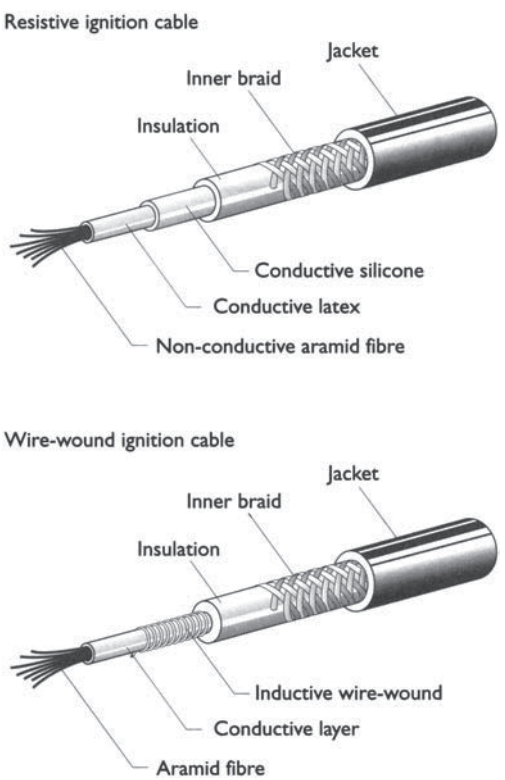


Figure 6.358 Ignition plug leads

Look back over the previous section and write out a list of the key bullet points.

Create a mind map to illustrate the important features of a component or system in this section.

Now complete the multiple-choice quiz associated with this topic/subject area.

6.6 Air supply, exhaust and emissions

6.6.1 Air pollution 1

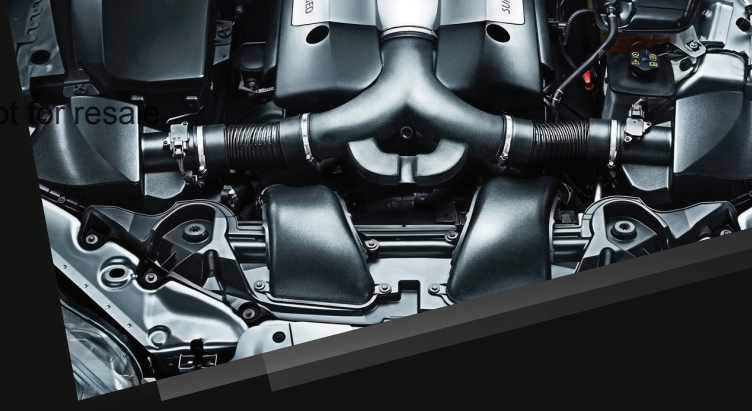
Atmospheric pollution has become a serious problem for the environment and the health of people. Many urban areas are now heavily polluted, with people suffering medically from the effects of vehicle exhaust pollution.

Make a simple sketch to show the composition of exhaust gas.

Fossil fuels There have been many changes in climatic conditions in the world. Many of these have occurred over a long period and animals and plants have adapted to the changes naturally. However, the rapid burning of fossil fuels during this century has increased carbon dioxide levels in the atmosphere.

Vehicle designs are concentrating on weight reduction, aerodynamics, reducing rolling resistance, and on fuel-efficient engines. Alternative fuel sources to reduce fossil-fuel usage and to conserve the world's stock of these fuels have also been developed.

Carbon dioxide allows the sun's heat in but reduces the ability of the heat to radiate outward, causing the Earth to warm up. Many studies of the warming process indicate that the rate of Earth warming is increasing too quickly and preventing animals and



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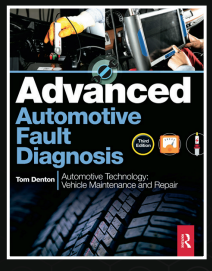

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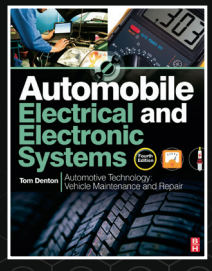

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