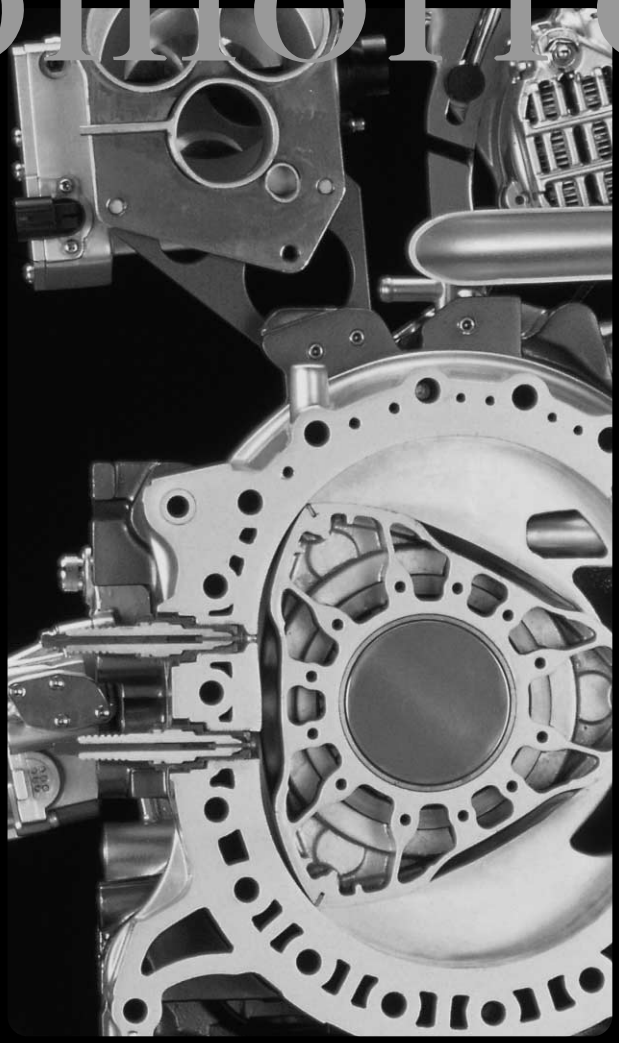
Rotary Engine Today and Tomorrow

Chapter 1



As the sole automobile manufacturer in the world that produces rotary engined cars, Mazda assumes full responsibility for the future of this excellent mechanism. Through 38 years of commitment to the research of the rotary engine, Mazda has developed its high potential and created series-production engines with excellent commercial value. However, our challenge has not yet ceased. This chapter focused on the latest innovations and future technologies of the Mazda rotary engine.

The Rotary Engine: A Technology to Symbolize Mazda's Brand Personality

In 1961 Mazda focused on the development of the newly-invented rotary engine and, after overcoming many engineering challenges, succeeded in making it a viable commercial proposition.

This engine generated power very smoothly by rotation alone. Many talented scientists and researchers from nearly all the major manufacturers had tried in vain to develop this idea—but Mazda persevered with the development and succeeded in commercializing this unique concept. Through the development and success of the rotary engine, Mazda became a household name—even though the company was a relative newcomer to the automobile industry.

But Mazda did not rest on its laurels. Even after becoming, by the mid-70's, the only company designing and producing rotary engine cars, Mazda continued to meet the challenge of improving this unique engine's technology, fuel efficiency and emissions. In fact Mazda devoted itself to developing products that fully expressed the strength and personality of the remarkable rotary engine; compact, lightweight, and high performance. Mazda has introduced dozens of new vehicles powered by the rotary engine, including the legendary Cosmo Sport and the highly-praised RX-7. As of September 1999 the accumulated total production of our rotary engine vehicles had reached nearly 1.8 million.

Mazda has participated in motor sports events around the world to showcase the technological potential and reliability of the rotary engine. The highlight came in 1991 when Mazda's rotary engine car achieved overall victory in the world famous Le Mans 24 Hours race - the first win for a rotary engine and the only win ever for a Japanese car.

Introduction

ary Engine

The rotary engine is a truly unique asset possessed exclusively by Mazda, and we regard it as a technology that symbolizes the personality of the Mazda brand—a personality which is Stylish, Insightful and Spirited.

The Potential of the Rotary Engine

We believe that the rotary engine has enormous potential for the future. The new experimental engine, "RENESIS" which powers the "RX-EVOLV" concept car at the 33rd Tokyo Motor Show, represents such future potential. Due to its compact size, the RENESIS engine allows the RX-EVOLV to accommodate four adults comfortably in a body size of the RX-7, while achieving enhanced driving performance as a true sports car.

The RENESIS is conceived using a side port layout and lighter rotors. As a result, it boasts 280 PS, the highest output ever achieved by a naturally aspirated two-rotor rotary engine and has a 10,000 rev limit. The side port layout has also contributed to improved fuel economy and cleaner exhaust. Such achievement has been enabled by applying Mazda's technologies in many fields such as new materials and combustion.

Mazda awaits with anticipation the reaction of the public and media to this latest development of Mazda's unique rotary engine.

