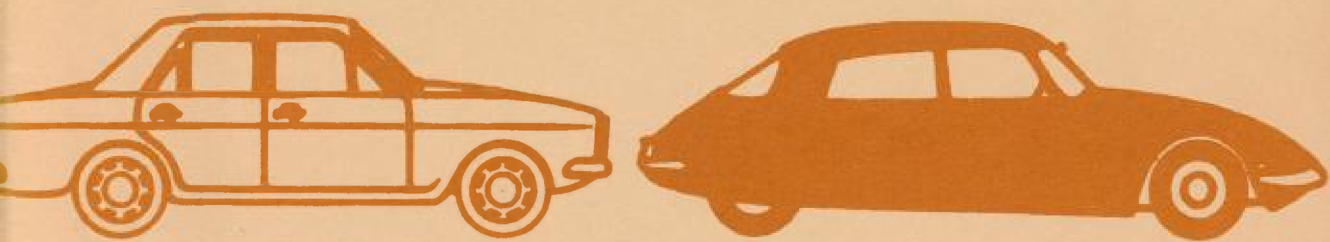
STATE POLLUTION CONTROL COMMISSION

Control of Pollution from Motor Vehicles

PUBLICATION MV-3
Revised March 1980



Issued under the authority of
**The Hon Eric Bedford, B A, M P,
Minister for Planning and Environment**

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ISBN 0 7240 1290 7

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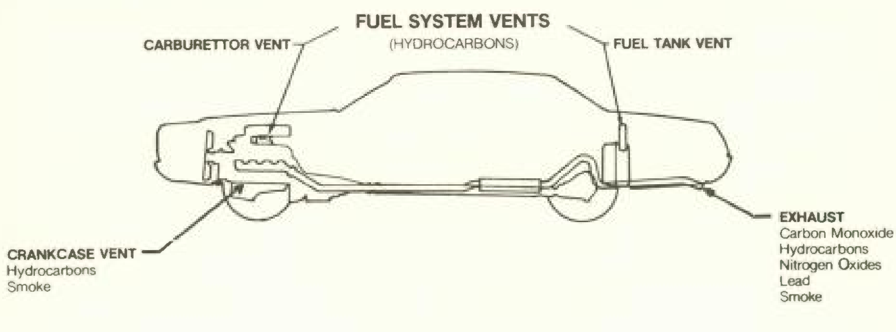
1 Introduction

In recent years the number of motor vehicles has increased sufficiently to make them a major source of air pollution in most large cities of the world. The following notes examine the problem of air pollution from motor vehicles and include discussions on the formation and control of pollutants and the legislative action which has been taken in New South Wales to reduce emissions.

Motor vehicles emit pollutants from the exhaust pipe and from crankcase, fuel-tank and carburettor vents. Approximately 50% of the hydrocarbons from an uncontrolled vehicle are emitted via the exhaust, 20% from the crankcase vent, 10% from the carburettor vent and 20% from the fuel-tank vent. All the carbon monoxide, oxides of

SOURCES OF AIR POLLUTION FROM MOTOR VEHICLES



nitrogen and lead are emitted from the exhaust pipe. Since positive crankcase ventilation (PCV) has been used for a number of years to control crankcase emissions, these notes deal only with exhaust and fuel-system emissions.

2 The Combustion Process

The combustion process is responsible for most of the emissions of pollutants from internal-combustion engines. Fuels such as petrol, diesel oil, liquefied petroleum gas and natural gas are hydrocarbons, ie, compounds containing hydrogen and carbon. When fuel is burned in the combustion chamber, the principal reactants are oxygen and nitrogen from the air and carbon and hydrogen from the fuel. Complete combustion is never achieved in the cylinder, hence exhaust gases contain products of combustion and other compounds that have not been completely burnt. Carbon dioxide, carbon monoxide, oxides of nitrogen, water vapour, carbon particles and unburnt hydrocarbons, as well as fuel additives such as lead compounds, are emitted.

3 The Pollutants

3.1 Photochemical Smog

Although photochemical smog is measured as the concentration of ozone in the atmosphere, it consists of a number of substances, including ozone, nitrogen dioxide, peroxyacetyl nitrate and small particles termed, collectively, oxidants. These substances are formed in the atmosphere as a result of photochemical reactions between hydrocarbons and oxides of nitrogen, both of which are emitted in large volumes from motor vehicles.

Photochemical smog usually occurs on sunny days in the warmer months, when a stationary high pressure system and low early morning wind speeds also occur. The worst smog occurs in the central, southern and western areas of Sydney – an area occupied by more than two million people.

The effects of photochemical smog on plants, materials and visibility are well-established. Loss of crop yield, slowing of growth and death have been observed in certain plant species as a consequence of exposure to smog levels corresponding to ozone concentrations of 10 parts per hundred million (pphm) and above. Certain materials, such as fabrics and rubber, age faster in the presence of smog. Photochemically formed aerosols contribute to haze and cause decreased visibility. On days when smog concentrations are high, reduced visibility and increased glare are very evident.

Ozone, once considered a health-giving substance, is now known to be, at high enough concentrations, a broncho-pulmonary irritant which affects the mucous lining, other lung tissues and respiratory functions. It has been demonstrated in clinical and epidemiological studies that ozone can impair lung functions and cause clinical symptoms such as chest tightness, coughs and wheezing. In sensitive individuals these effects may occur on exposure to short-term ozone concentrations with an estimated threshold range between 15 and 25 pphm.

The amount of evidence emerging on the health effects of photochemical smog has been sufficient to influence the National Health and Medical Research Council to recommend that the one-hour average level of ozone in the atmosphere of Australian cities **not be allowed to exceed 12 pphm more than once per year.**

This is the first medically-based goal for control of ozone set for Australia. It is the same level as the US standard, but exceeds the Japanese standard of 8 pphm and the World Health Organization long-term goal of 6 pphm.

The NH & MRC goal is exceeded in Sydney on about 40 days each year. Sydney's highest ever reading was 38 pphm.

3.2 Hydrocarbons (HC)

Hydrocarbons are compounds consisting of various proportions of hydrogen and carbon. There are over 100 different hydrocarbons commonly present in a polluted atmosphere.

Motor vehicles contribute a little more than half of the 660 tonnes of hydrocarbons emitted daily in Sydney. They can cause injury to sensitive plants, and some are carcinogenic (cancer-causing). Their main effect on air quality, however, arises from their reaction with oxides of nitrogen to form photochemical smog.

