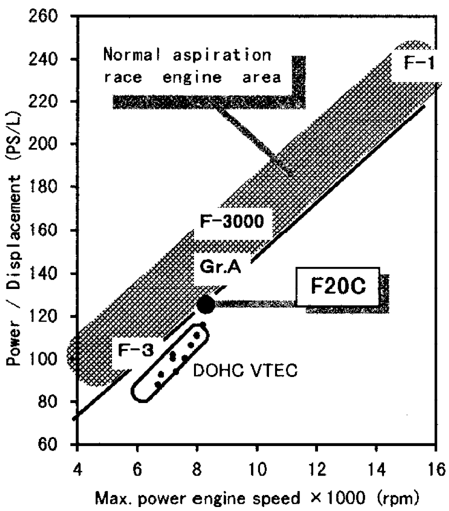
EXECUTIVE SUMMARY

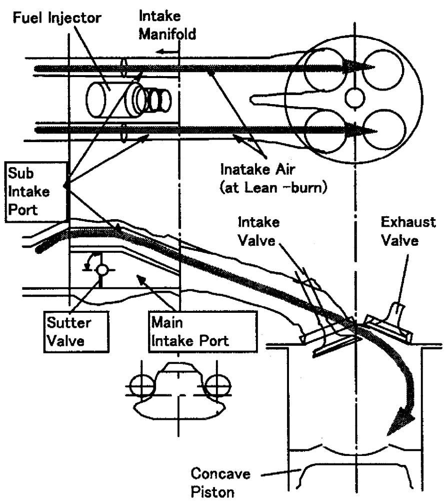
1.0 TECHNOLOGY TO INCREASE POWER OUTPUT OF A LOW-EMISSION/HIGH-EFFICIENCY ENGINE

Honda Redesigns Two-Liter Engine for More Power, Reduced Emissions [Akimoto et al.]: Engineers at Honda R&D Co., Ltd., introduced technology employed for developing a two-liter, inline-four engine called the F20C. The model F20C is the upscale version of the F20B which has been the powerplant of the Honda Accord™. The engine was uniquely designed to produce high specific power of 125 PS (93.2 kW) per liter considering the limited space requirement for the balanced weight distribution (50 percent front and 50 percent rear) of the S2000™ sports car sold in Japan. Cylinder bore was increased from 85 to 87 mm and the stroke was reduced from 88 to 84 mm. Engine speed was increased from 7200 rpm to 8300 rpm to produce the maximum power of 184 kW with the maximum torque increased to 218 Nm at 7500 rpm. While technology was developed for increasing

Note: Name in bracket designates references at end of this report



SPECIFIC POWER (PS/L) AS A FUNCTION OF ENGINE SPEED [Akimoto et al.]



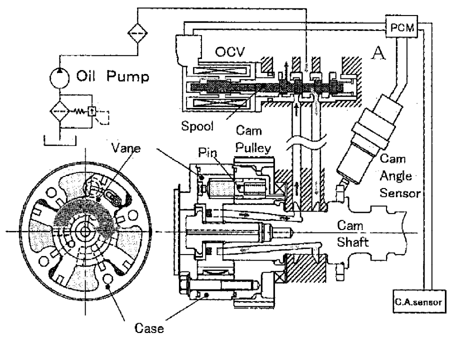
AIR JET SWIRLER (AJS) [Nishizawa et al.]

the maximum power, emissions control technology was refined to meet future emissions standards. The catalyst's substrate was changed from ceramic to metal. Secondary air injection was employed to increase the catalyst temperature-rise rate when the engine is cold. Under the Japan 10-15 mode emissions test conditions, all three gaseous emissions, carbon monoxide (CO), hydrocarbon (HC), and nitrogen oxides (NOx), met the target of half of Japan's emissions standards for the year 2000.

