SAE TECHNICAL PAPER SERIES

2000-01-0668

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The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL

SAE 2000 World Congress
Detroit, Michigan
March 6-9, 2000

400 Commonwealth Drive, Warrendale, PA 15096-0001 U.S.A. Tel: (724) 776-4841 Fax: (724) 776-5760

ISSN 0148-7191

Printed in USA

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ABSTRACT

Since the VQ engine series of lightweight, compact, low friction and high response engines was released in 1994, they have been rated highly both at home and abroad. Two new 3.0-liter and 3.5-liter V6 engines have been developed as the second generation of the VQ engine and introduced into the North American market. Continuing the characteristics of the first generation, this new VQ engine series achieves a performance figure of 98Nm/L as a result of adopting part shapes defined with a three-dimensional analysis method.

The new VQ30DE engine adopts a plastic intake manifold which incorporates a variable induction system with a rotary valve. The new VQ35DE engine adopts a continuously variable valve timing control system and a long branch intake manifold with an inertial induction system. It also incorporates a new concept piston and a hot coined connecting rod to reduce its reciprocating inertial mass. These features enable it to continue the advantages of the VQ engine such as lightweight, high response and excellent fuel economy despite the increased displacement. Consequently, the pin diameter of the crankshaft per liter has been reduced to one of the thinnest in use. High productivity has also been achieved, maintaining the rate of automatic assembly at 70% on a line for 2.0, 2.5, 3.0 and 3.5-liter engines due to the unification of parts and specifications.

DEVELOPMENT OBJECTIVES

The following main objectives were set for the development of this second-generation V6 engine series:

1. Reduction of weight and friction to maintain high response.
2. Improvement of quietness.
3. Improvement of volumetric efficiency to achieve one of the largest torque-per-liter figures in the world.
4. Improvement of thermal efficiency and reduction of friction to improve fuel economy.

ENGINE SPECIFICATIONS

The major specifications of the new V6 engine series are given in Table 1.

Table 1. Engine Specifications

	VQ35DE	**VQ30DE**
Number of Cylinders	6	6
V-angle (degree)	60	60
Displacement (cm^3)	3498	2988
Bore x Stroke (mm)	95.5 x 81.4	93 x 73.3
Compression Ratio	10.0:1	10.0:1
Valvetrain	DOHC 24 valves	DOHC 24 valves
Fuel Supply System	Nissan EGI	Nissan EGI
Fuel	Premium	Premium
Max Power (kW/rpm)	179/6000	166/6400
Max Torque (Nm/rpm)	357/3200	294/4000

REDUCTION OF WEIGHT AND FRICTION

PISTONS – The ADAMS analysis package was used for the VQ35DE to analyze the influence of the excitation forces, stiffness, behavior and offset of the pistons. The results indicated that slap noise could be controlled by reducing the stiffness of the piston skirt while decreasing friction by reducing the piston offset. This would achieve both lower friction and reduced slap noise.

The specific measures taken to reduce the stiffness of the lower part of the piston skirt were to abolish the lower piston rib and to provide a back rib around the pin center. Accordingly, the transfer distance of the load center is shortened when combustion pressure is applied to the piston crown and piston movement becomes smoother, thereby reducing the impact pressure on the bore wall and suppressing piston slap noise.

Because the lower part of the thrust side acts as a slipper, the skirt length can be shortened without affecting the suppression of slap noise, making it possible to reduce friction and weight even more. Further, friction is reduced further and durability against scuffing is improved because the load applied to the piston skirt is reduced by this stiffness reduction. Shortening the piston pin length by tapering the piston pin boss shape has the effect of reducing the bending moment, so the compression height can be lowered to reduce the piston weight. As a result, the piston weight was substantially reduced. Figure 1 shows relationship between piston weight and bore diameter.