3.3 Oxides of Nitrogen (NO_x)

Oxides of nitrogen are emitted from all combustion processes, with motor vehicles contributing about 85% of the 170 tonnes emitted daily in Sydney. These gases not only play an important role in the formation of photochemical smog, but can themselves cause adverse health effects. Nitrogen dioxide (NO_2), which is formed from the oxidation of nitric oxide, is more damaging, but data on its effects at concentrations that occur in the Sydney atmosphere are meagre. The action taken to control oxides of nitrogen will derive from the strategy adopted to control photochemical smog.

3.4 Carbon Monoxide (CO)

Petrol-engined motor vehicles contribute about 95% of the 2 200 tonnes of carbon monoxide emitted daily into the atmosphere of the Sydney region. Carbon monoxide is a toxic gas which, when inhaled, combines some 200 times faster than oxygen with the haemoglobin of the blood, so blocking oxygen transport through the body. There is no conclusive evidence that the intake of carbon monoxide into the blood from exposure to the atmosphere in city streets causes obvious health damage. Nevertheless, on the basis of a number of studies, there is increasing concern that carbon monoxide exposure arising from traffic exhaust fumes may be a factor in heart disease. The low value of the long-term goal of 10 milligrams per cubic metre (8-hour average) recommended by the World Health Organization reflects the concern of health authorities over the effects of exposure to this pollutant. Values in excess of 10 milligrams per cubic metre are recorded frequently in Sydney. The goal was exceeded in the city on 270 days in 1978. The maximum eight-hour average of 62 milligrams per cubic metre in Sydney was recorded in 1975.

3.5 Smoke and Odour

Smoke and odour emissions from motor vehicles, particularly those with diesel engines, cause discomfort to many people. Smoke emissions generally have been associated with respiratory effects in sensitive people, particularly when the smoke is accompanied by other gaseous pollutants. Carcinogenic compounds are contained in exhaust smoke, particularly that from diesel vehicles. Odorous emissions from diesel vehicles are objectionable, and complaints of nausea so caused are frequently made. As with many odorous substances, the precise compounds involved are difficult to identify. Nevertheless, detailed scientific and medical knowledge of the causes and effects of odorous emissions is not required before steps towards control are commenced. Their objectionable nature makes the need obvious.

3.6 Lead

Lead is a cumulative poison which, when inhaled or ingested in sufficient amounts, can cause severe health damage and even death. Approximately one million kilograms of lead is emitted into the Sydney atmosphere from motor vehicles each year. Its effects on children are of particular concern since their developing nervous systems are more easily damaged than those of adults, making them more susceptible to the toxic effects of lead. Apart from inhaling the air-borne lead, young children ingest significant quantities as a result of having their hands and toys contaminated by the lead in urban dust, transferring this to their mouths.

The National Health and Medical Research Council has taken a firm position by recommending that the three-monthly average levels of lead in the ambient air of Australian cities **not be allowed to exceed 1.5 micrograms per cubic metre of air.** The Council also has set a concentration of 30 micrograms of lead per 100 millilitres of blood as being a level of concern.

These conclusions of the National Health and Medical Research Council give rise to concern when it is known that the recommended maximum level of 1.5 micrograms per cubic metre is exceeded at all of Sydney's city and suburban monitoring stations, and that values more than double this are recorded in the city. Also, researchers at the University of New South Wales have found that up to 22% of children tested by them in some parts of Sydney had blood levels in excess of the level of concern – 30 micrograms per 100 millilitres of blood.

Most developed countries have introduced restrictions on the lead content of petrol. The United States, Canada and Japan are well advanced in programmes to totally eliminate lead from petrol.

The maximum allowable lead content of petrol sold in Sydney, Wollongong and Newcastle has dropped from an original oil industry standard of 0.84 gram per litre in 1974 to a legal limit of 0.4 gram per litre in 1980.

4 Legislation

The Clean Air Act provides for the control of emissions from motor vehicles. The Act prohibits the sale or use of any motor vehicle that emits air impurities in excess of the prescribed standards. It also prohibits the sale or use of a motor vehicle not fitted with the prescribed anti-pollution devices, and requires that such devices be properly maintained.

The Act empowers the Minister to issue orders prohibiting the use of motor vehicles in any area and at any time he considers necessary. Regulations may be made under the Act dealing with with operation, inspection and testing of motor vehicles, and with the fuels used in their operation.

Several regulations have been made to deal with particular problems that arise from vehicles. They require the control of smoke emissions from all types of vehicles and the control of carbon monoxide, hydrocarbons and oxides of nitrogen from new petrol-powered vehicles. A vertical exhaust pipe, three metres in height, is required on most new heavy-duty diesel vehicles to reduce odour at ground level.

The more important regulations are summarized below:

- All vehicles are required to be so adjusted and maintained that they do not emit smoke which is visible for continuous periods of more than ten seconds.
- All new motor vehicles, including motor cycles, are required to be adjusted so that the concentration of carbon monoxide during idling is less than 4.5%.
- All new petrol-fuelled motor vehicles, other than motor cycles, are required to be fitted with a device which limits the emission of hydrocarbon vapours from the carburettor and petrol tank vents.
- Most new diesel-fuelled trucks and buses are required to be fitted with a vertical exhaust pipe at least 3 metres high. Vehicles fitted with very low emission engines are exempted.
- New passenger cars and derivatives manufactured after 1 July 1976 have been required to be designed and manufactured so that the emissions of carbon monoxide, hydrocarbons and oxides of nitrogen do not exceed the following limits:

Carbon Monoxide	24.2 grams per kilometre
Hydrocarbons	2.1 grams per kilometre
Oxides of Nitrogen	1.9 grams per kilometre

  The above requirement also has applied to new petrol-powered light commercial vehicles manufactured since 1 January 1977.

  When comparing "in-service" vehicles manufactured before 1974 with "in-service" vehicles manufactured to the above requirements, reductions of 44% in carbon monoxide emissions, 42% in hydrocarbon emissions and 35% in oxides of nitrogen emissions were achieved.

From 1 January 1981, new passenger cars and derivatives will be required to meet the following limits:

Carbon Monoxide	18.6 grams per kilometre
Hydrocarbons	1.75 grams per kilometre
Oxides of Nitrogen	1.9 grams per kilometre

- From 1 January 1975, the lead content of petrol sold in Sydney, Newcastle and Wollongong was limited to 0.64 gram per litre. From 1 January 1977 the limit was reduced to 0.45 gram per litre, and from 1 January 1980 to 0.4 gram per litre.