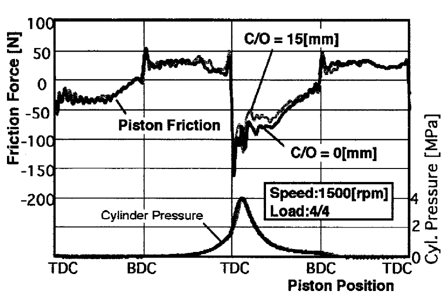
Nissan Improves Power, Emissions with Effective Intake System and Piston Crown Design [Nishizawa et al.]: Nissan's RB20DE, a 1.998-liter, in-line six engine, powerplant of a sport sedan called "Skyline™," has been revised to consume less fuel and produce more power. Engineers at Nissan developed lean-burn technology for a short-stroke engine which has been known to be difficult compared to application in a long-stroke engine. Tumble air motion was effectively generated by the low-restriction intake system called the "Air Jet Swirler" (AJS). The uniquely configured, concave piston crown retained turbulence intensity longer near top dead center (TDC). Both the AJS and the concave piston crown successfully increased the burn rate of lean mixture in a short-stroke engine. In addition, engine friction was reduced by 20 percent at all engine speeds, and idle speed was set lower to gain fuel economy. The automatic transmission was redesigned as well to improve power transmission of the lean-burn engine. As a result, fuel economy improved by 14 percent under the Japan 10-15 mode operating conditions compared to that of the previous model. Engine power output was increased by improving charging efficiency. The peak torque increased to 186 Nm at 4400 rpm, and the maximum power increased to 114 kW at 6400 rpm compared to those of the previous model.

2.0 MAZDA'S 1.5-LITER ENGINE WITH CONTINUOUSLY VARIABLE VALVE TIMING

Design Changes in Continuously Variable Valve Timing, Inertial Charge and Scavenging Increase Torque [Fukuma et al.]: Engineers at Mazda Motor Corporation developed technology to increase torque of a 1.5-liter, inline-four engine, powerplant of



OIL CONTROL VALVE AND CAMSHAFT ACTUATOR [Fukuma et al.]

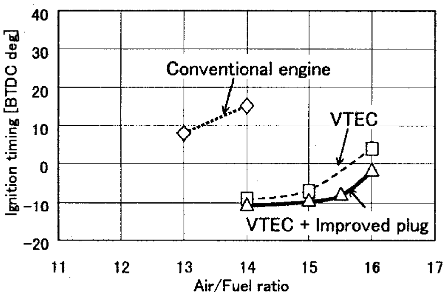


PISTON FRICTIONAL FORCE MEASURED FOR THE EFFECT OF CRANKSHAFT OFFSET AT 1500 RPM [Takiguchi et al.]

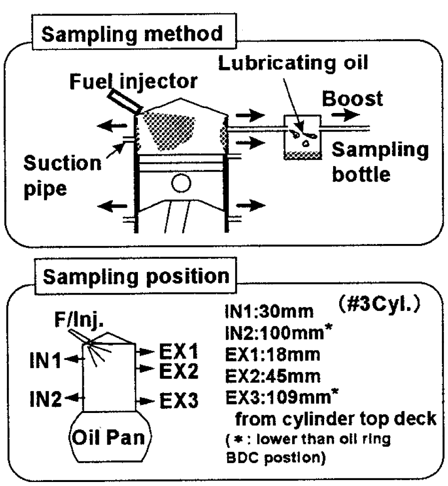
Mazda's compact sedan called "Familia" ™ which has been sold in Japan for many years. Approaches employed for increasing torque include continuously variable valve-timing adjustment, inertial charge at high speed, and an efficient scavenging process in a wide engine-speed range. The intake cam profile was also modified to help increase charging efficiency. Compared to that of the previous model, torque increased in a wide engine-speed range, while peak torque increased from 126 to 141 Nm and the maximum brake power increased to 96 from 92 kW.