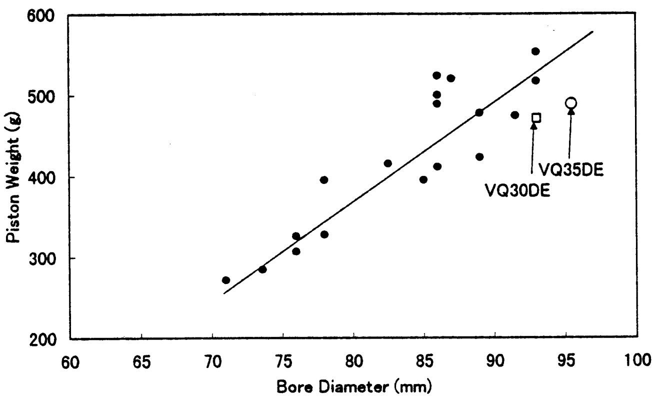

Figure 1. Relationship between Piston Weight and Bore Diameter

CONNECTING RODS – Connecting rods are usually cold coined to correct the deformation induced in the I-section by the heat treatment process. However, the VQ35DE connecting rods are made of vanadium steel, making the heat treatment process unnecessary. I-section deformation is corrected by hot coining to prevent deterioration of fatigue strength due to residual stress and deterioration of buckling strength due to dislocations. This improvement of I-section strength allows the sectional area of the connecting rod to be reduced for a weight saving.

The small end shape has been tapered to reduce friction and weight without increasing pressure on the pin bushing when combustion pressure is applied. The way of fastening the connecting rods was changed from bolts and nuts to bolts only to reduce overall weight. Consequently, their reciprocating inertial mass was considerably reduced. Figure 2 shows relationship between connecting rod weight and displacement. Figure 3 shows relationship between connecting rod I-section area and displacement.

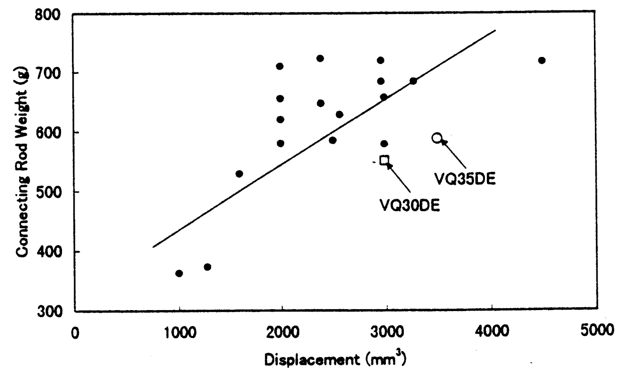

Figure 2. Relationship between Connecting Rod Weight and Displacement

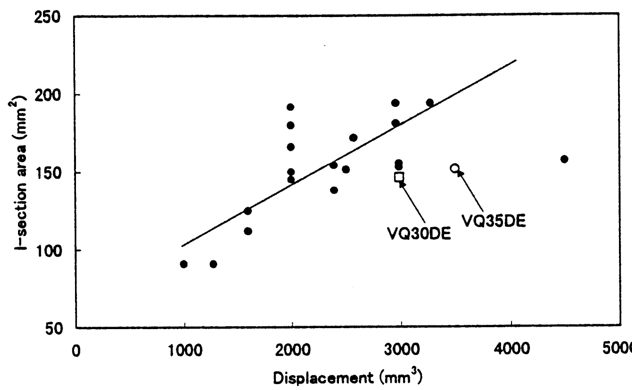

Figure 3. Relationship between Connecting Rod I-section area and Displacement

CRANKSHAFT – The VQ35DE crankshaft pin diameter was thickened to accommodate the increased displacement. But the increase in the diameter was kept to a minimum through the aforementioned weight reduction of the pistons and connecting rods. As a result, the diameter of the crankshaft pin per liter is one of the smallest in the world, making it possible to reduce the inertial mass and friction of all reciprocating parts considerably. Figure 4 shows relationship between crankshaft pin diameter and displacement.

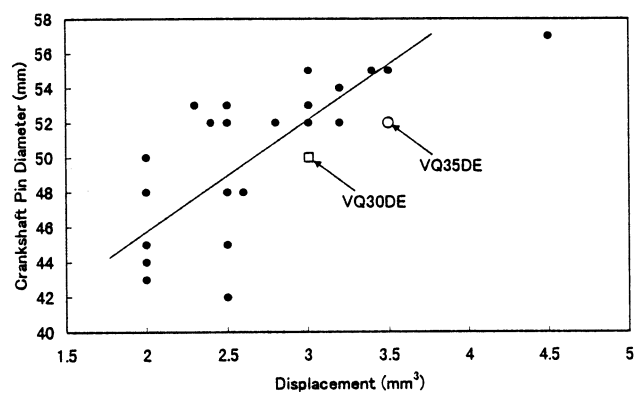

Figure 4. Relationship between Crankshaft pin diameter and displacement

Through the foregoing improvement of reciprocating parts, the friction of the whole engine was reduced to maintain the high response characteristic of the VQ engine.

