

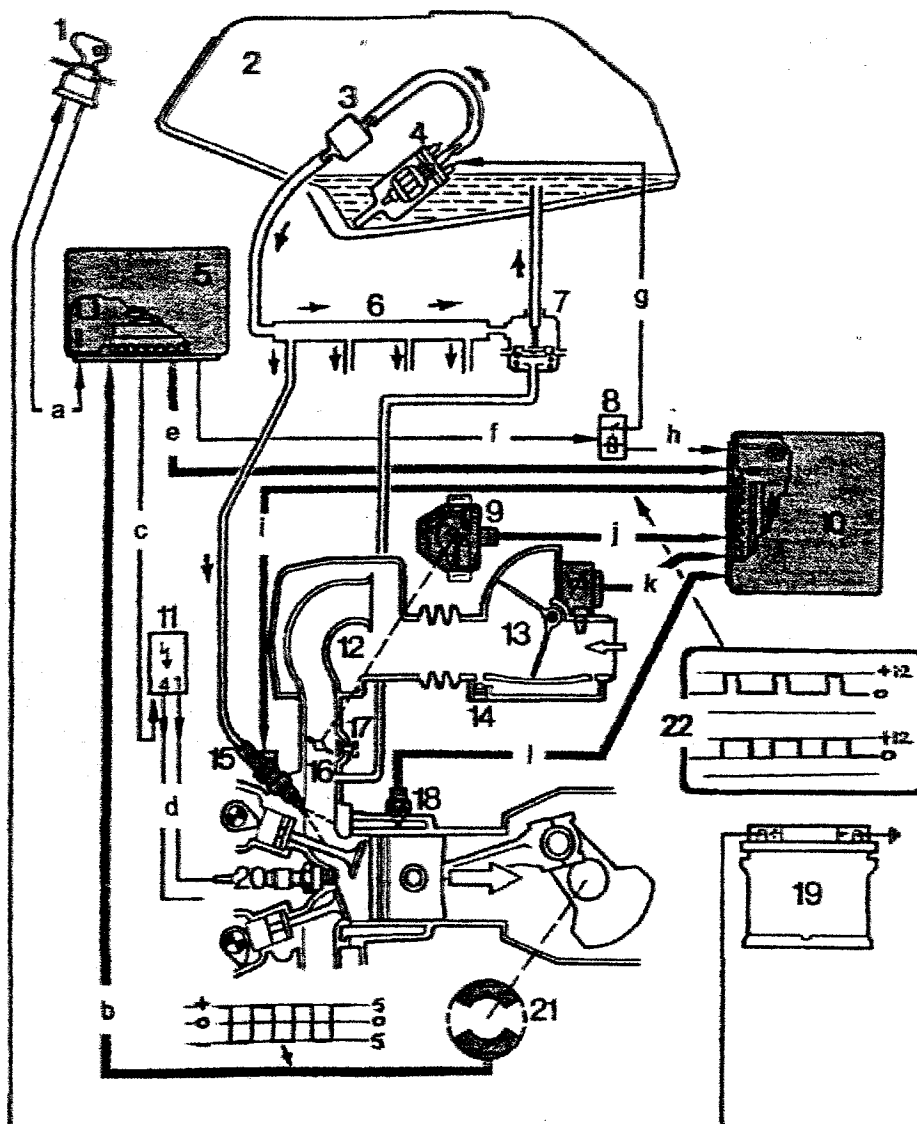


BMW Club South-West Section

Technical Bulletin No.8

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Bosch LE-Jetronic Fuel Injection System

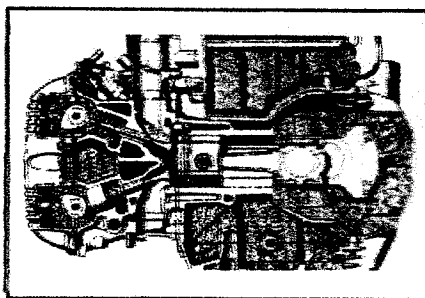


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Back in 1984, when the K100 was launched upon a public who regarded even electronic ignition as being new-fangled, BMW's extravagant claim that this new machine was dependent upon the actions of two computers which communicated with each other was just too much for some, who refused to buy what they perceived to be such potentially troublesome machines. Even then, however, the LE-Jetronic injection system and its associated ignition unit were well-established on the automotive scene, and had developed a reputation for the utmost reliability. They are arguably the most reliable parts of the machine, and have since become one of those items, such as a frame or crankshaft, whose continued operation is taken for granted.