3.0 INVESTIGATION OF CRANKSHAFT OFFSET FOR EFFECTS ON PISTON FRICTION AND MOTION

Friction Reduction by Crankshaft Offset Requires Piston Design Technology Development [Takiguchi et al.]: Researchers at Musashi Institute of Technology experimentally investigated the effect of crankshaft offset on piston friction. Researchers used a floating liner method to measure piston frictional force in real time in a single-cylinder engine. In addition, the engine was modified to install a provision to change crankshaft offset up to 15 mm. Crankshaft offset can decrease piston frictional force during the expansion stroke. With a 15-mm offset, the piston frictional force decreased by about 10 and 5 percent when the engine was operated under full load at 1500 and 2000 rpm, respectively. Calculation results indicated the reduction of piston side force during the expansion stroke when crankshaft offset was increased. However, the piston friction did not decrease accordingly, especially at 2000 rpm. At 2000 rpm, the crankshaft offset actually decreased piston side force; however, the upper-skirt contact force against the cylinder wall did not decrease at the same ratio as much as the decrease at 1500 rpm. If crankshaft offset is used to reduce piston friction, a specific piston design modification will be necessary to reduce piston side force, particularly at the upper piston skirt. For information useful in piston design improvement, continued investigation will be necessary to better understand the relationship between the piston and wall contact phenomenon and piston deformation.



The Relationship between Spark Timing and Air/Fuel Ratio [Kishi et al.]



Oil Sampling Locations [Fujimoto et al.]

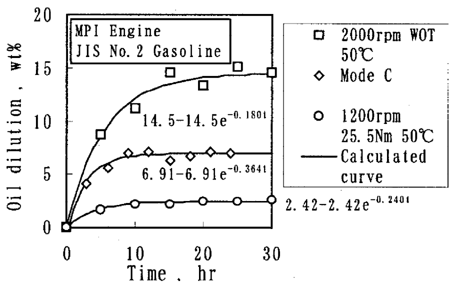
4.0 HONDA'S SIMPLIFIED THREE-STAGE EMISSIONS CONTROL TECHNIQUE

ZLEV Design Modifications Further Reduce Emissions and Production Cost [Kishi et al. and Kikuchi et al.]: As previously reported, Honda has worked to develop a zero-emissions vehicle (ZLEV), a vehicle with an emissions level almost equivalent to the overall emissions produced by an electric vehicle (EV) considering emissions produced at an electric power generation plant. Honda's target for the ZLEV is one-tenth of California's ultra-low emissions vehicle (ULEV) standard. Engineers at Honda R&D continue ZLEV development to simplify the emissions control system. Electric power consumption of the electrically-heated catalyst (EHC) was originally of concern and was reduced to a low level. The latest system eliminated the EHC system yet still achieved the target emissions level. The key elements employed for the latest system include:

- High swirl combustion with a significantly retarded spark ignition timing and a reliable spark plug with a thin iridium electrode,
- Increased number of catalyst cells (1200 cpi) and decreased wall thickness (2.0 mil),
- Enhanced oxidation of desorbed HC on a hybrid catalyst, and
- Air/fuel ratio control with predictive catalyst oxygen storage amount and dual oxygen sensors.

5.0 OIL DILUTION WITH INJECTED FUEL IN A DI GASOLINE ENGINE

DI as well as MPI Gasoline Engine Tests Reveal Fuel Consumption Significantly Affects Oil Dilution [Fujimoto et al.]: Engineers at Nissan Motor Co., Ltd., investigated oil dilution in a prototype DI gasoline engine. For comparison, oil dilution in a conventional multi-point injection (MPI) engine was also investigated. They focused on fuel diluted in oil on the cylinder wall and sampled oil from various locations on the cylinder wall. The oil dilution rate was characterized for the effects of various factors including fuel consumption, fuel injection timing, oil and coolant water temperatures, piston crown geometries, fuel spray penetration, and fuel spray type. In the case of the DI engine, oil dilution occurred on both the intake and exhaust sides on the cylinder wall, while the MPI engine had oil dilution on the exhaust side only. Oil dilution on the intake side in the DI engine is mainly caused by air motion and turbulence. The oil dilution measurement results were summarized to determine the factors to which the oil dilution rate was sensitive. As a result it was determined that fuel consumption most significantly affected oil dilution. Using the empirical formula, the oil dilution rate that was predicted in the map of torque and speed was found to increase when the engine was operated under peak torque conditions.