IMPROVEMENT OF VOLUMETRIC EFFICIENCY

REDUCTION OF INTAKE RESISTANCE – Intake resistance has been reduced in the VQ30DE by adopting a plastic intake manifold so as to reduce surface roughness . It has also been reduced in the VQ35DE through the selection of a suitable diameter of intake port molding sand without increasing the engine cost.

Intake resistance of the VQ35DE has also been reduced by using three-dimensional analysis to define the detailed shapes of the intake manifold.

REDUCTION OF AIR LEAK OF VARIABLE INTAKE SYSTEM – In the VQ30DE, the air leak in the variable intake system has been reduced by adopting a labyrinth structure for the rotary valve, which is used as the inertia adjustment valve. Since the inertia effect can be utilized more effectively, volumetric efficiency is improved.

CONTINUOUSLY VARIABLE VALVE TIMING CONTROL SYSTEM (CVTC) – The VQ35DE adopts a continuously variable valve timing control system that allows suitable valve timing control relative to the engine speed and intake manifold length for improved volumetric efficiency. Figure 5 shows effect of CVTC on volumetric efficiency.

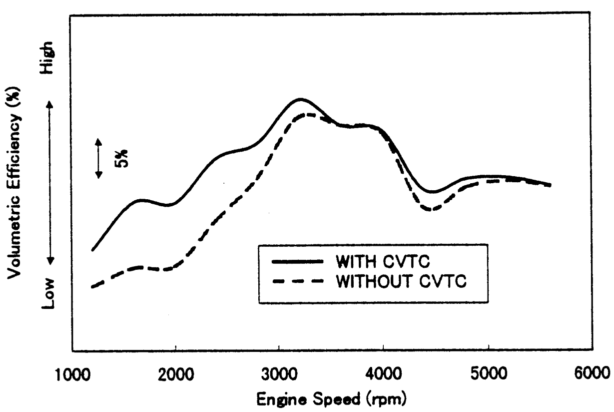

Figure 5. Effect of CVTC on Volumetric Efficiency

These improvements have greatly improved volumetric efficiency over that of the previous engine.

IMPROVEMENT OF THERMAL EFFICIENCY

IMPROVEMENT OF EXHAUST PORT SHAPE – Knock resistance of the VQ35DE has been improved by reducing the temperature around the combustion chamber as a result of improving exhaust gas flow by adopting an improved exhaust port shape. Figure 6 shows air flow mass comparison for exhaust port shapes.

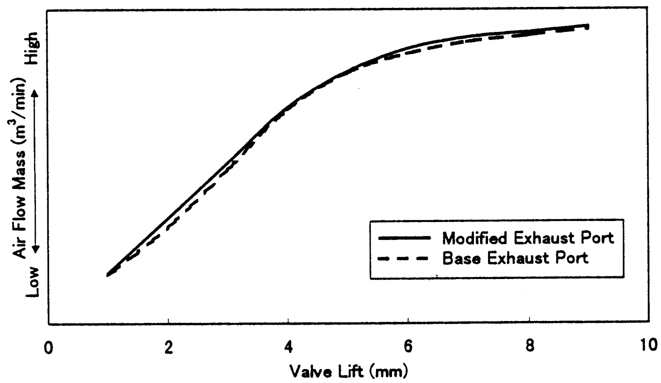

Figure 6. Air Flow Mass Comparison for Exhaust Port Shapes

Consequently, the engine achieves on of the world's highest compression ratio to bore diameter.

IMPROVEMENT OF WATER FLOW BY LONG REACH SPARK PLUG – Cooling performance of the VQ35DE has been improved by expanding the water jacket around the spark plug as a result of increasing the spark plug screw length. Consequently, knock resistance has been improved. Figure 7 shows the effect of the water jacket sectional area on knock resistance.