It is sometimes claimed that 'LE' denotes that the system is based upon 'Luft' (air) measurement and is the 'E' (European) version, but it also provides 'Limited' – as distinct from 'Kontinuous' (eg: K-Jetronic) – injection, and includes an 'Eco/Economy' facility to cut off the fuel delivery in certain circumstances. Unlike the later Motronic digital equipments, LE-Jetronic is an analogue system, therefore having a closer relationship to a sophisticated amplifier rather than a computer. Its characteristics are fixed, and output (fuel delivery) is dependent upon inputs from resistive sensors, switches, and an engine speed signal derived from the ignition unit.

The injection control unit operates in conjunction with the ignition control unit, and it is therefore necessary to consider the actions of both units, and their ancillary equipment.

Ignition Control Unit:

The ignition unit contains two coil switching circuits, each of which is triggered by a Hall Effect unit behind the cover at the front of the engine. A drum-type shutter is mounted on the nose of the crankshaft, with a cut-out which enables each trigger to change its output polarity for 37° during each crankshaft revolution. The Hall Effect unit is merely an electronic switch, which, under the influence of a magnetic field, is able to switch its output quickly and cleanly, so producing, in graphical form, what is known as a square wave. When the engine rotates, and this output changes from positive to negative, the ignition unit will switch off the primary current flowing through the associated coil, so generating a spark; as the output reverts to positive, the coil primary winding will be switched on again.

The K100 uses a pair of double-ended coils, operating on the 'wasted spark' principle with sparks on cylinders 1 & 3, and 2 & 4 just before TDC on the compression and exhaust strokes. The K75 uses orthodox single-ended coils and therefore provides sparks on the compression stroke only.

In the case of the K75, two Hall Effect triggers are still employed, but use a 44° shutter cut-out, and are set at 120° to each other. The 'missing' third trigger signal is electronically synthesised within the ignition control unit.

Each Hall Effect signal is produced, of course, once per revolution, and their rate is proportional to engine speed. One is used by the ignition unit to generate an injection control signal at every revolution, while the other is used to produce a speed signal for ignition advance control, overspeed protection, and starter motor inhibition purposes.

At low speeds – below about 1,300 rpm – a time delay is introduced between the arrival of the signal and the switching of the coils, which, in terms of crankshaft rotation, is equal to the angle of maximum advance; as rpm increases, this delay is progressively reduced, so bringing the coil switching point closer to the Hall Effect triggering point – in other words, advancing the ignition. The time delay is carefully tailored to the requirements of the engine, so producing what the magazines love to refer to as an 'Ignition Map', but which is really just an advance curve!

Early K100 models were equipped with a vacuum switch, connected from the front throttle body, which caused a changeover to a secondary 'Part-Throttle' advance curve, providing up to 8° additional advance in the low to mid speed range at high levels of inlet vacuum – ie: when running on small throttle openings – to promote additional fuel economy. This facility has since been

discontinued. Both curves merge at 6,500 rpm.

If engine speed exceeds 8,650 rpm the ignition timing will be retarded to 6° BTDC, and at 8,770 rpm the fuel injection control signal will be cut off, so stopping fuel delivery, this two-stage overspeed protection providing a gentle reminder to the rider. It has been claimed that this characteristic can be overridden by pressing the starter push while at full speed.

Safety Features & Starting:

On the earlier machines, when the supply to the ignition unit is initially switched on, the fuel pump relay is energised. If no crankshaft rotation is sensed, the fuel pump relay will be switched off after a second, so inhibiting fuel delivery. This short run was designed to purge the fuel system of any fuel which, while standing, had absorbed heat from the engine. Under conditions of low pressure and heat absorption this fuel could evaporate within the fuel rail, and so lead to problem in starting when hot. This facility was found to be unnecessary, and was disabled on later models. Operation of the starter push will reset these safety measures, and also provide a small increase in mixture strength during a normal start-up procedure.