5 Test Procedures

5.1 Lidcombe Laboratory

The earlier regulations were written around relatively simple test procedures such as the measurement of carbon monoxide at idle. Later regulations, which aim to bring about much greater reductions in emissions, have more complex test procedures. The reason is that large amounts of pollutants are emitted in modes other than idle, and the emission rate of a pollutant at idle might give no indication at all of its emission rate during acceleration, cruise or deceleration.

Briefly described below are the test procedures used. Detailed descriptions may be found in the legislation. The New South Wales State Pollution Control Commission has a laboratory at Lidcombe fitted with the necessary equipment to follow these procedures. When commissioned, this testing facility was the first such laboratory operated by a government instrumentality in Australia.

5.2 Regulation 22(1)(c) and (d)

The purpose of this test is to measure the emissions of carbon monoxide while the vehicle is idling. Before the test, the sump-oil temperature of the vehicle must be greater than 60°C or the engine must have been running continuously for more than 13 minutes. The sample line from a non-dispersive infra-red carbon monoxide analyzer is inserted into the exhaust pipe (or pipes) and the concentration of CO monitored for at least 30 seconds.

5.3 Regulation 22(1)(f)

The purpose of this test is to measure the rates of emission of carbon monoxide, hydrocarbons and oxides of nitrogen during typical city driving conditions. To determine compliance with this regulation, the vehicle under test is driven on a chassis dynamometer. Vehicle inertia is simulated by means of rotating weights connected to the dynamometer rolls. Road friction and wind resistance are simulated by using a power absorption unit fitted to the rolls. Before each test the inertia weights and load absorption unit are set according to the mass of the vehicle to be tested.

A chart recorder (usually called a driver's aid) continuously determines vehicle speed. This enables the driver to follow the speed-time trace, or driving cycle, specified in the regulations and printed on the chart. As the chart moves through the recorder, the driver uses the accelerator and brake to ensure the vehicle is travelling at the prescribed speed.

The driving cycle is 23 minutes long and covers a wide range of speeds and acceleration and deceleration rates. It is claimed to closely simulate peak-hour driving conditions in large United States cities. Studies have shown that for practical purposes the cycle is representative of Sydney driving conditions.

A constant-volume sampler (CVS) is used to mix clean air with the exhaust gases by means of a constant-displacement blower. This dilutes the gases and reduces condensation and rates of reactions between the various compounds present. A small proportion of dilute exhaust gases is collected in a bag and analyzed at the end of the test for CO, HC and NO_x concentrations. The cycle and analytical system are shown in Figs 1(a) and 1(b).

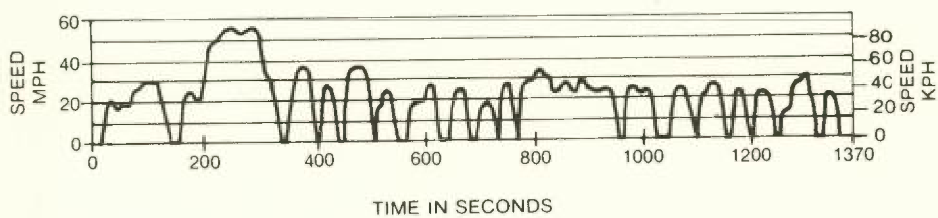


Figure 1a

DRIVING SCHEDULE FOR REGULATION 22(1)(f)

The final result, expressed in grams per kilometre, is calculated using the total volume of dilute exhaust gases displaced during the test, the concentrations of pollutants in the bag and the distance covered during the driving cycle.

5.4 Regulation 24

This test is used to determine the quantity of evaporative emissions. The vehicle is preconditioned by driving it at least 25 kilometres either on the road or on a chassis dynamometer, and then driving it on a chassis dynamometer over the driving cycle specified in Regulation 22(1)(f).

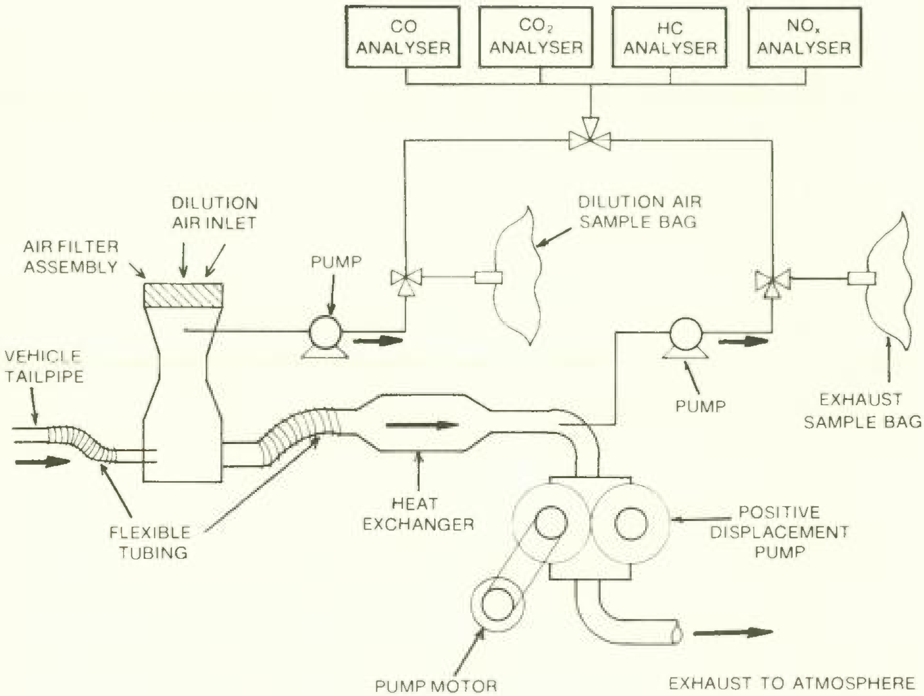


Figure 1b

ANALYTICAL SYSTEM FOR REGULATION 22(1)(f)

The vehicle then stands for about 12 hours at between 20°C and 30°C. The fuel tank is drained and test fuel, at approximately 15°C, is added to the fuel tank until it is filled to 40% of its capacity.

Canisters of known weight are connected to all external fuel-tank vents, carburettor float-bowl vents and the air-cleaner inlet. These canisters contain activated charcoal that absorbs hydrocarbon vapours.

The fuel in the tank is heated (by an electric blanket or infra-red lamps) to approximately 29°C over a period of one hour. Any vapour emitted is trapped in the canisters. The car is driven over a 22(1)(f) cycle, and allowed to stand for another hour before the vapour-collection canisters are removed. The canisters are weighed again, and the mass of hydrocarbons emitted is calculated by comparing the test weights of the collection canisters before and after.