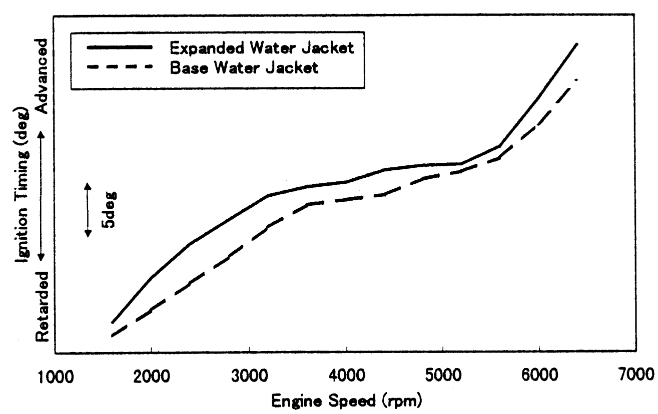

Figure 7. Effect of the Water Jacket Sectional Area on Knock Resistance

TWO-WAY COOLING SYSTEM – Generally, reducing the temperature at which the thermostat valve opens is one way of improving knock resistance. However, this approach reduces the bore temperature more than necessary and consequently may cause friction to increase. To manage both temperatures suitably, a two-way cooling system has been adopted in the VQ30DE and the VQ35DE that switches by means of a thermostat. Figure 8 shows effect of this two-way cooling system on improving fuel economy.

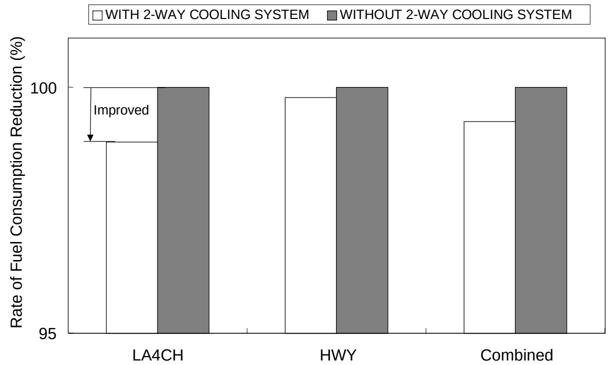

Figure 8. Effect of Two-way Cooling System on Improving Fuel Economy

These measures have improved fuel economy over the level of the previous engine.

REDUCTION OF NOISE AND VIBRATION

Crankshaft stiffness of the VQ35DE has been improved by increasing the crankshaft pin diameter. Furthermore, main journal clearance of the VQ30DE and the VQ35DE was reduced by subdividing the grade of the journal and bearing diameter. Consequently, noise and vibration have been reduced. Figure 9 shows relationship between journal clearance and noise level.

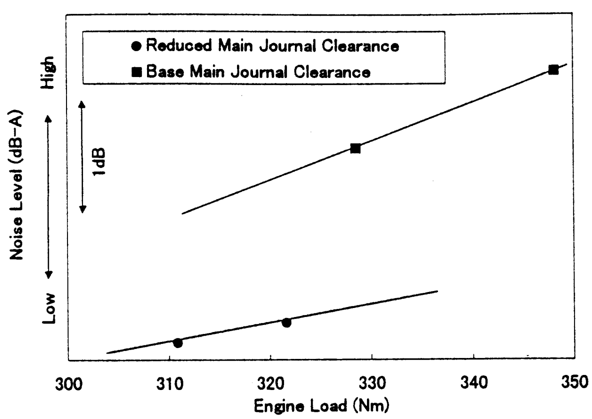

Figure 9. Relationship between Journal Clearance and Noise Level

IMPROVEMENT OF PRODUCTIVITY

Part specifications were determined by taking the factory equipment into consideration to ensure a high rate of automatic assembly. Consequently, these second-generation engines maintain the 70% automatic assembly rate achieved for the VQ engine series.

SUMMARY

Through the improvements described here, this second-generation V6 engine series further improves the excellent performance and high response characteristic of the previous generation. Consequently, the power performance of vehicles fitted with these engines ranks among the highest in the world for passenger cars and SUVs . Figure 10 and 11 shows engine performance curves.