After a successful start, the starter relay will be inhibited above about 700 rpm. Should the engine stop while the ignition is switched on, after one second the fuel pump relay will be de-energised as a safety precaution, and the ignition coils switched off to prevent overheating.

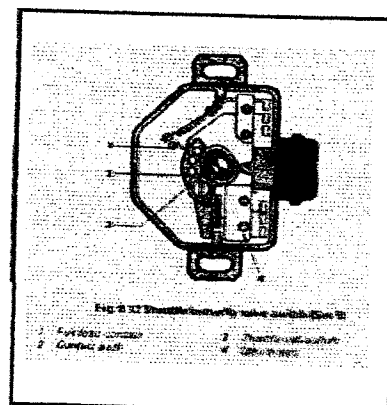
Sensors:

The injection system operates in a pre-set mode, in response to engine speed, and signals from sensors monitoring engine coolant temperature, mass air flow (ie: total air weight, based upon volume and temperature) and, in some circumstances, throttle position. Models destined for certain markets (eg: USA and South Africa) were equipped with a plug-in link, which modified the mixture characteristics for use at high altitude.

Air Flow: The air flow sensor basically consists of two resistors, one being a variable type, connected to a spring-loaded moving plate, the other being fixed, and used as a temperature sensor. As air flows into the engine it causes the plate to pivot, so adjusting the variable resistor. The currents flowing in the variable resistor and fixed resistors (ie: air flow and temperature signals) are combined within the injection control unit to provide a signal which is proportional to the weight of air flowing into the engine under a very wide range of atmospheric pressure and temperature. When suddenly accelerating, the increased air flow and the inertia of the sensor plate will cause it to slightly overrun (just like the piston in a Bing CV carburettor) so providing a small additional enrichment for a short period.

An air flow by-pass passage connects both sides of the air flow sensor plate, flow through this passage being controlled by the CO adjustment screw. As this passage provides an additional unmetered air flow, for which no additional amount of fuel has been provided, opening this passage will weaken the mixture strength, and vice versa. This effect is more noticeable at small throttle openings. The unit provides a variable DC voltage which is inversely proportional to air flow - in other words, full input at zero flow, falling to around 0.6 volt at full flow.

Coolant Temperature: The coolant discharge gallery on the cylinder head houses a pair of resistive temperature sensors in a common housing, the resistance of which falls with temperature. One sensor supplies a temperature signal to the injection control unit, while the other is connected to the fan/warning lamp controller; the fan starts at 103°C, while the warning lamp operates at 111°C. The sensor does not generate an output voltage, its resistance characteristics increasing the current flowing through the resistance elements as temperature increases.



Throttle Position: A switch, mounted at the back of the throttle bank, is open under most throttle settings. When the throttles are closed this switch will provide a signal to the injection control unit, which, at speeds over about 3,000 rpm will cause the injectors to close, so saving fuel and eliminating exhaust emissions until the engine falls below this speed, when the injectors will be energised and the engine will restart. At throttle openings of over two-thirds the switch will close another contact to provide an alternative signal, enriching the mixture for maximum performance.

Injection Control Unit:

When the ignition is switched on, the injection control unit remains inactive until an injection control signal from the ignition control unit resets its circuits to restore normal operation, and provide a power supply to the injectors. This supply is in the form of a square wave, generated at every crankshaft revolution, the duration of which varies between 1.5 and 9 milliseconds in response to the demand for fuel, based on engine speed, coolant temperature, intake air flow/temperature, and, in certain conditions, throttle position.

The injectors are normally closed, and are opened by solenoid coils. They are connected in parallel, and open simultaneously; injection is therefore not timed with regard to the position of each piston, as would be the case in a diesel engine.

While the starter push is depressed the fuel supply is slightly enriched to provide a good start.