Tadahiko Takiguchi

Senior Managing Director
Mazda Motor Corporation

The RENESIS is Mazda's new-generation rotary engine, which will take this extraordinary power unit into the next millennium. Fully exploiting and enhancing the engine's inherent virtues—the compact size, light weight and high power density, this latest rotary is also environmentally friendly, Mazda's engineers having made great strides in both efficiency and low emissions.

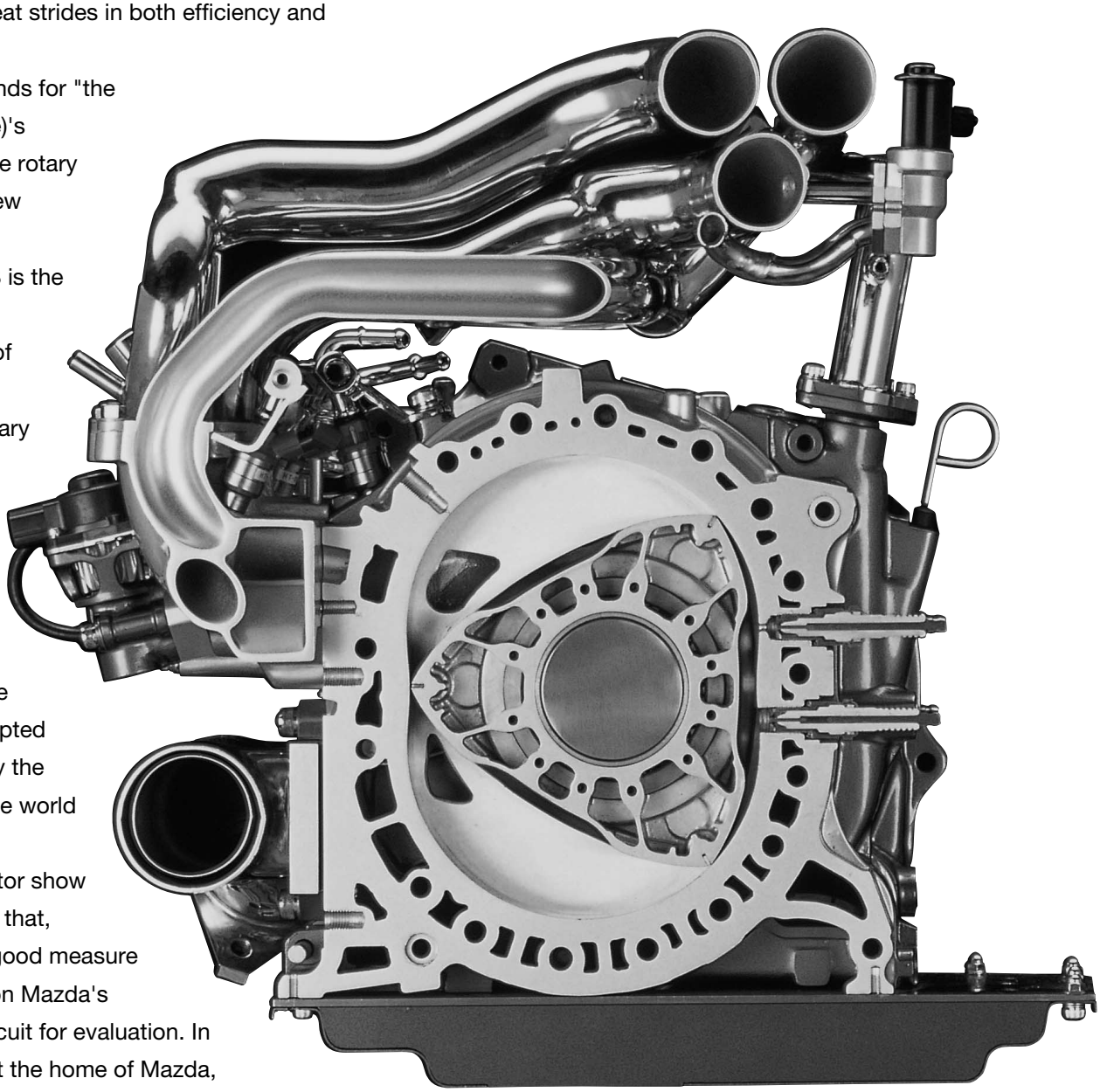
RENESIS stands for "the RE(rotary engine)'s GENESIS", or the rotary engine for the new millenium.

The RENESIS is the development and refinement of the MSP-RE experimental rotary engine which powered the RX-01 concept sports car unveiled at the 1995 Tokyo Motor Show. The RX-01 was accepted with applause by the public all over the world while touring a international motor show circuit and, after that, accumulated a good measure of fast mileage on Mazda's Global Road Circuit for evaluation. In the meantime, at the home of Mazda, the rotary engine development team continued its work to improve the MSP-RE to an entirely new level, one that deserves the new name, RENESIS.

Highest Power Density for Naturally Aspirated Rotary Engine

The RENESIS propels the RX-EVOLV 4-door Sports concept car, an automobile that combines exhilarating performance with superbly comfortable accommodation for four people. The engine produces 280PS(206kW) at 9,000rpm (target value) and 23.0kg-m (226Nm) at 8,000rpm (target value), the highest power density ever achieved by a naturally aspirated rotary engine for a road-going automobile.