6 The Formation of CO, HC and NO_x

6.1 Carbon Monoxide (CO)

The concentration of CO in the exhaust gas is dependent upon the air-fuel ratio. A rich mixture gives high CO and a lean mixture gives lower CO.

6.2 Hydrocarbons (HC)

Hydrocarbon emissions are in fact emissions of unburned fuel; therefore, any cause of incomplete burning in the cylinder causes HC emissions.

Incomplete burning is caused by two factors. The first and most important is inability of the flame to penetrate right to the cylinder walls. Hence fuel in this thin quench zone is not burnt. The second and more obvious factor is poor combustion, caused by a weak or mistimed spark, an excessively rich or lean mixture, etc. As previously mentioned, hydrocarbons are also emitted when petrol vapour escapes from fuel-tank breathers, carburettor float-bowl vents and crankcase breathers.

6.3 Oxides of Nitrogen (NO_x)

Oxides of nitrogen are formed during the combustion process. The amount formed increases sharply with higher temperatures. Oxygen available after combustion increases the rate of NO_x formation, hence NO_x levels are also a function of the air-fuel ratio. In addition, spark timing, which affects combustion temperatures, has an important effect on NO_x levels.

7 Methods of Reducing Emissions

Figure 2 shows typical emissions for various air-fuel ratios from a car cruising at approximately 100 km per hour. The figure highlights the problem faced in designing engines to reduce

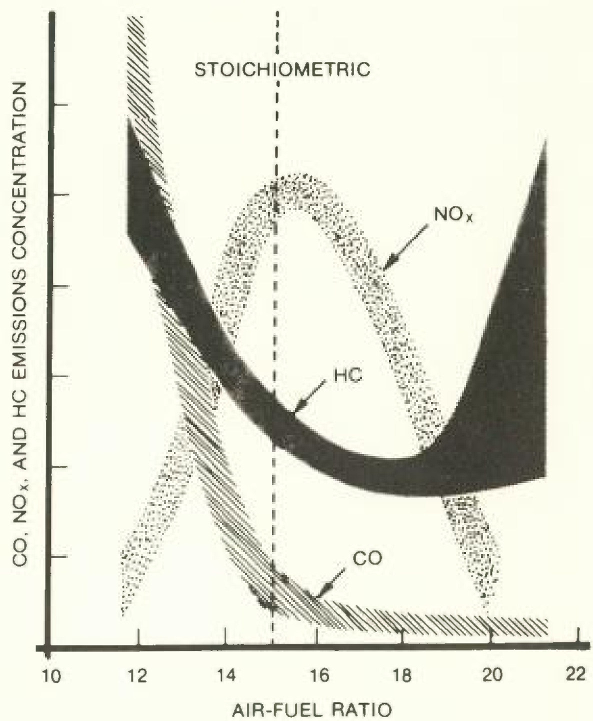


Figure 2

EFFECTS OF AIR-FUEL RATIO ON EXHAUST COMPOSITION

emissions. A change which reduces the emissions of one pollutant often increases the emissions of one or more of the others.

7.1 Lean Mixture

Reference to Fig 2 shows that CO and HC emissions are low at air-fuel ratios around 15-17:1 because ample air is available for oxidation and the quantity of hydrocarbons caught in the quench zone are at a minimum. NO_x emissions, however, are near maximum under these conditions. A relatively "lean" mixture can also lead to problems such as rough idle, overheating, misfire, running on and poor starting. In order to maintain good driveability, many design criteria need to be changed before an engine can operate on lean mixtures.

Improved design, closer manufacturing tolerances and accurate adjustments are necessary for any components which affect combustion in the cylinders, viz carburettor or injection system; inlet manifold; combustion chambers; cam profile and valve timing; all ignition components. Small light vehicles are able to meet the emission limit of Regulation 22(1)(f) with little more than these improvements, which allow the engine to operate on "lean" mixtures. The heavier the vehicle, and the bigger its engine, the more likely it is to need other control devices to meet the HC and NO_x limits.

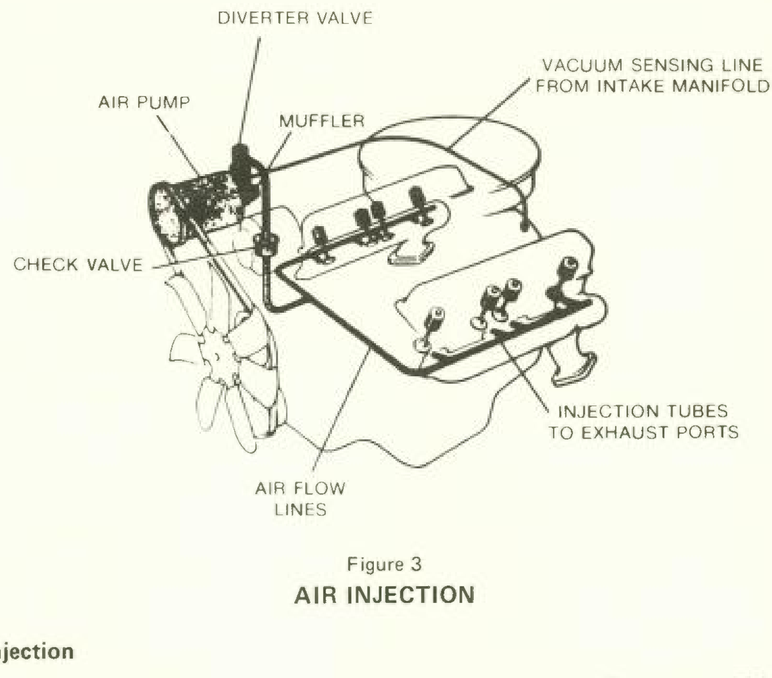


Figure 3
AIR INJECTION

7.2 Air Injection

Air injection is a control technique used on some engines to meet Regulation 22(1)(f). Air is injected into the exhaust system (as close as possible to the exhaust valve) by means of a pump, usually belt-driven, and a manifold (see Fig 3).

The exhaust gases are still hot enough to burn when they leave the combustion chamber and the introduction of additional air enables oxidation to continue in the exhaust pipe. Emissions of HC and to a lesser extent CO can be reduced by this method. Two valves are usually incorporated in the system; a one-way valve to prevent reversal of flow and a diverter valve which prevents air injection during deceleration.