At low speeds – below 950 rpm – where the airflow sensor cannot react accurately to the reduced flow, mixture strength is controlled solely by engine temperature, while at speeds above 950 rpm an enriched mixture, based on temperature and air flow, is weakened at a greater rate. Do not, therefore, allow the engine to idle on a winter morning, while you enjoy that last cigarette – get on it and ride!

In response to signals from the throttle switch, fuel delivery is slightly increased for full power operation, or cut off to reduce fuel consumption and eliminate exhaust emissions above about 3,000 rpm..

Should the rpm signal cease, due to the engine stopping, injection will be inhibited as a safety measure.

Although the injection control unit will provide sufficient additional fuel to cater for starting in the most extreme conditions, the provision of a matching quantity of air is up to the rider! The 'Choke' control is actually a hand throttle, which, in its first position, provides a small increase on the normal idle position of the throttles, with a larger increment on its second, spring-loaded position. Should even this fail to provide a good start, further manual throttle opening is required, though by this time the spark plugs will probably have become wet.

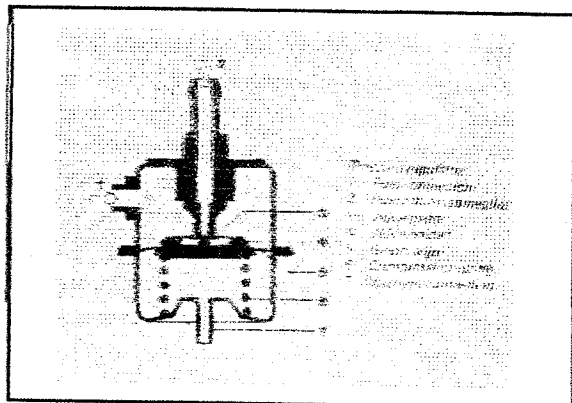
A switch, fitted at the front of the throttle bank, controls the operation of the 'Choke' warning lamp.

Fuel System:

Fuel Pump: Fuel is supplied from the tank under pressure from the pump, which is a standard car-type rolling cell unit, running immersed in fuel.

Fuel is 'rolled' through a section of flexible tube, the pump being able to provide a flow rate of 45 litres per hour. The pump is supplied by a relay, which is controlled by the ignition control unit. Fuel is passed through a pick-up screen in the pump, and a paper filter within the tank, to the front end of the fuel rail.

Fuel Filter: This is a uni-directional flow paper filter, with an aluminium body, mounted in the pump discharge pipes inside the fuel tank. Some early models were prone to low fuel pressure problems



caused by splits developing in the filter body. This problem was rapidly cured by stopping the stamping of part numbers etc into the filter body. the filter is quite small, but is non the less expensive, and it can usefully be substituted by the much larger type used on the later Volkswagen Golf GTi etc. Always carry a spare filter on any long run, particularly if travelling in some of the more rural areas of Europe.

Fuel Rail: Fuel is delivered into one end of the fuel rail, which supplies the injectors, excess fuel returning to the tank from the other end via the pressure regulator. This constant return flow prevents the fuel contained within the rail from being heated beyond its vaporisation point, and forming pockets of vapour, which would promote pinking, difficult starting, and misfires.

Injectors: The injectors are connected to the fuel rail, and discharge directly into the inlet ports. Each injector nozzle is normally closed by a spring-loaded needle which is magnetically withdrawn by a solenoid, operated by the injection control unit. A small mesh fuel filter is fitted inside each injector. The injectors are all pulsed simultaneously, the period of opening being varied to control the fuel delivery and so the mixture strength.

Fuel Pressure Regulator: This unit is mounted between the rear throttle body and the air filter; it therefore cannot be seen, and is difficult to get at! It maintains a constant pressure differential between the fuel rail and the downstream side of the throttles, by means of a connection to the rear throttle body which permits the inlet vacuum to evacuate one side of a diaphragm, so allowing atmospheric pressure on its other side to compress an accurately-calibrated spring. As the throttles are closed, inlet vacuum increases, the spring is further compressed, and the valve is opened further to increase the rate of fuel return to the tank, and so lower the pressure in the fuel rail. Fuel pressure at the injectors is thereby maintained at 2.5 Bar (35 psi) more than the partial vacuum in the throttle body, in order to maintain the optimum spray pattern of the injector nozzles under all load conditions.