The RENESIS' fuel efficiency has been further improved over its predecessor, the MSP-RE experimental engine, which had already improved idling consumption by 20 percent over the 13B-REW unit powering the current Mazda RX-7. This gain has now been extended up to 40 percent.



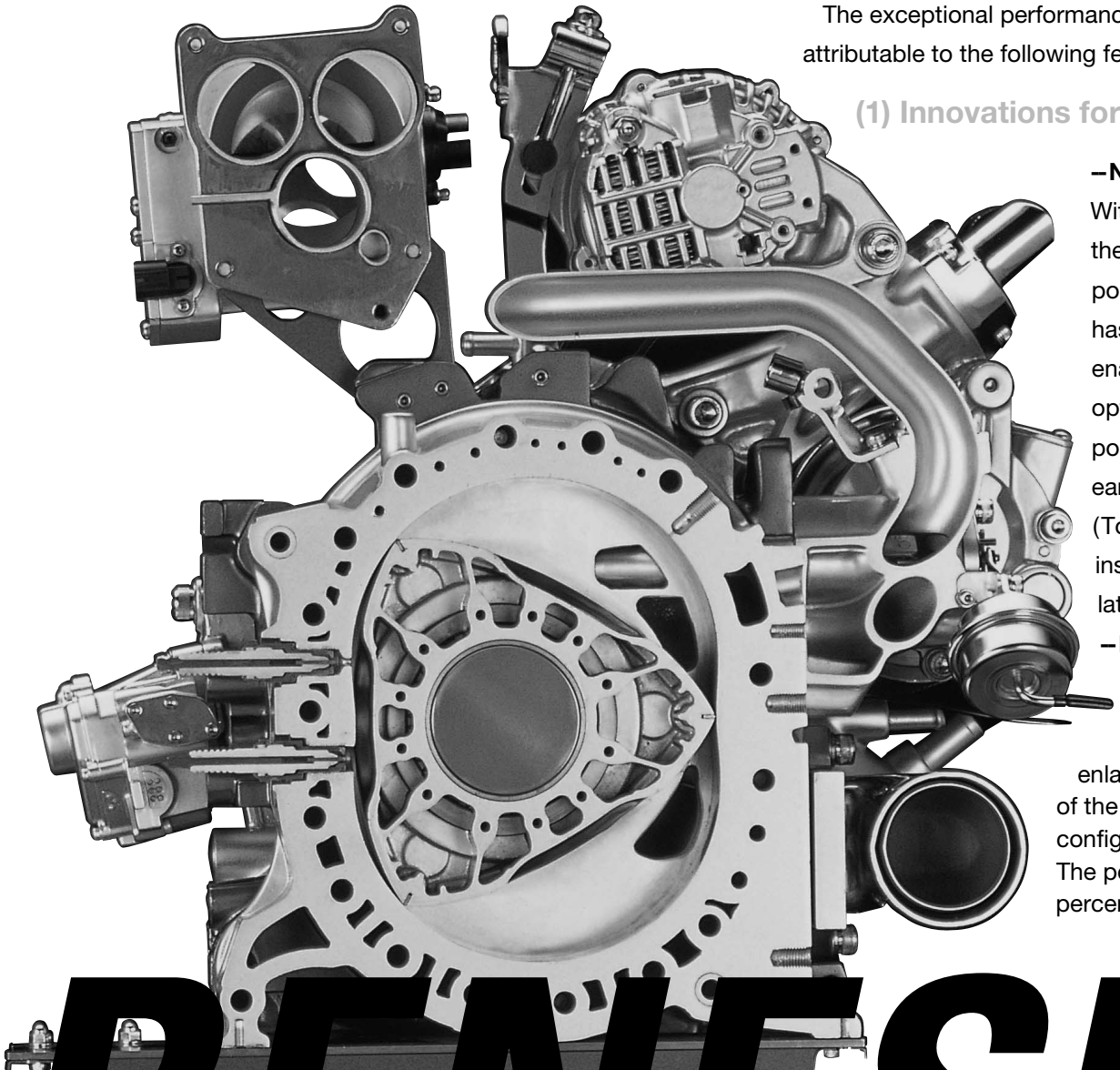
The RENESIS is designed to qualify for the stringent new emission standards, soon to be implemented in Japan, by greatly reducing all three major pollutants in the exhaust gas(NOx, HC and CO), to very low levels.

Side-Exhaust and Side-Intake Ports.

The RENESIS inherits the MSP-RE's port configuration. MSP stands for Multi Side Ports, with both intake and exhaust ports in the side housings of each rotor chamber, versus the successful hallmark design of the series production engine which has side intake and peripheral exhaust ports. Actually, the side-intake, side-exhaust configuration was one of many port variations Mazda's design team had tried in the earliest days of rotary engine research. It was Mazda's mastery of rotary engine gas-and oil-sealing technology that once again directed the designers' attention to the Multi-Side-Port possibility.

The design's potential, however, far surpassed Mazda's expectation, proving its worth in three major areas—performance, fuel efficiency and emission characteristics.

The exceptional performance of the RENESIS is attributable to the following features.



