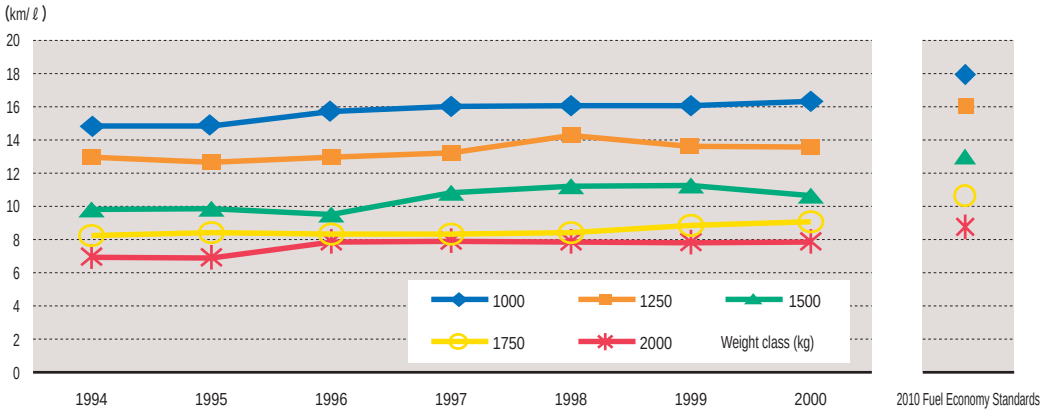
Improving Fuel Economy and Reducing Exhaust Emissions

Pressing Ahead to Improve the Fuel Economy of Existing Engines and Reduce Exhaust Emissions by Various Means

Improved Fuel Economy

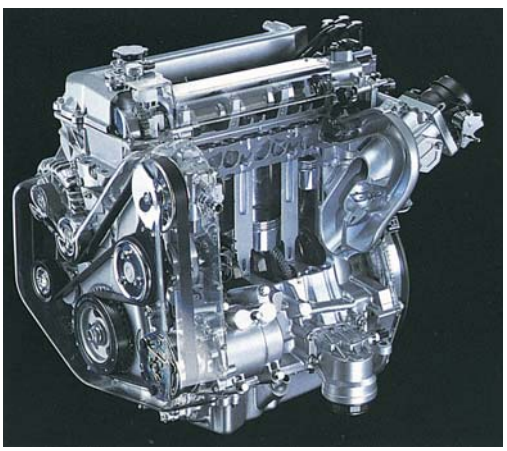
It is clear that the first realistic step in reducing CO_2 emissions is to improve the fuel economy of existing engines. This is due to the fact that as long as gasoline and diesel powered vehicles, which are so numerous in comparison to "Clean Cars" such as Electric Vehicles, remain unchanged, there will be little reduction in the volume of CO_2 being released to the atmosphere. The internal-combustion engine loses a large part of its combustion energy through heat loss and mechanical resistance. Much research has been done into ways of reducing this energy loss and improving the energy efficiency of the engine. Lightening the weight of the crankshaft and other parts, for instance, and increasing the accuracy of processing, reduces resistance energy loss. Improvements to catalysts have also raised energy efficiency. Amidst this research, advances in electronic controlling technology have occurred in line with deepening understanding of the combustion phenomenon, and these promise further levels of fuel economy improvement.
Mazda is proceeding concurrently along both tracks, of improvement fuel economy for existing engines, and reductions in emissions.

Transition in Average Fuel Economy by Vehicle Category



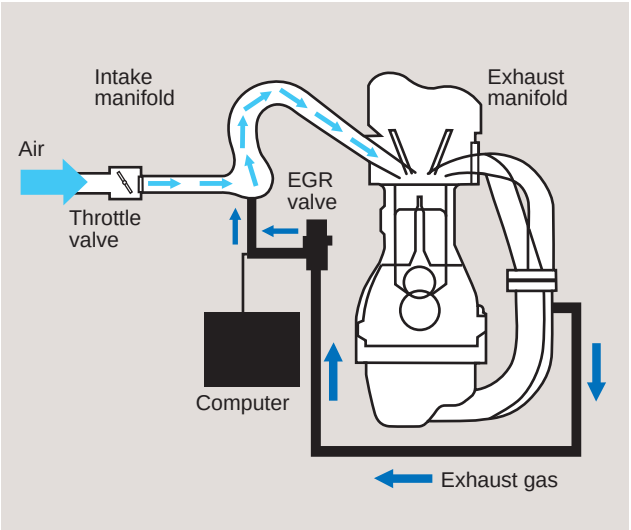
Joint Development of New Engine Series with Ford

Mazda has worked jointly with Ford in the development of the new in-line four-cylinder engine, which is to be produced in sequence at the Mazda Hiroshima Plant and Ford's Dearbone, Chihuahua and Valencia plants. This new engine not only possesses superior capability, but is also lightweight, and is environmentally friendly in other ways - it has excellent fuel economy and low exhaust emissions. (Mazda's plant will begin production of the engine at begining of 2002).