Throttle Bank: The throttle bodies are bolted together, their upper ends being terminated in curved ram pipes within a sealed plenum chamber, the volume of which is designed to provide for sudden airflow demands, and to also absorb and silence the shock waves which run backwards along the inlet tracts when a 'slug' of moving air hits the back of a closed inlet valve.

Each throttle body contains an idle adjustment screw, controlling a by-pass passage, which enables idle vacuum levels to be equalised.

The individual throttles are not directly coupled, but are operated from the 'master' throttle, which is attached to the throttle cable. Each throttle is equipped with a return spring, which presses its operating arm against a platform operated by the spindle of the adjacent throttle, via an adjusting screw and locknut. The spindle of the rear throttle body operates the throttle switch.

Fuel Problems:

LE-Jetronic was very well-proven in automotive use before being fitted to the K100, and in our application it has been very reliable, with virtually no failures of the so-called 'computers' and very few of anything else; there are now many K100s which have covered more than 250,000 miles without any injection system problems – how many Bing carburettor users can boast of that? I have even heard of a K100RS which was submerged in sea water for a week during a flood; yet after hosing down it started cleanly!

Most breakdowns have been due to fuel starvation, caused by bad contact in the fuel pump relay base, or blocked fuel filters due to dirty fuel (such as in the former Yugoslavia) or water contamination – the filter will not pass water, as it has a higher surface tension than petrol. Unusual problems are, by their very nature, difficult to define, but one such is a gradual rise of the oil level of the sump. This is caused by a leak within the fuel pressure regulator, so passing small amounts of fuel into regulator vacuum hose and so into the rear throttle body. This additional fuel does not seem to cause obviously rich running, yet finds its way past the piston rings and so to the sump.

Misfires are generally caused by air leaks between the airflow sensor and cylinder head, usually taking place at any flexible rubber joint, or at the 'O' rings which seal the injectors to the cylinder head.

Electrical Problems:

An intermittent, if not total engine failure can be caused by a simple wiring fault, as the K-Series could have benefited from a little more care in design and installation of the wiring for the LE-Jetronic injection control unit. The cable harness of the large multi-way socket from the control unit exits the socket body towards the rear of the machine, which forces it to make an acute bend in order to follow the frame tube.

The cable harness is tightly secured to the frame at this bend, where it is inevitably subjected to flexing by the movement of the control unit on its two sets of rubber mounts — not to mention the larger movement necessary to disconnect the socket prior to checking the battery levels. The result of this is that some of the very small (0.5 mm) cables it contains can fracture within their insulation, causing intermittent contact, which interferes with operation of the injection system. In extreme cases this interference can be of a permanent nature.

This problem may affect the injector solenoid supply, fuel injection control signal from the ignition unit, power supply, or any other cables associated with the control unit, but can easily be diagnosed by use of a test meter while the wiring harness is flexed about.

While it is not widespread, this entire problem could have been prevented if the cable harness had exited the socket body towards the front of the machine, where such a tight bend would not have been necessary. The use of cable ties so close to the bend exacerbates the situation.

If you have the necessary time, ability and equipment, it is possible to remove the damaged wiring and replace the socket by one with a forward-facing cable outlet.

For most owners, however, replacement is the best policy as a failure in this area can be both inconvenient and potentially dangerous. The injection system employs its own wiring harness, so wholesale replacement of the wiring system is not required, but an investment of about £170 is!

If you have not experienced this problem, remove the cable ties for at least six inches below the control unit, and ensure that the wiring harness is not subjected to tight bends, or excessive movement when the control unit is disconnected prior to annually checking the battery levels.

It has been known for the throttle switch to stick in the 'throttle closed' position, usually due to the entry of water. In such cases it will dutifully inhibit injection at any attempt to exceed about 50 mph. This can easily be checked by simply unplugging the switch, so disabling the fuel shut-off and full-throttle enrichment facilities. Although not recommended for the faint-hearted, it is possible to open the switch with nothing more than a breadknife and a screwdriver, to clean the full-load contacts and the idle microswitch plunger. The microswitch can be replaced.