RENESIS

Mazda's Rotary Engine for the Next Millennium

Max.Output:280PS (206kw)/9,000rpm
Max.Torque:23.0Kg-m (226Nm)/8,000rpm

(1) Innovations for Higher Output

—New Port Profiles
With the adoption of the side exhaust ports, port opening overlap has been eliminated, enabling port profile optimization. Intake ports now open earlier, close to TDC (Top Dead Center) instead of opening later.

—Enlarged Port Area
The intake and exhaust port areas have been greatly enlarged, as the result of the new port configuration. The port area is 30 percent larger, as the intake port begins to open, and the exhaust port area, two ports per chamber now, is almost twice as large, improving flow characteristics.

—New Three-Stage Induction System
This system employs variable induction tracts that feed into six ports (three for each rotor

chamber), and utilizes the incoming air's dynamic charge effect to improve filling efficiency. A new variable port control valve has reduced air resistance.

–Lightweight Rotor

Produced through a precision casting technique, which greatly reduces thermal loads, the rotor employed in the RENESIS is lighter by 14 percent than that of the series production unit. As a result, the engine's rev limit becomes 10,000 rpm.

–Higher Compression Ratio

Improved combustion of the RENESIS has allowed the compression ratio to be raised.

(2) Innovations for Improved Fuel Efficiency

–Eliminated Overlap

An improved exhaust port profile eliminates overlap and delays exhaust port opening, increasing the power (expansion) stroke and improving thermal efficiency, without exhaust gas diluting the incoming charge. The engine runs on leaner mixtures without the need for internal exhaust gas recirculation.

– Finer Fuel Atomization

The RENESIS features new small fuel injectors to improve fuel atomization.

– Lean Mixture Setting at High Speeds

The rotary engine's unique combustion characteristics require less enrichment of mixture in a higher speed range than a comparable

The concept car RX-01, powered by the concept rotary engine, MSP-RE, was first unveiled at the 1995 Tokyo Motor Show.

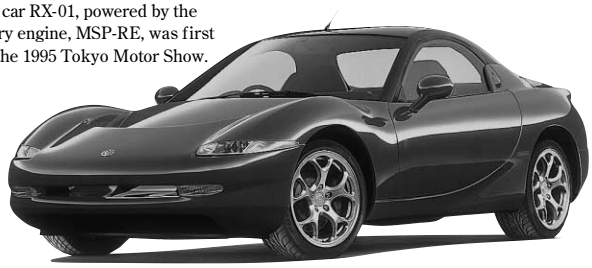


Figure 1 : Compatibility of Performance and Fuel Economy

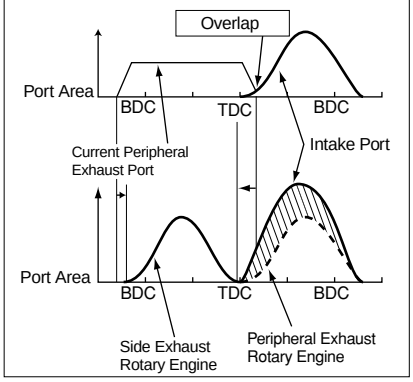


Figure 2 : Increased Intake Port Area

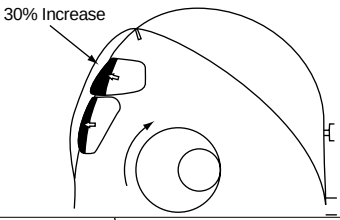
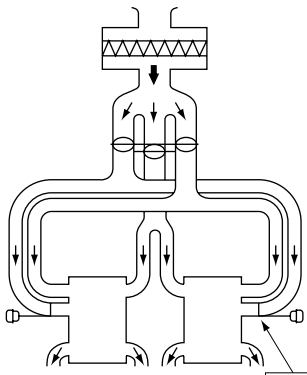
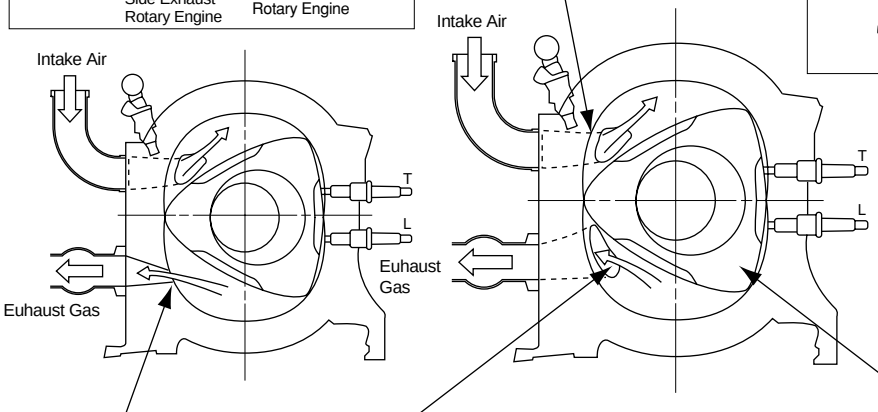


Figure 3 : 3-stage Intake System





TECHNICAL HIGHLIGHTS OF THE RENESIS

By removing the location of the exhaust ports, from the trochoid to the side housings, Mazda engineers eliminated the overlap of the port timing. As a result, the intake port area has been increased and breathing efficiency improved. In addition, the new three-stage induction system maximizes chamber filling and the newly-developed lightweight rotors allow a higher rev limit. Emission of Hydrocarbon has also been reduced with the adoption of the side exhaust ports.