Diluted-Burn Engines

Mazda's new combustion system diluted-burn engine has achieved high engine output across the board, whilst at the same time giving increased fuel economy and reducing NOx emissions.
This system uses an electronically controlled stepper motor, which refluxes large amounts of exhaust gas into the combustion chamber, across a large range from acceleration to cruising, and dilutes the air-fuel mixture before combustion.
The first important effect of exhaust gas recirculation (EGR) is that it lowers the resistant loss (pumping loss) during the intake process, resulting in improved combustion efficiency. Next, the inert gases (EGR) being pumped into the cylinder lowers the combustion temperature, and reduces emissions of NOx.
Mazda has developed the diluted-burn engine, which is a simple system requiring no particularly complex structure, and currently features them in Capella and Familia in Japan.

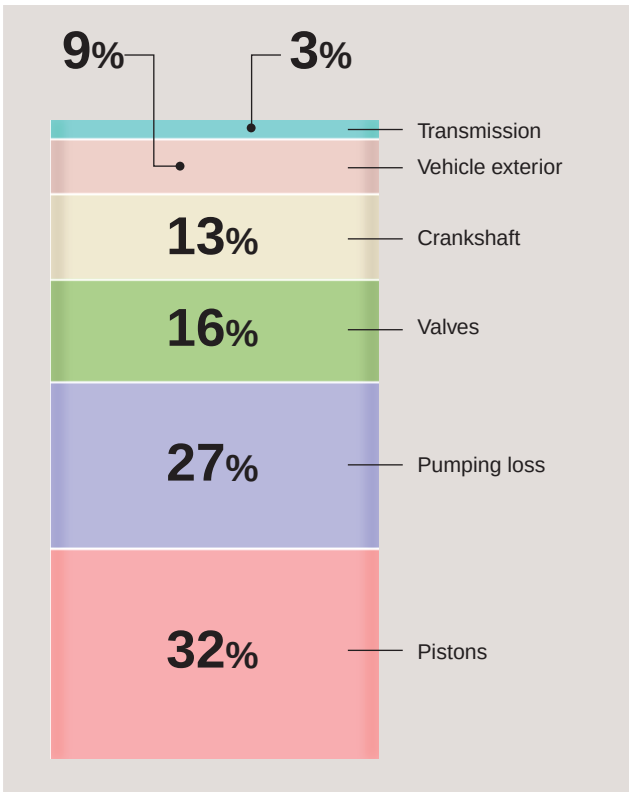


Exhaust Gas Recirculation System

[Mechanism for improved fuel economy]

Pumping loss is the second biggest cause of mechanical resistance energy loss in engines. This occurs in the throttle valve, through the process of controlling intake gas. Through refluxing large amounts of EGR, which contains no oxygen, into the area downward of the throttle valve, the difference in pressure between the inside of the air intake port and the atmosphere is lessened, reducing pumping loss. As a result of this technology, the 1997 Capella, had an output 36% higher than that of any previous model, whilst improving fuel economy by 18% (the FS type 2.0-liter engine with automatic).
This same EGR teahnology is employed in standard engines, though the amount of gas recirculated is of the order of 10%. Mazda's diluted-burn engine recirculate between 13 and 20% of EGR during acceleration and cruising (though not during deceleration).

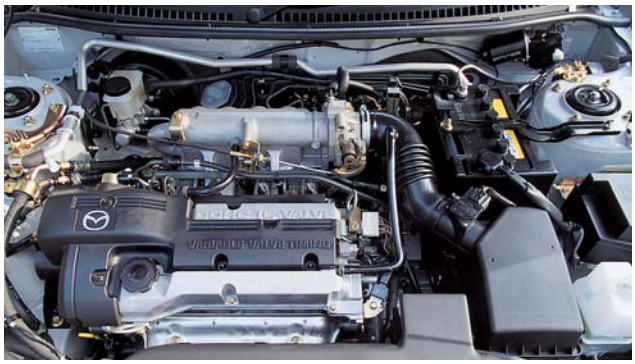
Types of Mechanical Resistance Energy Loss at 40km/h