Another odd problem concerns the fuel tank base plate, through which the supply for the fuel tank passes via insulated connectors. It has been known for the conductors which carry the current through these insulators to become of high resistance. Under these circumstances the pump supply voltage at the base of the tank was satisfactory, but the voltage at the pump was too low to enable it to provide sufficient fuel pressure for full load operation.

In general, always follow a logical fault-finding path, write down what you have done, and if in doubt discuss your work with someone else.

Safety Precautions: Please remember that petrol — particularly modern unleaded types — is dangerous! Do not allow petrol to contaminate your skin or clothes, wear rubber gloves if necessary, and carefully soak up any spillages with a rag which is then disposed of safely — that means away from the place of work. If working inside the fuel tank, always unplug the fuel tank connector (behind the RH side panel) first.

If it is necessary to disconnect any part of the fuel system, such as the fuel tank or pipework, remember that it operates under pressure. Ideally leave the machine standing all night, when any residual pressure will have leaked away. I have never been able to depressurise the system in the manner suggested by Haynes, and so surround the pipe to be disconnected with a suitable rag before carefully removing it, allowing the small amount of excess fuel to soak into it.

Maintenance:

Virtually the only maintenance required is to change the fuel filter at 10-15,000 mile intervals, the air filter when necessary (about 50,000 miles in normal use), examine the pump filter screen from time to time, and check the CO level and idle vacuum levels every year or so.

Fuel Filter: This is easy, but always run down the fuel level first, and **observe all the usual safety precautions** – Remove the fuel filler cap (4 screws) and ensure it and its rubber gasket are replaced in exactly the same position, or the breather/drain pipe can become obstructed. unscrew the internal rubber hose connections to allow the filter to be extracted complete with its associated short section of rubber hose – this will make the job a lot easier. Carefully squeeze the two plastic clips on the pump body, and pull the pump out of its housing to check the filter screen. Take care that the new filter is fitted in the same flow direction as the original, this being signified by an arrow on the filter body.

Air Filter: Remove the RH side panel, and release the spring clips securing the top section of the filter. Lift it a little, and extract the air filter element – if you can! This is usually a lot more difficult than it should be, as the pipe which connects the upper part of the filter housing to the throttle body plenum chamber is quite rigid and is tightly clamped by screw-type clips at each end. The "throttle" end clip must be unscrewed from above, and on all but the very first models access is impeded by a long plastic shield running below the frame tubes. Remove the fuel tank, and carefully mark and drill a 9mm hole through this shield, in line with the clamp's screw, and as close to the centre frame tube as possible. A long screwdriver can then be used to slacken the clip without problem.

Injection Nozzles: Blockage of the filters within the injectors is unknown, but the nozzles can suffer from a build-up of carbon on their tips, so upsetting their spray patterns and combustion characteristics – this problem only seems to result from the use of poor-quality unleaded fuel (such as is found in Greek supermarkets, or the alcohol-mixed brands of the USA) and can be avoided by regular use of a good fuel additive, such as Formula 1, which will reduce carbon deposits throughout the engine. The use of such additives is a good thing under any conditions, as is evidenced by a total of 400,000 miles in my BMWs and Heather's Golf GTIs, during which I have yet to see a carbon deposit worthy of note.

Adjustment:

General: The K-Series seldom, if ever, require adjustment, and any such requirement should be carefully considered. Make sure that you are trying to cure a real problem rather than a symptom of something else.

Idle Screws: The idle by-pass screws should be adjusted to maintain uniform vacuum levels in all throttle bodies, the levels being adjusted to set the usual idle speed of 950 ± 50 rpm on a warm engine.

Increased Idle Speed ('Choke'): This is a simple cable adjustment, to set free play to a minimum. Check the adjustment by measuring the clearance between the throttle stop screw – in the first and second positions of the 'Choke'; this should be 1.5 and 3.5 mm (K75) or 1 mm and 2.5 mm (K100). Check the operation of this control on a cold engine.