7.3 Exhaust-Manifold Reactors

The use of air injection with a conventional exhaust manifold may not achieve the desired results on some engines, as heat losses through the manifold may cool the exhaust gas to a temperature at which oxidation does not occur readily. Exhaust-manifold reactors are an extension of the air-injection system. Exhaust gas is passed through a thermally insulated chamber where a high temperature is maintained and the gas is mixed more effectively with injected air, so enhancing conditions for oxidation.

7.4 Ignition Timing

An ignition-timing curve which provides best power and driveability is not always the best curve for low emissions.

The means by which manufacturers achieve the best ignition timing for low emissions and acceptable engine operation vary and usually depend on the extent of control needed and the other control devices used on the engine. The desired overall timing curve is obtained by using combinations of centrifugal advance, vacuum advance and/or vacuum retard.

7.5 Vacuum Retard Capsule

This is used to retard timing when the engine is idling. The capsule is connected to a point below the throttle butterfly, and usually incorporates a delay device so that the capsule does not operate during deceleration. The system can also incorporate a device which renders the capsule inoperative if the engine overheats during prolonged idling. A retard capsule can be used separately or in conjunction with a vacuum advance capsule.

7.6 Deceleration Controls

During deceleration a very rich mixture is supplied to the combustion chamber because all the fuel lining the inlet manifold vaporises under high vacuum conditions. The enriched mixture causes increased hydrocarbons. Some air-injection systems are made to be inoperative during these conditions to avoid explosions in the exhaust pipe. Other systems are used to reduce excessive hydrocarbon emissions. Basically, these systems limit the vacuum in the inlet manifold and add more air by keeping the throttle butterfly valve open slightly more than normal for an idle position or by using a vacuum-limiting valve which opens at high manifold vacuum.

7.7 Exhaust Gas Recirculation (EGR)

An effective means of reducing oxides of nitrogen levels is exhaust gas recirculation (EGR) (see Fig 4). EGR causes exhaust gas to be introduced into the combustion chamber, so reducing the peak combustion temperature. Normally, no exhaust gas is recirculated at idle or during deceleration, and the amount recirculated under other driving conditions is controlled by a valve sensitive to airflow rate through the carburettor, or some other indicator of engine-operating conditions.

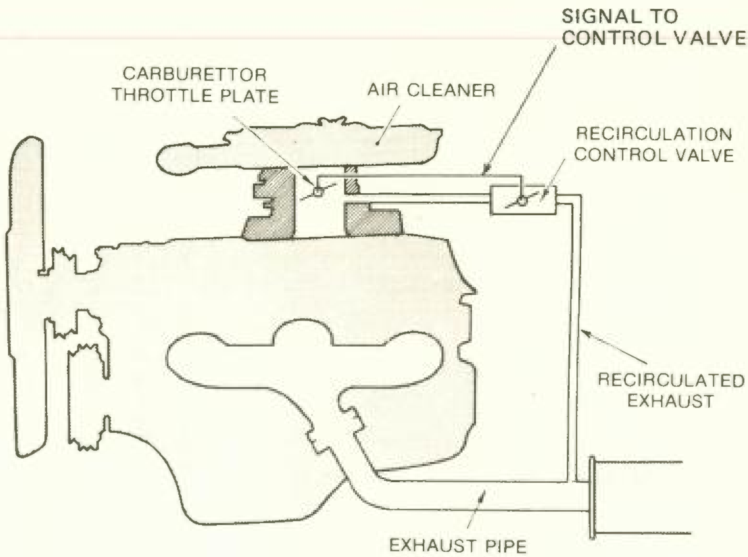


Figure 4
EXHAUST GAS RECIRCULATION (EGR)

7.8 Air Temperature Control (ATC)

To meet legislated limits on emissions, choke times need to be of shorter duration than they are on uncontrolled vehicles. Air-temperature control (Fig 5) improves cold-engine driveability and therefore affords a reduction in choke operating time by supplying warmed intake air from the exhaust manifold when the engine is cold. Some form of ATC or heated-inlet manifold is necessary on many cars to meet the limits imposed by Regulation 22(1)(f).

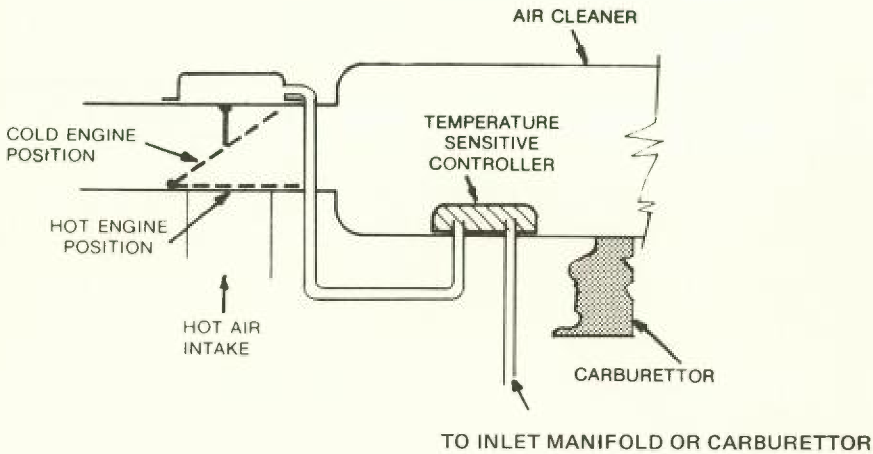


Figure 5

AIR TEMPERATURE CONTROL (ATC)

7.9 Exhaust Catalytic Converters

By definition, a catalyst accelerates a chemical reaction while itself remaining unchanged. An oxidizing catalyst promotes the oxidation of hydrocarbons and carbon monoxide, while a reducing catalyst converts oxides of nitrogen to nitrogen and oxygen. Catalytic converters are canister-like containers fitted in the exhaust system of vehicles, similar to the exhaust silencer but smaller. The catalyst is mounted in the converter assembly and the exhaust gases react over the catalyst, forming harmless products.

Catalytic converters are now widely used in the United States, Canada and Japan in order to meet stringent emission standards whilst providing improved fuel consumption and driveability. Vehicles fitted with catalytic converters require lead-free petrol which at present is not available in Australia. When petrol containing lead is burned, the exhaust gases contain lead compounds some of which are deposited on the catalyst. This process, termed catalyst "poisoning" causes rapid deterioration in the performance of the catalyst. Under normal operating conditions with the correct fuel, catalysts have been proven to be an effective emission-control technique. Very low emissions can be achieved whilst maintaining vehicle performance and driveability to a high standard.

