7.11 Automobile Exhaust Gas Control Measures

7.11.1 Introduction

Among the automobile exhaust gas control measures, those which apply to gasoline fueled vehicles have nearly been perfected technologically. An important issue which still remains to be resolved is that of how to handle the NOx, black smoke and particulate matter which are emitted from diesel powered vehicles.

7.11.2 Measure for gasoline fueled vehicle exhaust gas control

The basic concept on the reduction of exhaust gas from gasoline fueled vehicles focuses on ① the control of pollutants through the improvement of the combustion system, ② the after treatment during emission, and ③ the sealing off of areas open to the atmosphere plus the return of evaporative emission to the intake line. However, in general the measures put out for CO, HC and NOx are conflicting. The measures being taken for the reduction of emissions from gasoline fueled vehicles have become more complex. And more systems require a combination of a variety of reduction methods. Fig.7.11.1 illustrates a system of measures used for the reduction of exhaust gas from gasoline fueled vehicles.

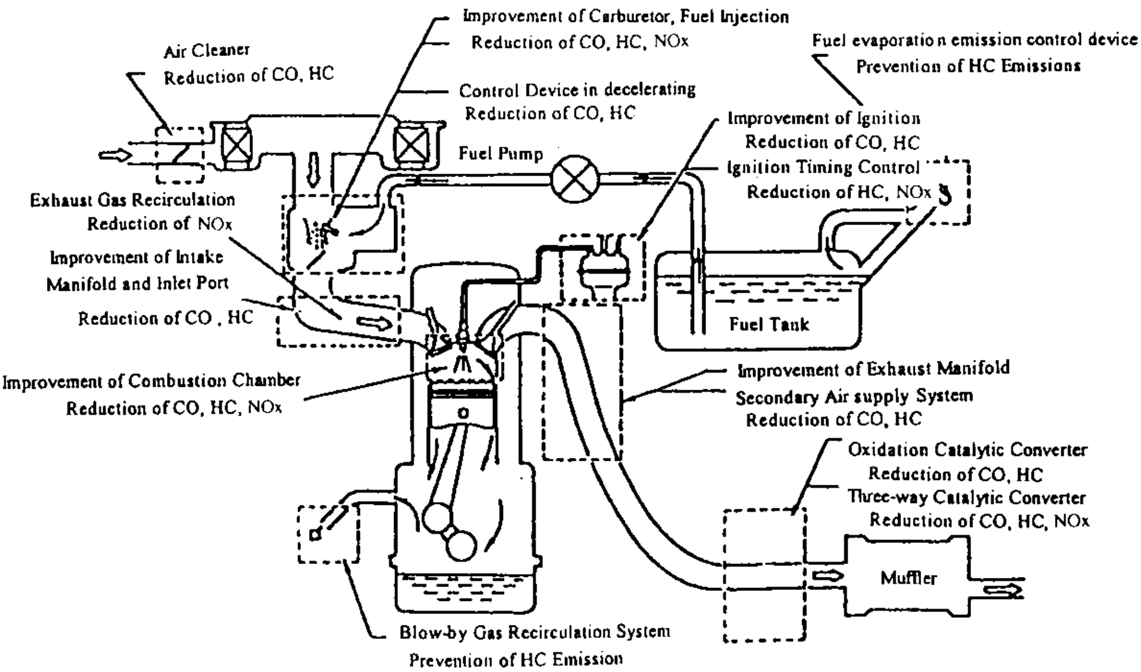


Fig.7.11.1 Example of Gasoline-Fueled Engine Meeting Exhaust Gas Standards

(1) Measures to control pollutants by improving the combustion system

① Ignition timing controlled: In general, by the retard of ignition timing NOx and HC can be reduced. However, if the retard of ignition timing is too far then there are adverse effects to the engine power and fuel efficiency.

Therefore, both driving performance and purification of emissions are controlled compatibly by computer.

② Fuel-cut in decelerating : When decelerating, the throttle valve closes, the amount of air in the combustion chamber lessens and incomplete combustion occurs. In order to prevent this from happening, the amount of fuel is cut at the time of deceleration. The vacuum in decelerating is detected and the throttle valve is forced open. The system then increases the intake air volume.

③ EGR: A part of exhaust gas returned into the intake air and the maximum temperature for combustion is lowered to control the production of NOx. The exhaust gas recirculation is 10% and the amount of NOx emitted is cut in half.