Figure 4 : Reduced Emission of HC

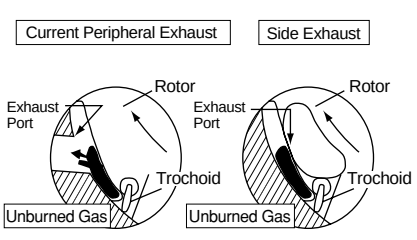
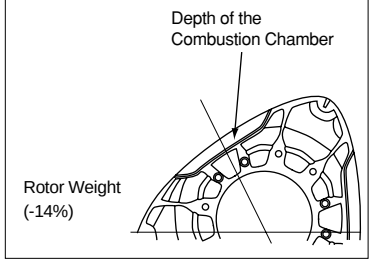


Figure 5 : Lightweight Rotor



reciprocating engine, which relies on strong swirl/vortex during low-and mid-speed operation, and is thus prone to unstable combustion (richer mixtures can overcome the condition at a cost of fuel consumption).

(3) Innovations for Lower Emission

–Reduced Emission of Hydrocarbon

With the adoption of the side-exhaust layout, unburned hydrocarbons no longer escape into the exhaust port, and is trapped within the chamber, carried over and, burnt in the following cycle.

–Improvement in the Catalyst System

A double-skin exhaust manifold maintains a high exhaust gas temperature to improve catalyst activation. The catalyst itself is now a two-stage type with manifold and underfloor converters.

(4) Other Innovations

– Tighter Sealing and New Management System

The gas- and oil-sealing of the RENESIS is unique and specific to the new port design: it ensures tight sealing, a major factor in the engine's performance, fuel efficiency and reduced emissions. The RENESIS also adopts an entirely new engine management system, even more advanced than the state-of-the-art oxygen-sensor feedback system.