7.10 Stratified-Charge Engines

Stratified-charge engines have been developed in an attempt to prevent the formation of pollutants in the combustion chamber rather than rely on devices such as air injection or catalysts to reduce emissions after they have formed.

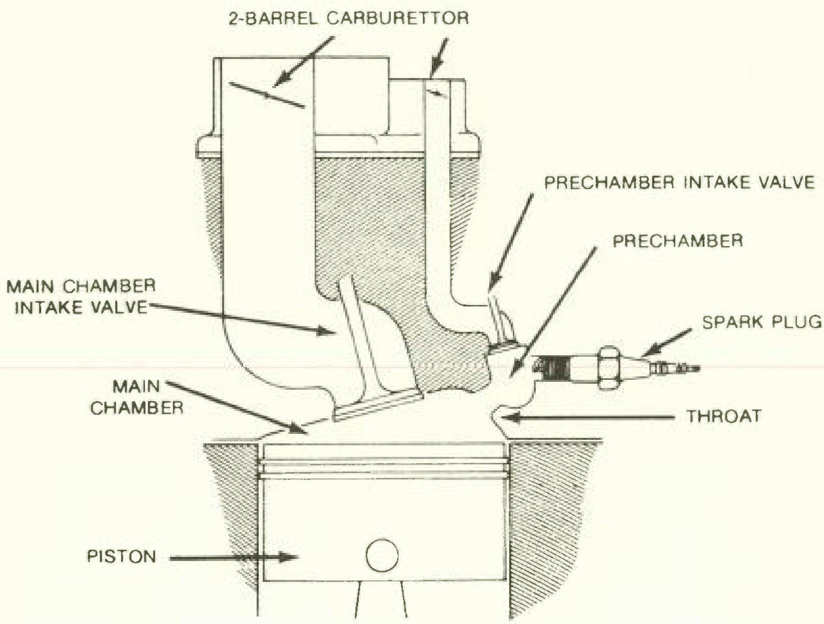


Figure 6
STRATIFIED CHARGE ENGINE

There are several types at various stages of development, but each has in common the principle of operating at very lean air-fuel ratios. Provided there is no misfire, hydrocarbons, CO and NO_x are all low. As already discussed, operation at even moderately lean mixtures causes problems with conventional engines, mainly in relation to ignition. Stratified-charge engines attempt to overcome this difficulty by having a small amount of rich mixture adjacent to the spark plug and a large amount of very lean mixture in the remainder of the cylinder. The rich mixture ignites easily and, once alight, acts as a powerful ignition source for the very lean mixture. The major difficulty is designing a combustion chamber and air-fuel charging system that stratifies the mixture in the required manner.

One such engine manufactured by Honda has its combustion chamber divided physically into two sections as shown in Fig 6. In fact, there are really two combustion chambers per cylinder and two carburettors.

One carburettor supplies a small volume of rich mixture to the pre-chamber in which the spark plug is located, while the other supplies the bulk of the mixture (very lean) to the main, conventional chamber. Note that each chamber has its own inlet valve, so that stratification is simply and surely achieved. There are other features which make the Honda engine an inherently low emitter. They involve turbulence produced in the main chamber by the appropriate placing and sizing of the passage joining the two chambers. The engine is known as the CVCC – compound vortex controlled combustion. It is being further developed in both Japan and the United States, but is already being marketed in these countries.

Other manufacturers are developing engines using the stratified-charge principle, and some are already in production overseas. It is possible that stratified-charge engines will be introduced into Australia. They are not prohibitively expensive and they run on conventional fuel. Quite low emissions can be achieved without affecting fuel economy, performance or driveability.

7.11 Evaporative-Loss Control (ELC)

About 30% of hydrocarbons emitted from uncontrolled petrol-fuelled vehicles are evaporation losses from the fuel tank and carburettor. There are two types of evaporative-loss-control systems but both perform the same basic function, ie, petrol vapour (HC), which would normally escape through vents to the atmosphere, is stored in a container when the engine is stopped. When the engine is operating, this vapour is drawn through the air inlet system and burnt in the combustion chamber.

The most commonly used storage system consists of a canister packed with activated charcoal granules.

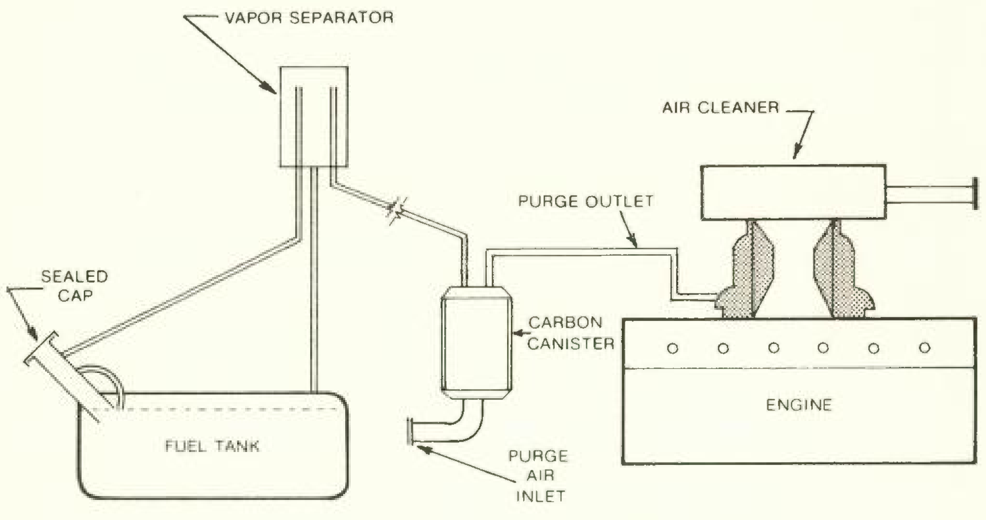


Figure 7

TYPICAL EVAPORATIVE LOSS CONTROL SYSTEM (ELC)

The fuel-tank breather pipe and any other vents likely to emit HC (eg, carburettor float-bowl vent) are connected to the top of the canister. Petrol vapour clings to the surface of carbon granules but is readily removed by a flow of clean air. A purge line connects the canister to the engine so that any vapour sucked through the purge line will in turn be drawn into the induction system and burned. The other end of the canister is open to the atmosphere, and the charcoal granules are located so that air can pass through the carbon and into the inlet system of the engine, thus purging the canister of HC when the engine is running. A typical system is shown in Fig 7.

Some manufacturers use *crankcase storage* as an alternative to a carbon canister. The crankcase volume is large enough to accommodate vapour which is emitted from the fuel tank. When the engine is running, the crankcase is purged by conventional positive crankcase ventilation.