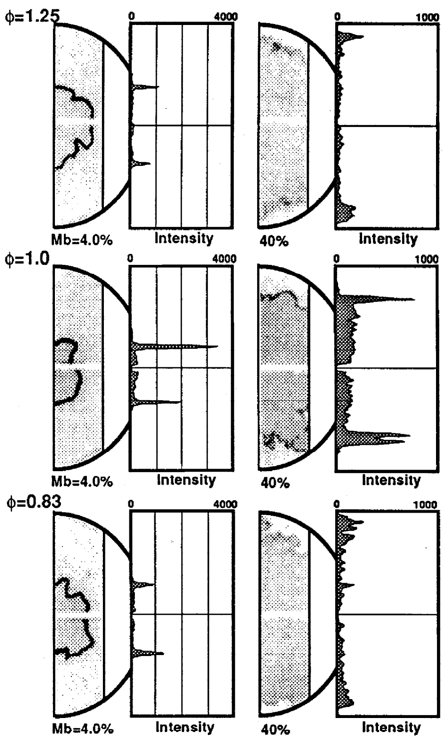


CORRELATION BETWEEN CALCULATION AND MEASUREMENT OF OIL DILUTION RATE AS A FUNCTION OF TIME FOR VARIOUS CONDITIONS IN THE MPI ENGINE [Sagawa et al.]

Nissan Develops Empirical Formula for Predicting Oil Dilution [Sagawa et al.]: Another group of Nissan engineers investigated the oil dilution rate in an oil sump and developed a method to predict the oil dilution rate as a function of time. Fuel type was added to the test parameters for the investigation in addition to fuel consumption and temperatures of coolant water and oil. Overall characterization results indicated that the oil dilution rate significantly changes in proportion to fuel consumption if the parameters of fuel type, fuel injection timing (DI only) and temperatures of coolant water and oil are not changed. Thus, from the fuel consumption data, the oil dilution rate could be predicted even under the mode operating conditions. The empirical formula developed for predicting the oil dilution rate for the effect of time and mode correlated well with the measurement results.

6.0 NITROGEN OXIDE DISTRIBUTION IN A DI ENGINE

NO Distribution in Homogeneous and Heterogenous Combustion Evaluated at Mazda [Tanaka et al. 1996 and Tanaka et al. 1998]: Engineers at Mazda Motor Corporation observed nitrogen oxide (NO) distribution in a combustion chamber using a planar laser-induced fluorescence (PLIF) technique. An image was captured by a charge couple device (CCD) camera with an image intensifier in the combustion gas to measure fluorescence intensity which changes in proportion to the concentration of NO. Engineers first characterized the NO distribution in a constant-



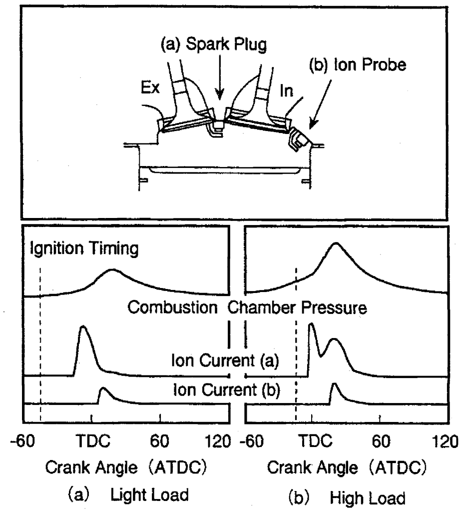
THE EFFECT OF EQUIVALENCE RATIO ON NO FLUORESCENCE INTENSITY IN THE CASE OF 4 AND 40 PERCENT BURN RATE
[Tanaka et al. 1996]

volume combustion vessel for the effects of equivalence ratio and turbulence. Subsequently, NO distribution in a single-cylinder, spark-ignition engine was investigated. An engine with a 78-mm bore and a 83.6-mm stroke was modified for optical access.