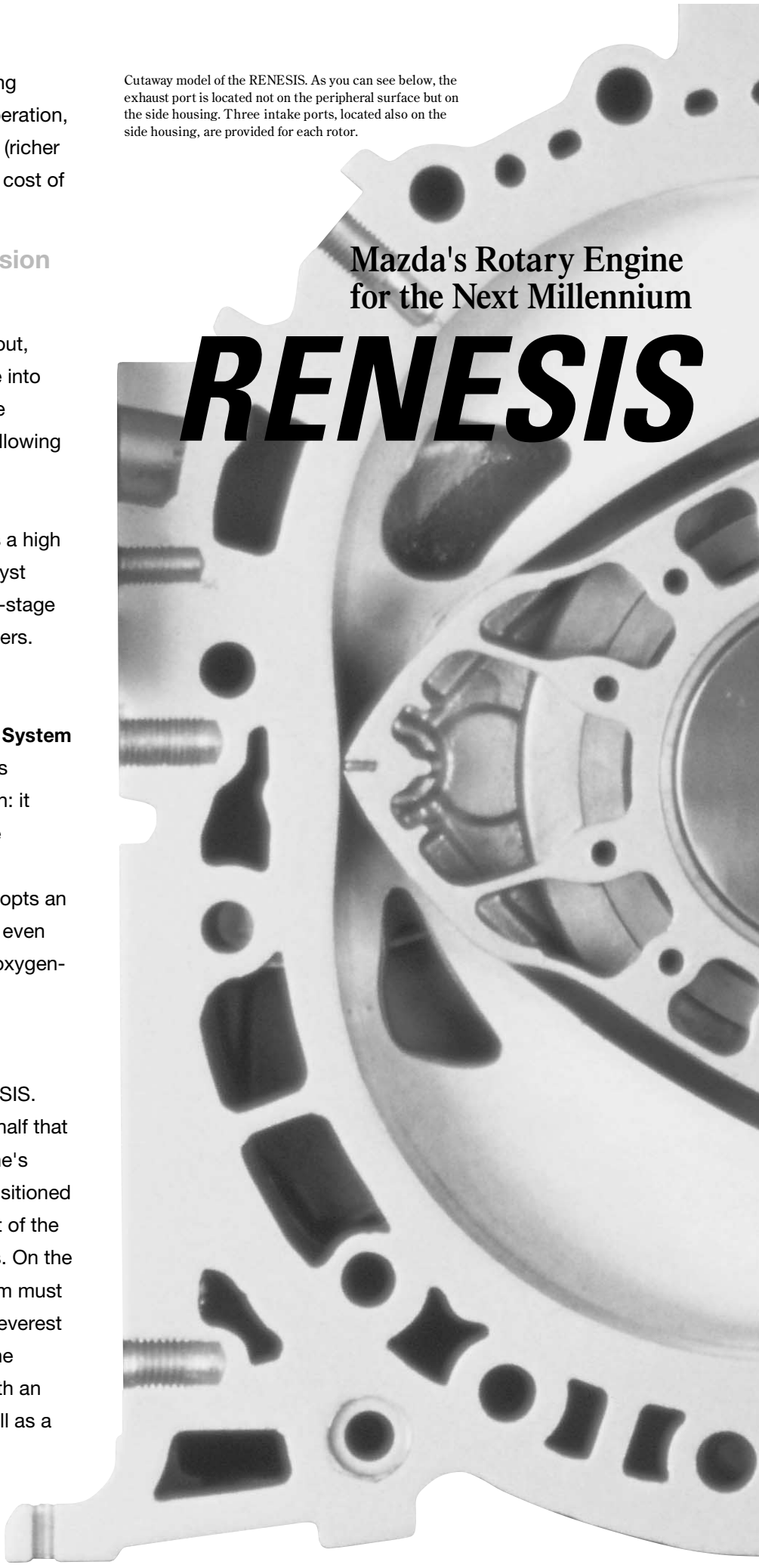
– New Wet-Sump Lubrication System

A new low-height, lightweight lubrication system has been developed for the RENESIS. The oil pan's 40-mm depth is about one-half that of a conventional oil pan. The rotary engine's advantage is that the eccentric shaft is positioned higher than a conventional crankshaft, out of the sump, and thus free from windage losses. On the other hand, the engine's lubrication system must ensure a supply of lubrication under the severest of lateral acceleration, as high as 1.0G. The RENESIS system has a widened sump with an elaborately shaped baffle chamber, as well as a high-suction strainer. The low-height wet-sump is about 3 kg lighter than a comparable dry-sump system which requires an engine-driven twin-pump installation and a lubricant reservoir.

Cutaway model of the RENESIS. As you can see below, the exhaust port is located not on the peripheral surface but on the side housing. Three intake ports, located also on the side housing, are provided for each rotor.

Mazda's Rotary Engine for the Next Millennium

RENESIS



13B-REW

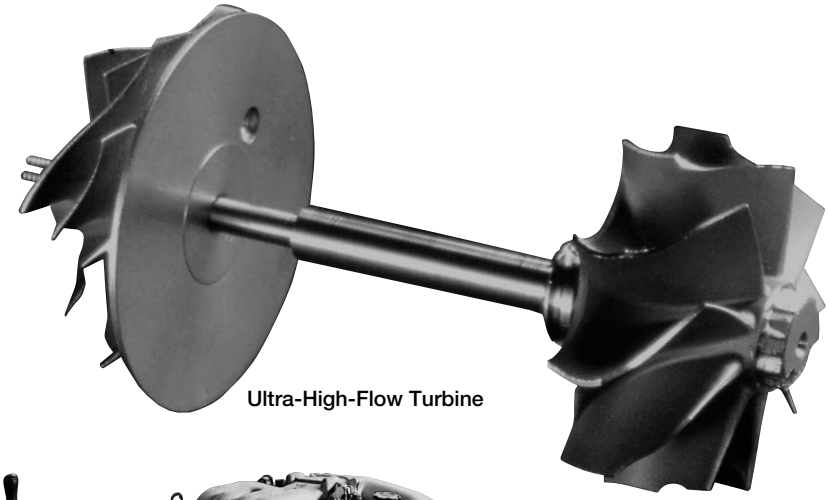
The Latest Version of Mazda's Series Production Rotary Engine Developing 280 PS, the Highest Power Available in the Domestic Cars.

The 13B-REW powering the current Mazda RX-7 is the world's only rotary engine for series production cars. The latest version of the proven type 13B two rotor unit, it features Mazda's unique Sequential Twin Turbo and offers outstanding power and response.

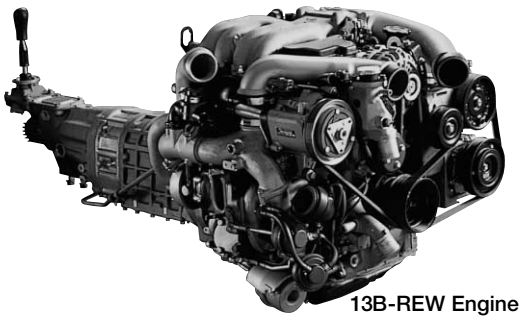
Late last year, the engine was comprehensively improved and its maximum power increased up to 280PS, the highest mark of any automobile engine available in Japan. The components then modified include the turbocharger, lubrication system, exhaust system and the cooling system. As a result, torque in the mid speed range (over 2,500 rpm) has been increased by 2.0 kg-m, contributing to improved driveability in daily use, while at speeds over 5,000rpm, output has been increased by 15 to 18 PS for even more striking performance at the top end.

Improved Efficiency and Greater Air Flow

The Sequential Twin Turbo developed by Mazda has been praised for its high supercharging efficiency over the whole speed range. To further enhance this attribute, Mazda engineers incorporated several new



Ultra-High-Flow Turbine

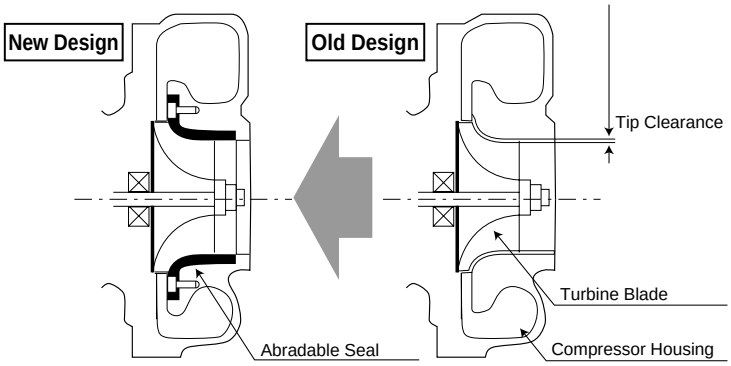


13B-REW Engine

Ultra-High-Flow Turbine adopted on the latest version of the 13B-REW. The turbine's outer diameter(50mm) is smaller than the previous design, but the increased inclined angle and extended length of the blade resulted in reduced inertia mass and increased air flow.