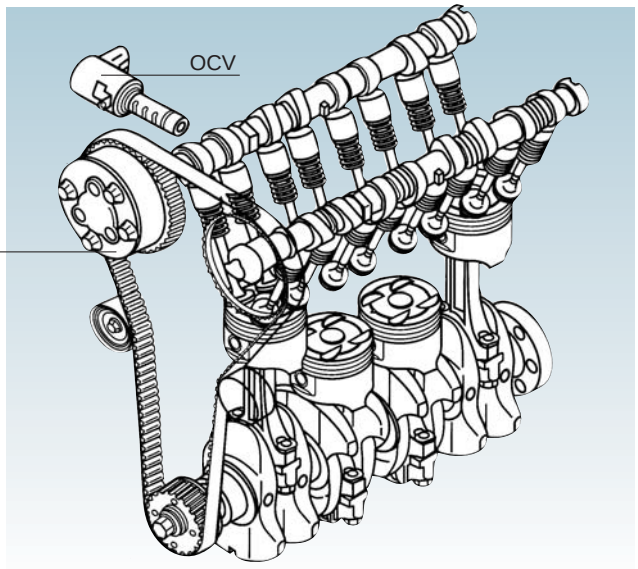
S-VT: Continuously Variable Valve Timing

S-VT (sequential valve timing) controls the valve timing in various driving modes, through continually varying the opening and closing timing of the intake valve, to give the most suitable operation. The application of this control technology has simultaneously improved both the performance of the engine and its fuel efficiency, and Mazda has adopted this technology to the Familia, as its main engine (the 1.5-liter ZL-VE type introduced in 1998). CO_2 emissions have been reduced by 16% and NOx by 14% over previous models, while the pleasure of driving the car has increased.

S-VT is composed of a vane actuator, which continually varies the phase of the intake valve timing and the crank angle through oil pressure, along with a computer, which calculates the intake valve timing, and an oil control valve (OCV), which controls the oil pressure in accordance with instructions from the computer. The most appropriate valve timing control can be achieved through detection of the engine's revolutions, intake volume and water temperature. NOx emissions are also reduced, through the implementation of EGR.



■S-VT Engine
Maximum output: 96kW (130PS)/7000rpm
Maximum torque: 141N･m(14.4kg-m)/4000rpm



Direct-Injection Gasoline Engine with Stratified Charge

Mazda is currently pressing ahead with the development of the direct-injection gasoline engine, which makes possible a further level of diluted combustion. The direct-injection engine takes in only air from its intake port, and directly injects fuel into the combustion chamber. At this point, if the easily ignited air-fuel mixture can be positioned only in the immediate area of the spark plug, it is possible to achieve a higher air-fuel ratio than even that of a lean burn engine. This process of thinning the air-fuel mix to burn it is known as stratified diluted burn.

This type of engine can ensure the supply of motive power for acceleration and at other times when a large torque is required through using not stratified diluted burn but uniform air-fuel combustion according to theoretical air-fuel ratios. Even then, since its average air-fuel ratio is high, the engine achieves a CO_2 emissions reduction of 30%. Other effects of the direct injection system are that it raises maximum output by 10%, and gives an increased response to the depression of the accelerator.

■Mazda DIREC-G
Exhaust output of water-cooled in-line four cylinder DOHC 16 valve gasoline engine: 1,498cc
Maximum output (target value): 77kW (105PS) / 6,000rpm
Maximum torque (target value): 105N･m (15.2kg-m) / 3,500rpm

Compact Direct-Injection Turbo Diesel Engine

A direct-injection type of engine has existed for a long time in the area of diesel engines, mainly for use in large trucks. The direct-injection engine experiences less heat loss than an indirect injection system with an auxiliary chamber, and so has greater output and higher fuel efficiency. The direct-injection system, however, is noisy due to the high speed of combustion, and since combustion temperatures are high, NOx emissions increase. Mazda has been working to produce a small direct-injection diesel engine suitable for passenger cars, and in 1998 developed the RF type 2.0litre DI-TD (direct-injection turbo diesel) engine, which was then used in the Capella series. The DI-TD engine has reduced noise and NOx emissions down to auxiliary chamber levels, while increasing maximum output by around 14% and maximum torque by around 18%, and giving roughly a 16% improvement in fuel efficiency (at a steady speed of 60km/h, when compared with previous models' supercharged engines).

[Achieving mild combustion using more air]

The RF model direct injection diesel engine uses a mechanism of four valves per cylinder, with a central fuel injection and an electronically controlled fuel injection system, to produce highly efficient fuel use.

The use of a turbocharger and the change to 4 valves means that an increased volume of air can be taken in, and the double tangential intake port creates a strong swirl. As a result, the atomized fuel, which is injected into the center of the combustion chamber, can utilize the air within the chamber without it being exhausted. The resulting mild combustion gives higher fuel efficiency and lower emission levels.