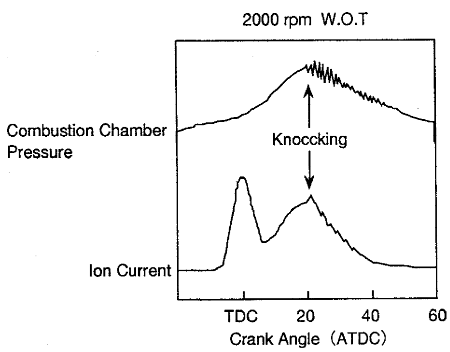
Homogenous combustion was first investigated for NO distribution. Then, NO distribution was investigated in a heterogenous mixture combustion that simulated direct-injection (DI) spark-ignition engine. A propane mixture was used as fuel. Two gas nozzles located tangentially at the periphery of the combustion chamber were used to inject air to produce heterogeneous mixture in the combustion chamber. Peak NO fluorescence intensity was observed at the location almost corresponding to the flame front. This NO was produced by the formation of prompt NO due to rich and high-temperature combustion. Behind the flame front, NO was produced by the Zeldovich mechanism, which is sensitive to equivalence ratio and temperature. The Zeldovich NO formation zone was characterized using the width of the fluorescence intensity distribution at half the level of the peak NO fluorescence intensity. In the heterogeneous mixture, the zone width was narrow in the middle of the combustion chamber and increased toward the wall corresponding to the mixture distribution, which changed the mixture from rich to lean toward the wall. Thus, the Zeldovich NO was produced in the mixture near the wall. The various observation results indicated that NO reduction technology for a DI gasoline engine will probably need to consider an approach to reduce prompt NO especially when the engine is operated on a lean overall mixture.

7.0 ION CURRENT USED FOR COMBUSTION DIAGNOSIS

Ion Current Used to Diagnose Cylinder Pressure [Nakata et al.]: Engineers at Toyota Motor Corporation investigated the feasibility of using ion current to evaluate combustion quality in a spark-ignited mixture. They characterized ion current for the effects of the air/fuel ratio, swirl, and cylinder pressure. A single peak of ion current was measured when the engine was operated under light load. With increased cylinder pressure at a higher load, an additional peak occurred which was caused by the



ION CURRENT AND COMBUSTION PRESSURE
[Nakata et al.]



HIGH-FREQUENCY FLUCTUATION OF ION CURRENT SIGNAL CORRESPONDING TO THAT OF CYLINDER PRESSURE IN COMBUSTION KNOCK [Nakata et al.]

increased cylinder pressure. These two peaks of the ion current were studied for their correlations with the combustion characteristics. Ion current produced immediately after the spark is discharged is fundamentally possible to detect by using a spark plug as an ion detection probe. Although there is a trade-off between ion current measurement and spark discharge time since the ion current cannot be measured during spark discharge, ion current can be used to diagnose cylinder pressure if the cylinder pressure is more than 2 MPa.

Ion Current Studied in Relation to Combustion Knock [Kinoshita et al.]: Another group of Toyota engineers studied the relationship between ion current and cylinder pressure when combustion knock was intentionally produced in a test engine. Combustion images were obtained using a shadowgraph technique, and the combustion knock area and shock wave-induced pressure development could be observed in the image. The shock wave produced by self-ignition of end gas increased ion current once it reached an ion probe. Ion current fluctuated depending on the pressure wave. The effect of polarity was observed in the ion current history during one engine cycle. When the center electrode of an ion probe was changed from positive to negative or vice-versa, the frequency of the ion current signal was affected. With the negative center electrode, ion was only detected by the negative pole of the center electrode where the positive electrode allowed the entire combustion chamber to detect ion. Therefore, the frequency characteristics of ion current were found to be different depending on the polarity of the ion probe.