④ Lean burn: In general, CO and HC are heavily emitted when the air fuel ratio is overrich. NOx reaches its maximum concentration once it nears its stoichometric air fuel ratio. Anything less than this level in the air fuel ratio results in a reduction in concentration of emissions. Therefore the air fuel ratio is controlled at around 22-24, controlling the amount of CO, HC, and NOx. A separate measure must be implemented in order to deal with instability in the engine which will occur along with the control of air fuel ratio, in order to obtain compatibility between the reduction in NOx and fuel efficiency.

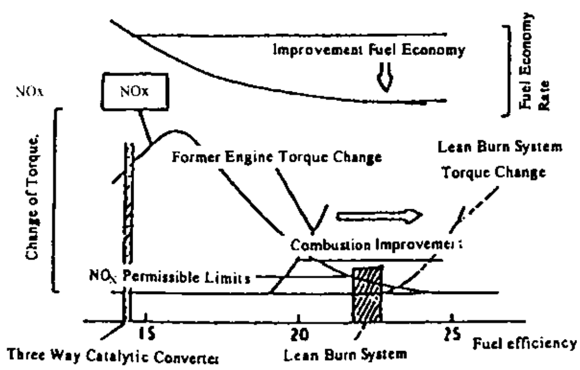
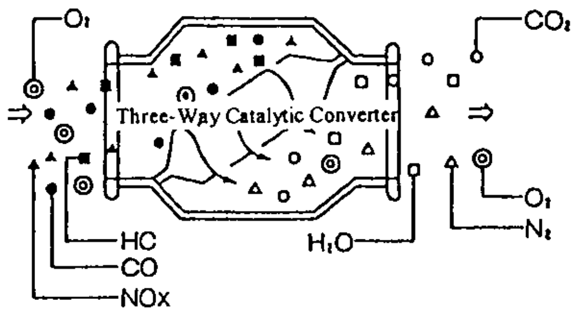


Fig.7.11.2 Lean Burn System

(2) After treatment technologies in the exhaust line

①Oxidation catalytic converter: A catalyst (platinum, palladium, etc.) are installed midway in the exhaust pipe. As the exhaust gas passes through the pipe, the CO and HC are oxidized and are changed into harmless forms, CO_2 and H_2O. In this case, a system which supplies secondary air before the catalyst is necessary. In the secondary air supply system there is a secondary air injection system which forces air through using an air pump. There is also a system with a secondary air vent which opens into the atmosphere when exhaust gas vacuum is registered in the pulsation of the exhaust pressure from inside the engine exhaust pipe and introduces secondary air into the exhaust pipe corresponding with the exhaust gas vacuum.

②Three way catalytic converter: This device uses platinum or rhodium as its catalyst. Through an oxidation reaction with the CO and HC within the exhaust gas, and by a reduction reaction with the NOx, all three substances are simultaneously converted into non-toxic substances. This differs from an oxidation catalytic converter in that there is a need to control the air fuel ratio to its stoichometric level. For this purpose, the air fuels ratio feedback system is indispensable, where the O_2 concentration in the exhaust gas is continuously detected and the data is sent to a computer. Also, the fuel supply system uses a electronic controlled fuel injection system to deal with various types of air fuel ratio controls. (Fig.7.11.3)



$HC \rightarrow CO_2 + H_2O$ $CO \rightarrow CO_2$	oxidization reaction
$NOx \rightarrow N_2 + O_2$	reduction reaction

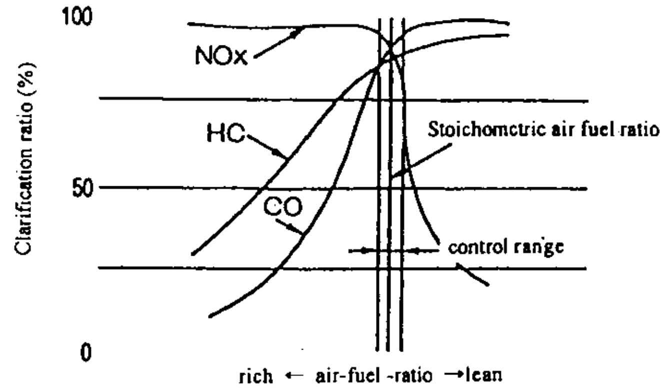


Fig.7.11.3 Principle of a three-way catalytic converter

(3) Countermeasure of unburned fuel

① Blow-by Gas Recirculation system: The blow-by gas which is blown past the pistons and cylinders, is once again recirculated to the intake line for combustion.