■DI-TD (Direct-Injection Turbo Diesel) Engine
Exhaust output of water-cooled in-line four cylinder DOHC 16 valve diesel engine: 1,998cc
Maximum output: 100ps / 4,000rpm
Maximum torque: 22.4kg-m / 2,000rpm

Reducing of Exhaust Emissions

In order to further reduce exhaust emissions, Mazda is committed to research and development into catalyst systems, engine combustion control systems, and other contributory measures. Using the results of this research, we are pushing forward with the market introduction of cars that improve upon Japan's national emissions standards - Excellent-Low Emission Vehicles (*1) and Good-Low Emission Vehicles (*1)

(*1) The Ministry of Land, Infrastructure and Transport has established Low Emission Vehicle Approval System, in order to accelerate the popularization of vehicles with lower emissions. This system is in place as of April 2000. There are three types of approval criteria depending on the level of exhaust emissions, and vehicles that meet the criteria are permitted to display a sticker stating that they are low emissions vehicles.

Low Emissions Vehicles Approval Criteria:
Ultra-Low Emissions: 75% reduction on the emissions standards for 2000
Excellent-Low Emissions: 50% reduction on the emissions standards for 2000
Good-Low Emissions: 25% reduction on the emissions standards for 2000

Demio Pieare

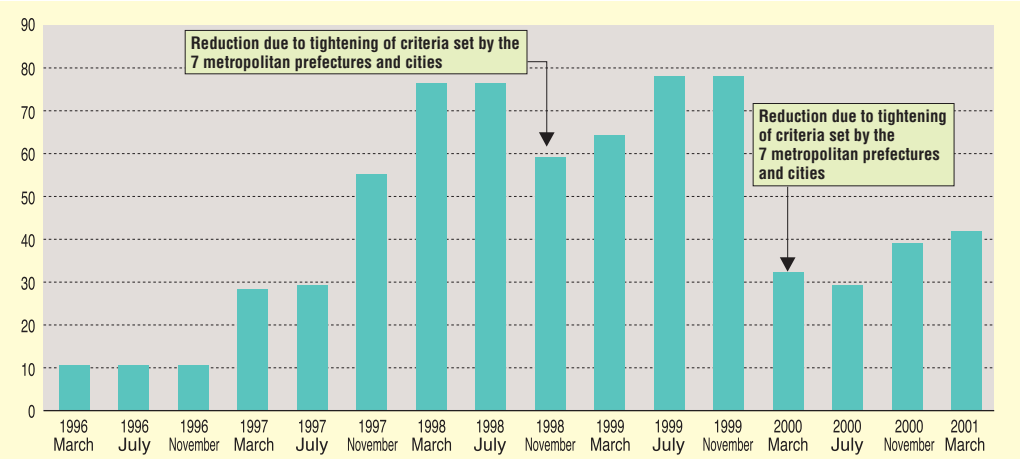
Familia S-Wagon Sport 20

Premacy Sport

Transition in Vehicles receiving Approval under the Low Pollution Vehicles Designation System

Mazda has proactively developed and marketed gasoline, diesel, LPG and CNG powered vehicles amongst others, which fulfill the emissions criteria set for designation as "Low Pollution Vehicles" by the 7 Metropolitan Prefectures and Cities Designated Low Pollution Vehicles System (*2), and the Kyoto / Osaka / Kobe 6 Prefectures and Cities Designation (*3) (LEV-6).
Each of these local governments operates a system of designation for low pollution vehicles, with the aim of popularizing low emissions vehicles. Similarly to the Ministry of Land, Infrastructure and Transport's Low Emissions Vehicle Approval System, the system allows cars that meet the criteria set for low pollution vehicle designation, according to their level of emissions, to display a label stating the fact that they have been designated.

No. of models designated as 7 Metropolitan Prefectures and Cities Designated Low Pollution Vehicles



(*2, *3) ・7 metropolitan prefectures and cities: Saitama Prefecture, Chiba Prefecture, Metropolitan Tokyo, Kanagawa Prefecture, Cities of Yokohama, Kawasaki and Chiba.
・6 prefectures and cities: Kyoto and Osaka Prefectures, Hyogo Prefecture, Cities of Kyoto, Osaka and Kobe.
(Note) The reason that the number of models shown as Designated Low Pollution Vehicles drops at points on the graph to the right is that the criteria for designation were tightened, and some models were undesignated.

Emissions Reduction Technology

The Familia, which was introduced to the market in the year 2000 and has gained an Excellent-Low Emissions Vehicle rating, features a newly developed 2-bed closed couple catalyzer, which gives a high standard of purification immediately after the engine is started, as well as an early sensor for activated O_2, which monitors the stability of combustion from the moment the engine is turned on, giving the vehicle super-clean capability.

Explanation of 2-bed closed couple catalyzer and O_2 sensor