Adoption of Abradable Seal

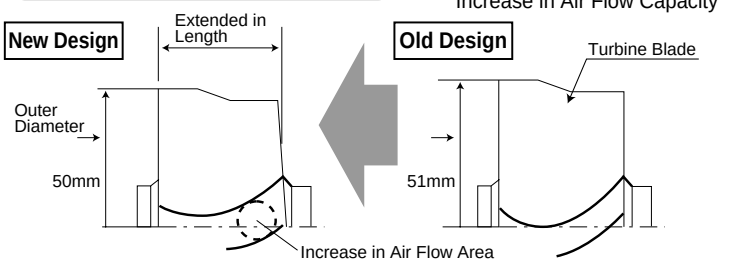
Improvement in Compressor Efficiency



After assembly has been completed, each turbine is spun at high speed and wears the resin surface to create a custom precision fit to its housing.

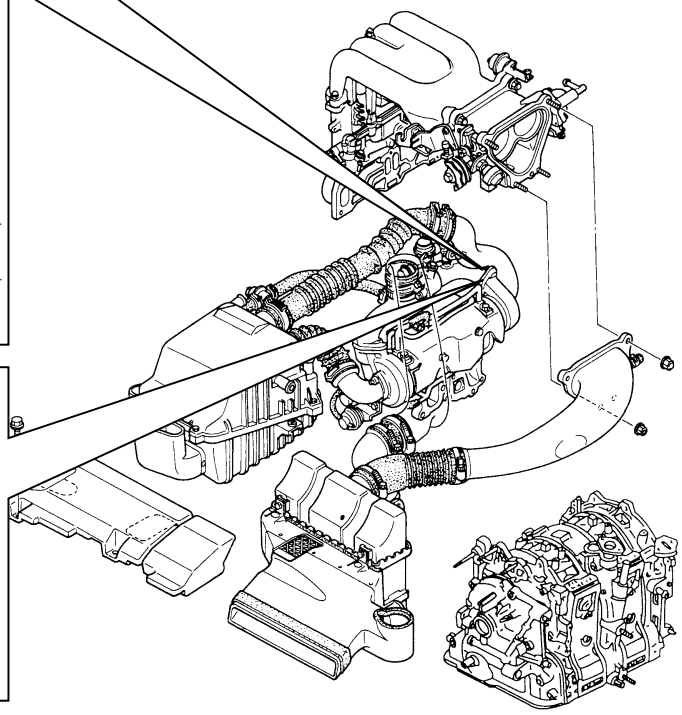
Ultra-High-Flow Turbine

Increase in Air Flow Capacity



The new turbine blade is smaller in diameter but larger in length.

The abradable seal is a device which is made of special resin and minimizes clearance between the turbine blade and housing of the compressor.



Face-lifted in late 1998, the mazda RX-7 has a new front fascia with enlarged air intake areas for enhanced cooling efficiency.

features.

First of all, to minimize clearance between the turbine blade and its housing, Mazda introduced the abradable seal on the compressor turbine. The seal is made of a special resin. After assembly has been completed, each turbine is spun at high speed and wears the resin surface to create a custom precision fit to its housing. This assembly method also minimizes differences in clearance among individual units and ensures optimized efficiency.

At the same time, the turbine blade itself was improved, reducing outer diameter from 51mm to 50mm and increasing blade's angle of inclination for reduced inertia mass and accelerated air flow. In addition, to make maximum use of the rotary engine's inherent strong exhaust pulses and further increase air flow, the blade has been extended in length.

With the adoption of this "Ultra-High-Flow Turbine", efficiency of the turbochager has been improved by 10% and the maximum boost pressure raised from 470 mmHg to 560 mmHg, contributing greatly to the engine's higher output.

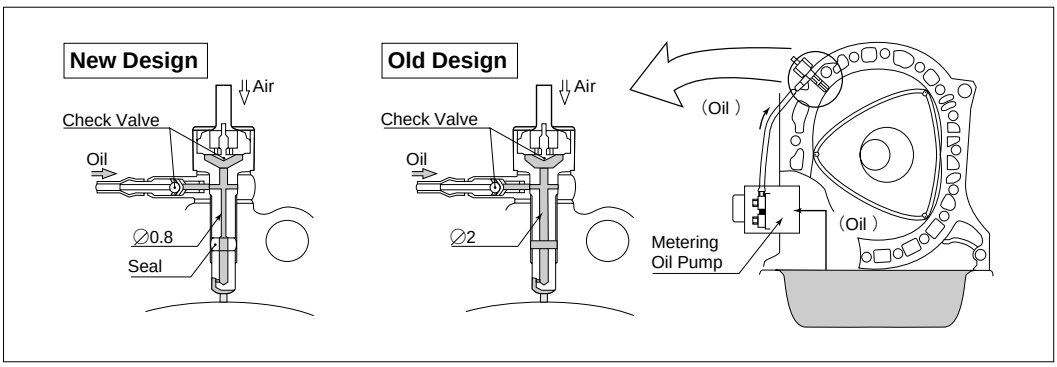
Improvements in Lubrication, Exhaust and Cooling Systems