② Fuel Evaporative Emission Control Device: The evaporative fuel from the fuel tank and carburetor is initially adsorbed by the activated carbon (charcoal canister) and the engines exhaust gas vacuum is used to recirculate it into the intake line once more.

7.11.3 Diesel powered vehicles exhaust gas emission control measures

Exhaust gas emission control for diesel powered vehicles include ①the improvement of the exhaust and intake line, ② improvement of the combustion chamber, ③improvement of the fuel injection system, ④after treatment, and ⑤ improvements to the fuel itself. An outline of these related technologies is shown in Fig.7.11.4.

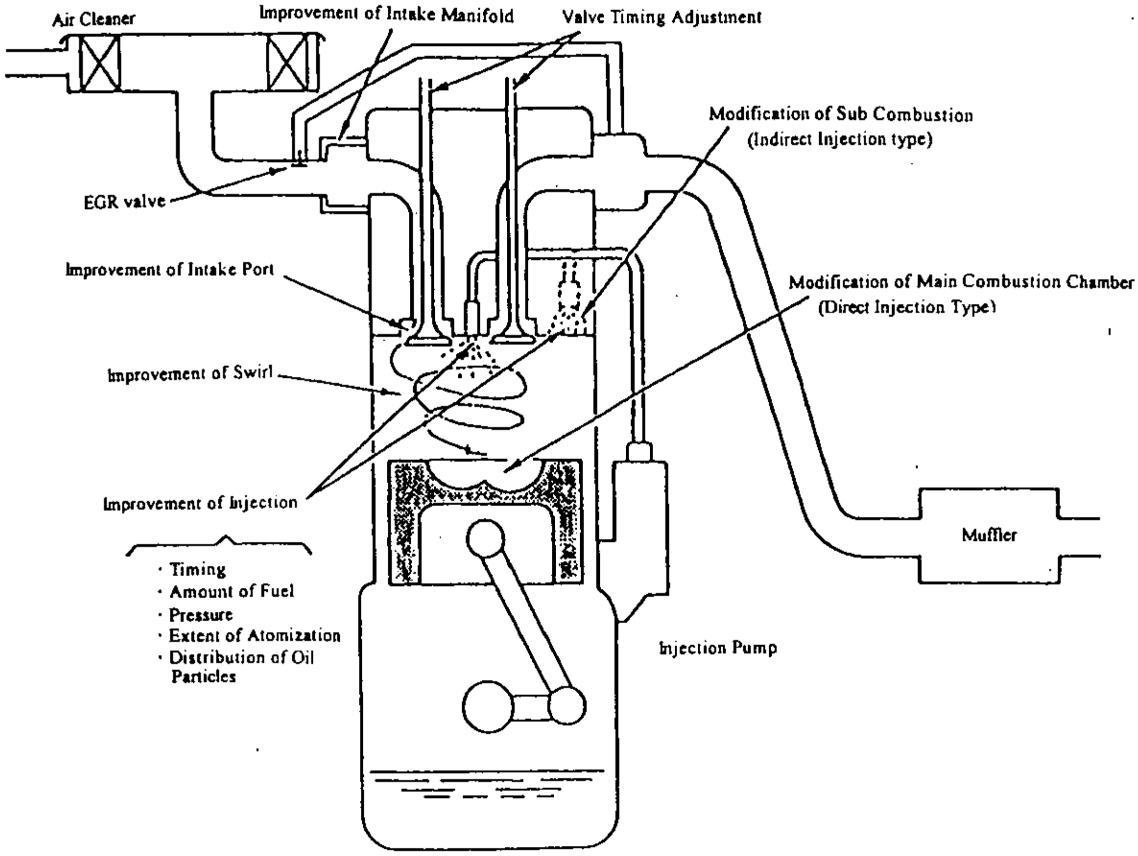


Fig.7.11.4 Example of Diesel-Powered Engine Meeting Exhaust Gas Standards

(1) Improvement of intake and exhaust line

In the intake line the aim is to improve the optimization and volumetric efficiency of the air flow. Improvements in the intake manifold, intake port, and changes of the valve timing are performed. The air intake resistance is reduced and the trapping efficiency is lifted. This not only allows for sufficient appropriation of the air necessary for combustion but also improvements in the mixing of air with fuel using a moderate swirl. This allows for proper performance in fuel combustion.