Throttle Bank: The Master Throttle is provided with an abutment into which the throttle cable is inserted, and a screw adjuster. This throttle stop screw can be used to collectively alter the position of the throttles, in order to ensure that the throttle switch is operating at the very end of the throttle travel. It may also be used to make small changes in idle speed. Care should be taken not to prevent operation of the throttle switch - if this does not operate at the very end of the throttle travel, backfiring on the overrun will result.

The throttle adjusters are, it is claimed in the popular manuals, impossible to adjust, and any such requirement can only be satisfied by replacement of the entire bank! The story goes that a special 'Mass Air Flow' rig is essential, as indeed it is if the throttle bank is not connected to a working engine, as when it is manufactured. The engine, of course, provides an equal air mass through each throttle body at all speeds.

Individual adjustment is not usually necessary but it can be done, given good vacuum gauges and – most important – a special tool comprising a tubular spanner with a knurled knob at its top, containing a screwdriver which is a snug fit in the adjuster slot. Any multiple adjustment must be made in sequence from the 'master' throttle body, and is certainly a difficult business, due to the general flimsy construction of the adjusters, but it can be done!

CO Adjustment: Remember that most apparent reasons to adjust the CO level are in reality curing the symptoms of induction air leaks, defective spark plugs, or dirty injectors.

The adjuster operates on a by-pass passage across the main airflow path of the air flow sensor, mounted in the upper section of the air filter housing. It is accessed after removing a grommet in the top of the housing, and unless you are extremely fortunate, the fuel tank must first be removed.

As the engine will not run without the fuel tank, it is necessary to manufacture a suitable extension lead and pipe set to mount the fuel tank remotely during this procedure. An old wiring harness will provide the necessary plugs and sockets.

With the engine fully warm (let the fan start and stop) turn the adjuster with a 5mm hex key until a reading of 2 ± 0.5 % is obtained. In the absence of an exhaust gas analyser adjust to obtain an even and reliable idle, with good pick-up and freedom from backfiring on the overrun.

Testing:

The LE system is not a part left over from the Starship Enterprise! It is, indeed, fairly easy to work on, and most faults can be diagnosed by a suitably-informed owner with a little aptitude, good information, normal tools, and some decent but basic test equipment. Almost all the electrical signals associated with it are simple DC voltages, the exceptions being the alternating polarity of the DC voltage from the Hall-Effect triggers (which can be observed on a DC meter at low speeds) and the square wave signal which operates the injector solenoids, for which an oscilloscope is really needed. Measurement of voltages is easily made by carefully puncturing the insulation with a pin, and connecting the test cable to the pin.

No exotic tools are required for the majority of tests which the practical-minded owner may find necessary. A good toolkit, coupled with digital and analogue voltmeters, vacuum gauges, and a fuel pressure gauge are about all that is really required.

It is essential, however, that you become familiar with both the LE system and your BMW, in terms of their layout, operation, and wiring. Do not attempt to cure a problem unless you can be sure of not creating another!

In certain alleged 'Workshop Manuals' such as Clymer, it is claimed that the coolant temperature sensor is merely a 'switch' and that its operation may be tested by simply short-circuiting the two pins of its connector. This will simply join the temperature inputs of the injection system and fan control unit! The correct manner in which to test this unit is by measuring the resistance from the terminal of each sensor element to the body as the temperature is increased. Expect about 1,500 ohms at 0°C, falling to around 120°C at boiling point. Normal operating temperature (90°C) corresponds to 125 ohms.

The fan control unit, incidentally, can be tested by connecting a 115 ohm resistor between earth and the terminal connected to the violet/green wire. This will simulate a temperature for fan operation of just over 103°C. 110 ohms will approximate to 111°C for warning lamp operation.

Specialist Information:

The biggest problem associated with work on this or any similar system is that of obtaining detailed information, as few owner's manuals (eg: Clymer, Haynes etc) give any worthwhile facts on this system. There are, however, no secrets with regard to LE Jetronic, as genuine Bosch manuals can be purchased – at a price – from Delta Press (01442-877794) but a more realistic alternative is to obtain a copy of the Haynes Electrical Manual (ISBN 1 85010 823 4) which contains a wealth of information on this and other electrical systems.