Vehicles equipped with ELC have specially designed fuel tanks. There are no vents directly to atmosphere and, when air expands in the tank, or as the fuel level changes, the tank "breathes" through the canister or crankcase line.

In the interests of safety and correct system operation, liquid fuel must not reach the canister or crankcase via the vent line, and various systems are used to prevent this.

7.12 Alternative Fuels

Almost any conventional motor vehicle may be converted to gas fuel operation with a resultant lowering of emissions. The most common conversion is to liquefied petroleum gas (LGP) although compressed natural gas (CNG) may also be used.

Typically a 90% reduction in CO and a 40% reduction in HC (from that of petrol operation) is achieved when the system is tuned correctly.

Since these fuels are in a gaseous state when entering the carburettor they are more uniformly mixed with the air than petrol, thus allowing the engine to run on much leaner mixtures. The distribution to the cylinders is more uniform and the combustion is more complete.

The conversion kit, which must be fitted only by qualified installers, consists of a pressure tank (usually fitted in the boot of the car), gas pressure regulator, mixer and carburettor adaptor, together with appropriate plumbing.

Using LPG or CNG in high-mileage city fleet vehicles not only helps to reduce pollution in areas where the levels are already high, but has the added advantage of utilizing alternative energy sources and extending the range of crude oil supplies.

8 Servicing Emission-Controlled Motor Vehicles

Highly-trained service personnel are playing an ever-increasing role in the reduction of emissions from motor vehicles. New cars offered for sale in New South Wales must meet emission limits specified by law, but after only a few thousand kilometres emissions can deteriorate. Only properly trained service personnel are able to identify and rectify any problems.

New service techniques are being taught in an effort to reduce air pollution, and new priorities need to be established in motor-vehicle servicing. For example, because diesel engines develop more power when they are slightly over-fuelled, the great majority of diesel servicemen have, in the past, adjusted the fuel delivery accordingly. However, the darker smoke emitted by over-fuelled engines is unacceptable to the public and contravenes Regulation 22(1)(b). Clean exhausts must now take priority over extra power.

Another example is the widespread practice of enriching the idle mixture in petrol-fuelled engines to hide what are, in some cases, serious defects in the ignition system. Some mechanics still enrich mixtures simply because they believe that the exhaust valves will burn out if they don't. This may be true for some uncontrolled vehicles (although there are very few cars which will not operate successfully at around 3% CO provided the engine is reasonably tuned), but it is certainly not true of emission-controlled vehicles. Similarly, some service personnel pay no attention to the condition of the PCV valve which , when inoperative, can increase emissions.

8.1 Effects of Engine Tune on Emissions

At the present time, precise engine tuning is the most effective means by which service personnel can reduce emissions. For cars manufactured after 1 July, 1976, the regular servicing and maintenance of emission-control equipment is essential, but engine tuning still plays a major role.

The most important aspect of engine tuning is to adhere strictly to manufacturers' specifications. Experienced engineers and technicians spend hundreds of hours at the drawing board, making calculations, performing engine-dynamometer tests, emission tests and road tests, to obtain the optimum values for parameters such as ignition-timing curves, spark-plug gaps, etc. Yet there are mechanics who decide, on the basis of one drive around the block, that the manufacturers' specifications are incorrect.

8.1.1 The Secondary Ignition Circuit

A rich mixture can mask faults in an ignition system. For example, a rich mixture will sometimes cure an ignition breakdown and consequent misfire under load. Ignition systems break down more easily when mixtures are lean, as in emission-controlled engines, but mixture strength must not be increased to compensate.

Spark plugs, HT leads, coils, etc, must be in good condition to ensure proper burning of the mixture. Misfire through ignition breakdown causes a sharp increase in HC emissions and must be corrected. Misfire on one cylinder sometimes goes unnoticed in V8 engines, but HC emissions increase many times.

8.1.2 Ignition Timing

Ignition-timing curves are complex for most emission-controlled engines, and the components used to obtain such curves may also be complex. Some distributors have a vacuum-retard capsule with mechanical advance and no vacuum advance. Others use vacuum advance, vacuum-retard and mechanical advance. To further complicate matters in some control systems, changes in engine temperatures, manifold vacuum, and even the gear ratio selected, cause changes in the ignition timing. For example, vacuum-retard capsules usually retard timing to TDC or even ATDC at idle. But if the engine idles for a long period and begins to overheat, a thermostatically-controlled system renders the vacuum-retard capsule inoperative, and advances timing to prevent overheating. If the throttle is closed at high engine speed, the vacuum retard is overridden and the timing advanced to reduce HC and CO formation during deceleration. These examples should show the necessity for using workshop manuals when servicing emission-controlled cars. Manufacturers include descriptions of their own control systems, and lay down a procedure by which ignition timing should be adjusted.

8.1.3 Primary Ignition Circuit

Out-of-phase or worn distributor cam lobes, incorrect dwell adjustment, dirty or pitted points, etc, have a greater effect on the operation of engines that use lean mixtures, causing misfire and, consequently, excessive HC emissions. It is therefore essential that such components be serviced and adjusted correctly.

8.1.4 The Air-Intake System

(a) Air-Temperature Control (ATC)

Almost all emission-controlled engines will have some form of ATC to provide smooth running at low temperature and on lean mixtures.

The air cleaner usually has two intake systems. One draws hot air from around the exhaust manifold, and the other draws cold (ambient) air from the conventional position (Fig 5). A flap directs air from the hot system when the engine is cold, and closes the hot air intake when the engine is hot. If an engine is operating under heavy load, hot intake air can cause an excessively rich mixture, loss of power and high fuel consumption, even when the engine is cold. To overcome this problem, some manufacturers use overriding devices which cause the flap to direct cool air to the engine when manifold vacuum is low, regardless of engine temperature. This control usually incorporates a timing device which delays response of the flap. This prevents stalling if the accelerator is depressed suddenly while the engine is cold.

All components of ATC must be maintained according to manufacturers' recommendations. Faults in the system can cause excessive emissions of HC and CO, high fuel consumption, stalling, rough idle, poor driveability and loss of power.

(b) Air Cleaner

Partially blocked air cleaners cause excessive CO emissions and may increase HC emissions. These increases will occur before any fault becomes obvious in engine operation, and the only safe guideline to use is that of replacement when doubtful.