Also, by increasing vulves, the passage way through which the gas passes becomes that much wider, making it capable of performing quick and a lot of gas exhaust and intake. This improves volumetric efficiency. Supercharging is the process by which air, with pressure higher than that of atmospheric pressure, is sent to the engine via a compressor which is operated by a turbine being rotated by exhaust energy emitted from the engine. This supercharging reduces the air fuel ratio resulting in a decline in black smoke and PM (particulate matters). The creation of NOx is controlled by charging air, cooled down after having been heated by super charging, to the engine.

For passenger cars, the method where a portion of the exhaust gas is recirculated to the intake line and the combustion temperature is lowered to reduce the NOx is already in use. However, for trucks and buses which have a longer lifespan and are used under high load conditions, there are numerous issues dealing with reliability and durability such as corrosion of the inner engine due to the S content in diesel fuel, abrasion caused by dust, and deterioration of oil. The improvements in technology to control black smoke such as the reduction of the ratio of the S content in diesel fuel and the improvement of combustion, will likely see the increased application of EGR to smaller trucks in the future.

(2) Improvements of Combustion Chamber

In order to reduce black smoke and PM, the swirl in the combustion chamber should be increased. This is the opposite when aiming to reduce the NOx; the swirl should be reduced. The conditions of the gas flow within the cylinders are largely effected by factors in the combustion chamber.

(3) Improvements of fuel injection system

① The fuel injection timing retard: The NOx from diesel engines occurs most frequently for pre-mixed combustion. For pre-mixed combustion, the longer the time lapse between fuel injection and ignition, the more NOx emissions are created due to powerful combustion. Consequently, in order to reduce the occurrence of NOx, it is best to retard fuel injection as much as possible and shorten the pre-mixed combustion time. However, by timing retard fuel injection the combustion temperature is cut and an increase in black smoke and PM is experienced along with worsened fuel efficiency and power down. In order to overcome these demerits, improvements to the combustion chamber conditions, quicker air flow, and the promotion of a spray diffusion are just some of the improvements to combustion which must be made at the same time. Recently, the control of the fuel injection is being done in order to attain a balance between the reduction of black smoke and PM and improvement in performance. This is being done by controlling the pre-mixed combustion at the onset of combustion in order to reduce NOx and promote diffusion combustion during the latter half of fuel combustion.

② High pressure injection: Fuel is injected into the combustion chamber at high pressure and converted into fine particles in order to improve the mixture of air and fuel. By setting the injection pressure at anywhere between 400 kg/cm^2 and 1,000 kg/cm^2, black smoke can be reduced to 1/4. However, the improvement of combustion via high pressure injection causes an increase in NOx. Therefore it is necessary to simultaneously implement NOx countermeasures such as retarded fuel injection timing.

(4) After treatment

For diesel powered vehicles, it is difficult to utilize the oxidation catalytic converter or three-way catalytic converter used by gasoline fueled vehicles as the S content in diesel fuel causes and increase in sulfate and excess O_2 hinders NOx reduction treatment. However, measures to cut the ratio of the S content in diesel fuel in recent years, has led to the use of a SOF reducing oxidization catalytic converter in some types of vehicles. Also, development is progressing for the practical use of the Diesel Particulate Filter (DEF) which is a treatment which reduces black smoke by trapping dust in a honeycomb trap (material: cordierite or silicon carbide) through which the exhaust gas passes.

In regards to the reduction catalytic converter, zeolite (crystalline silicate minerals largely containing water) works in conditions where there is a high concentration of O_2. However, there are many problems such as, the NOx reduction is low (about 10%), low temperatures obtaining no results and the existence of water lowering its effects. Practical application of the catalyst is complex.

(5) Measures concerning fuel

The ratio of the S content in diesel fuel was reduced from 0.4% to 0.2% in 1992. Content was reduced to 0.05% starting from 1997. Also, by adding oxygenates such as polypropylene glycol alkyl ether or vegetable oil methyl ester to light oil, HC, CO, and PM can be reduced. In this case, the increase in NOx is controlled by the introduction of cetane number improver.

7.11.4 Specified Issues

There have been remarkable developments in the advancement of technology for reducing exhaust gas from gasoline fueled vehicles. In the future, higher costs for applying these solutions to heavy duty gasoline fueled vehicles is a major problem. Concerning diesel powered vehicle, the reduction of black smoke via improvements in combustion are progressing but the problem of increased NOx still remains. Also, in regards to DPF systems or hybrid systems, the issues of lower costs and reliability and durability of the system still exist.