Mazda's work on the 13B-REW had yielded impressive results in power and performance due to the turbo changes, therefore lubrication became even more critical, particularly lubrication of the apex seal. Mazda therefore decided to redesign the metering oil supply nozzle located on the torochoid housing to improve the feeding response of the lubridation. As a result, oil supply to the inner surface of the trochoid housing has become quicker and the lubrication of the apex seal more stable even during sudden accelerations.

On the other hand, improvements of the exhaust system included the use of 0.5~1.0mm thinner sheet metal in the front pipe wall, which increased exhaust flow area, as well as a change in the interior of the main silencer. These two improvements resulted in lowered exhaust backpressure (by 10% or about 100mmHg) for a substantial increase in engine power.

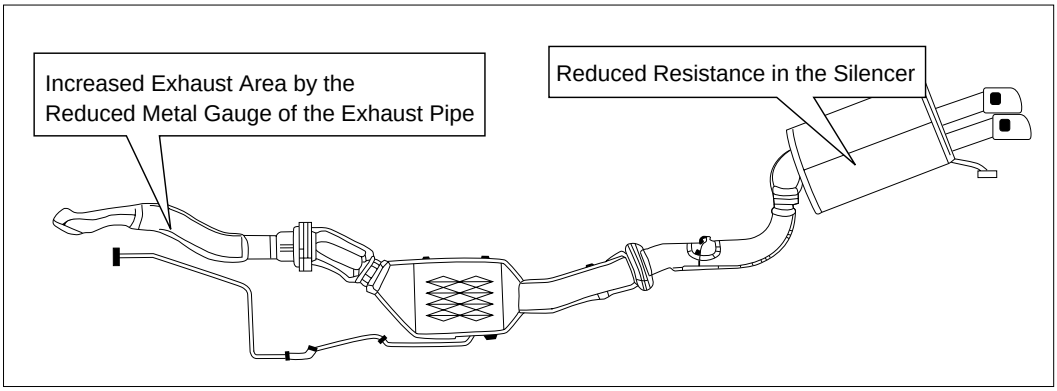
In addition, the enlarged air intakes in the car's front end also contributed to the enhanced performance of the 13B-REW. The RX-7's new front fascia design allowed an increase in cooling air intake area, by 110% for the radiator, by 80% for the intercooler, and by 80% for the oil cooler, respectively. Improved efficiency of the intercooler had a direct effect on the engine's performance, while the enhanced cooling capacity of the radiator, complemented by increased core thickness, helps improve the engine's reliability.

Improvement in Lubrication System



A higher output and higher rev limit means a greater load on the rotor's apex seals. Mazda therefore redesigned the nozzles which lubricate the inner surface of the rotor housing and improved response in oil supply.

Reduced Exhaust Resistance



To accommodate the increased exhaust flow, caused by the enhanced power output of the 13B-REW, Mazda modified the main silencer of the RX-7 (as shown in the right figure) andreduced exhaust backpressure.

13B-REW

The Latest Version of Mazda's Series Production Rotary Engine developing 280PS, the Highest Power Available in the Domestic Cars

Major Specifications of the 13B-REW Engine

Tuning Level			280PS	265PS	255PS
Model Code			13B－REW		
Type			Gasoline, Rotary Piston		
Total Displacement ℓ			0.654×2		
Number of Cylinder			Inline 2-rotor Longitudinaly-mounted		
Valve Mechanism			—		
Bore×Stroke mm			240.0×180.0×80.0 (Rotary)		
Compression Ratio			9.0：1		
Maximum Output (JIS net) PS / rpm			280 / 6,500	265 / 6,500	255 / 6,500
Maximum Torque (JIS net) kg-m / rpm			32.0 / 5,000	30.0 / 5,000	30.0 / 5,000
Port Timing	Intake	Opening	Primary －45° Secondary －32° BTDC		
		Closing	Primary 50° Secondary 50° ABDC		
	Exhaust	Opening	75° BBDC		
		Closing	48° ATDC		
Idling Speed rpm			700		700 (in P-position)
Lubrication System	Type		Forced Supply		
	Oil Pump		Trochoid Type		
	Oil Cooler		Independent, Air-cooled		
Cooling System	Type		Water-cooled, Electric-powered		
	Radiator		Sealed-type		
Supercharger Type			Turbo		
Intercooler Type			Air-cooled		
Air Purifier		Type	Paper Filters		
		Number	1		
Fuel Pump			Electric		
Fuel Injection			Electronic		
Jet Nozzle	Type		Pintle-type		
	Nozzle	Number	1		
		Diameter mm	1.31 (primary) 2.34 (secondary)		
	Injection Pressure kg/cm²		2.55