(c) Inlet Manifold

Air leaks in the inlet manifold, carburettor base, etc, can cause excessive emissions of HC and NO_x, even though the leaks may be small enough to remain undetected using normal diagnostic methods. Good engineering practice will keep leaks to a minimum. Service personnel should replace gaskets every time they are disturbed, face contacting surfaces if necessary, clean surfaces thoroughly, and torque bolts or nuts to manufacturers' specifications and sequence.

Where PCV is connected below the throttle butterfly, air leaks in any part of the crankcase system (tappet cover, oil-filler cap, dipstick hole, sump, etc) will affect engine operation.

Leaks must also be avoided in any component which is connected "down-stream" of the throttle butterfly, eg, brake booster, emission-control equipment, vacuum gauge.

8.1.5 Carburettor

The carburettor is the engine component on which low emissions and good driveability depend most. Service and adjustments must be carried out precisely to manufacturers' specifications, and no adjustments should be made without reference to the appropriate workshop manual.

(a) Mixture

Many service establishments are not equipped to adjust idle mixture correctly, and a number of manufacturers seal the idle-mixture adjustments to prevent "tampering". Mixture adjustments should not be made unless the operation can be performed with a modern carbon-monoxide analyzer and an operator who understands how to use it. Analyzers operating on the non-dispersive infra-red principle have been found to be the most suitable.

(b) Float Level

Precise metering is essential for the correct operation of emission-controlled engines. The level of fuel in the float bowl affects metering. If the float level is not as specified by the manufacturer, emissions of CO, HC or NO_x may increase, and driveability and fuel consumption may be affected.

(c) Choke

To meet low-emission requirements, automatic chokes are designed to provide the optimum enrichment during the warm-up period. Automatic chokes are pre-set under controlled factory conditions and should not need attention in service beyond ensuring free operation of the butterfly and correct operation of the fast-idle and choke vacuum-kick mechanisms. If cold engine operation is unacceptable, all other relevant factors should be checked before the choke duration is adjusted. Adjustment of choke vacuum-kick, fast-idle cam, etc, is more critical on modern carburettors to ensure correct cold operation of the engine. Faults in the ATC system, incorrect ignition timing, air leaks in the crankcase or inlet manifold, low float level and faulty cooling-system thermostat are examples of factors which could affect cold driveability.

(d) Throttle Linkage and Speed Adjustments

Emission-controlled carburettors usually have controls on the throttle linkage. Types of control are many and varied, but they all perform the same basic functions.

Their purpose is to reduce CO and HC during deceleration and at idle by keeping the throttle butterfly slightly open.

Some type of anti-run-on device is often used on carburettors with high idle speeds. An example is a solenoid which is engaged while the ignition is turned on, keeping the throttle butterfly open and idle speed high. When ignition is turned off, the solenoid allows the butterfly to close, thus preventing engine run-on.

Adjustment of hot idle, cold idle, solenoid travel, etc, is very important. Maladjustment can increase CO and HC emissions, make the car difficult to drive and decrease engine braking.

Repairs or adjustments should not be made without reference to the appropriate workshop manual.

(e) Throttle Butterfly Decel Valve

A decel valve in the throttle butterfly is an alternative to devices which keep the butterfly open.

The valve opens, against spring tension, in the direction of air flow through the carburettor. Spring tension is adjusted so that the valve opens when manifold vacuum reaches the levels experienced during deceleration (eg, 550 mm Hg), thus limiting the vacuum and allowing more air to enter the combustion chamber and burn the excess fuel more effectively.

If the valve leaks when sealed, or if spring tension is too low, erratic idle speeds will result. If the valve fails to open correctly, emission of CO and HC will increase. Adjustment in service should not be required, and most manufacturers will probably recommend replacement of the throttle butterfly assembly if the valve does not operate correctly.

8.1.6 Gaskets and Cylinder-Head Valves

Because the head and valve gear on internal-combustion engines influence the gas flow, combustion, etc, they also influence exhaust emissions.

Any defect which causes rough running or misfire increases HC and CO emissions. Examples are a leaking head gasket and a poor valve-seat seal.

When the surface of heads or blocks is ground, the depth removed should be the minimum required to correct the warp. Any increase in compression pressure will lead to an increase in emissions of NO_x.

Valves and seats should be carefully lapped to ensure proper sealing. After valve-spring assembly, the seal should be tested by ensuring that a low-viscosity fluid (such as petrol) will not pass from port to combustion chamber when the valves are closed.

Valve guides and valve-stem oil seals should allow no excess oil to enter the combustion chamber. Oil entry to the combustion chamber via rings or valve-stem seals increases HC emissions.

Correct valve clearance adjustment is very important. Incorrect adjustment, or adjustment outside manufacturers' specifications, may substantially affect emissions. Insufficient clearance can cause CO and HC emissions at idle, and excessive clearance can lead to an increase in NO_x emissions at medium cruise speeds. Manufacturers' procedures and specifications should be adhered to.

8.1.7 Evaporative Loss Control (ELC)

A well-designed, properly maintained evaporative-loss control system is a very effective means of reducing HC emissions from motor vehicles.

The charcoal canister, where fitted as standard equipment, should be replaced at the time or distance recommended by the manufacturer. If a canister is found to contain liquid fuel, it should be replaced immediately for reasons of safety and reduction of emissions. At the same time, the cause of the fault should be found and corrected.

Liquid fuel could enter the canister through a block in the return line from vapour separator to fuel tank, overfilling of the fuel tank or car-parking at an unusually steep angle.

All pipes and connections should be checked periodically. If the vent line is broken or disconnected, HC emissions increase. If the vent line becomes blocked, the fuel tank cannot breathe and fuel starvation will result.

8.1.8 Miscellaneous

Engine and ELC components are directly related to motor-vehicle pollution, but other components can have an effect.

Almost anything that affects the performance of a vehicle affects emissions, through the volume or changes in composition of the exhaust gas.

For example, binding brakes will require the accelerator to be depressed further to achieve the same speed, the volume of exhaust gas will therefore increase and its composition will change.

Other factors which may seem irrelevant but do, in fact, affect emissions are tyre size, final drive ratio, automatic-transmission adjustments, engine-cooling system and exhaust system. These components should be maintained in good order and not changed from manufacturers' specifications.

9 Conclusion

It cannot be overemphasized that correct maintenance and adjustment procedures are absolutely essential if the improved pollution levels of modern motor vehicles are to be sustained throughout their working lives.

The reduction of harmful emissions to achieve the required standard is the common aim of manufacturers, but the methods by which emissions are reduced vary from one manufacturer to another and even from model to model. Therefore, the use of workshop manuals is imperative for the correct servicing of emission-controlled cars.

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