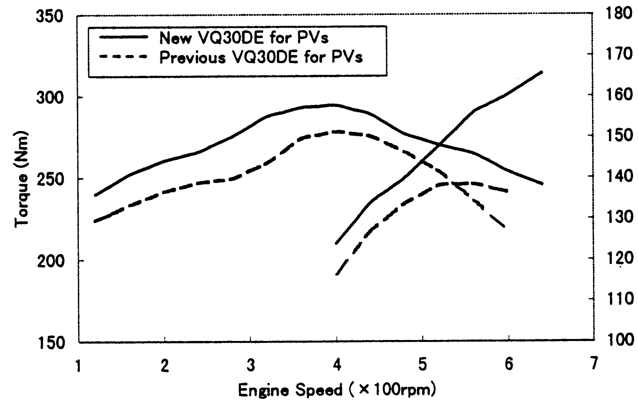

Figure 10. Engine Performance Curves of New VQ30DE

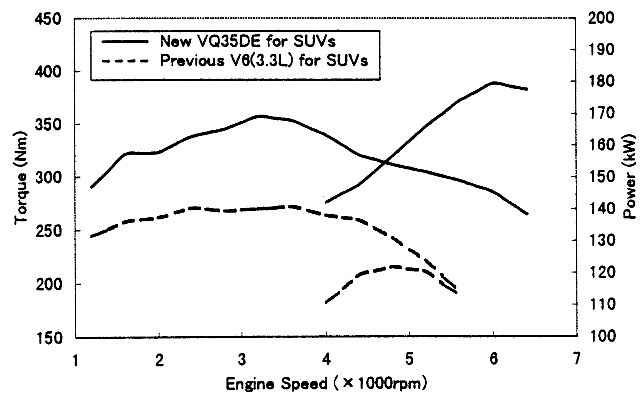

Figure 11. Engine Performance Curves of New VQ35DE

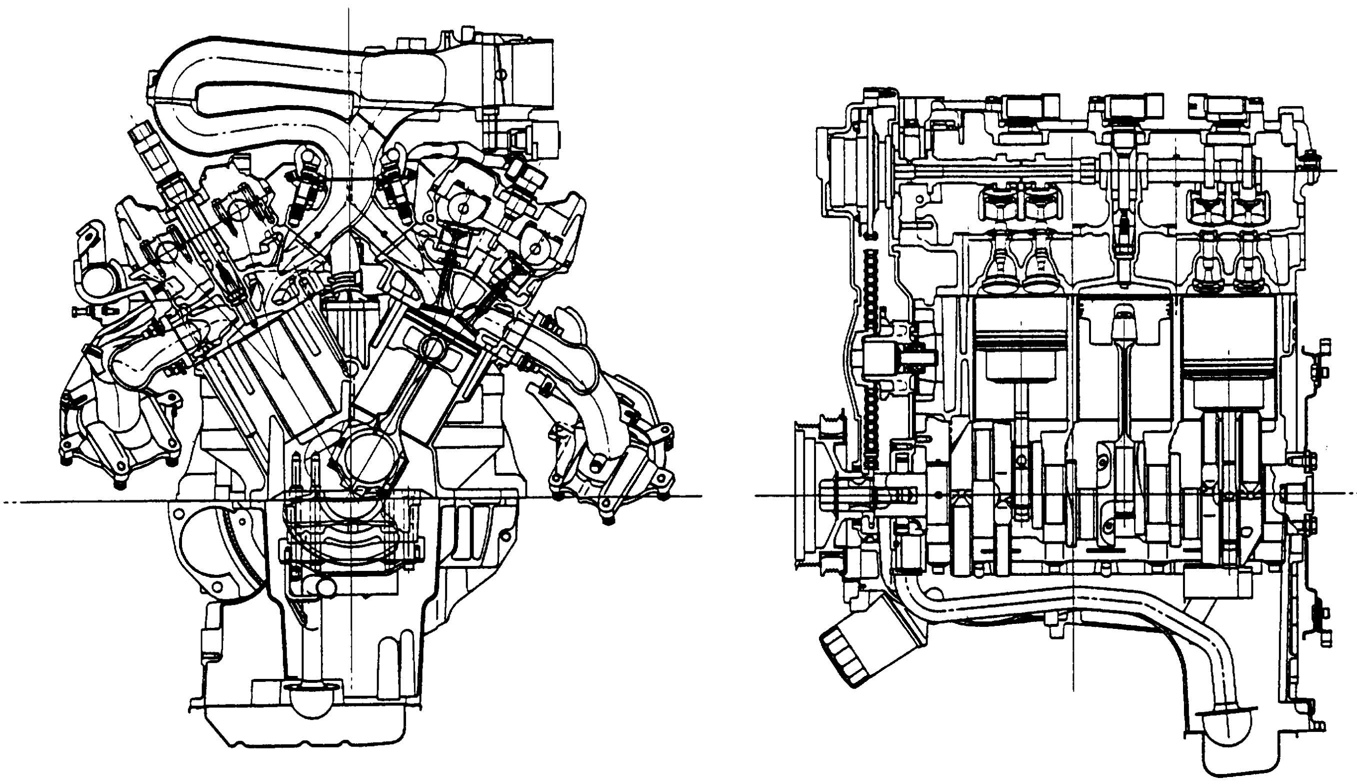

Figure 12.   Sectional View of VQ35DE