Technical Highlights of the RENESIS Rotary Engine

The RENESIS engine installed in the RX-8 has its roots in the MSP-RE, unveiled at the 1995 Tokyo Motor Show as the power unit for the RX-01 concept sports car. The name RENESIS was given to the engine as exhibited in the 1999 iteration of the RX-01, after which RENESIS was meticulously prepared for series production.

By capitalizing on the intrinsic benefits of the RENESIS rotary engine—namely, low weight, compact size and high performance—Mazda was able to develop the RX-8, a wholly new concept, 4-door 4-seater genuine sports car. RENESIS is a 654cc x 2 rotor engine that generates an outstanding 250 PS (184 kW) maximum power at 8500rpm and 216 N.m (22.0 kg-m) maximum torque at 5500rpm*. Thanks to its naturally-aspirated design, the engine realizes smooth, crisp response right up to very high speeds. RENESIS also shows a vast improvement over the engine installed in the RX-7 in terms of fuel-efficiency and exhaust gas emissions. All of this was made possible by MDI (Mazda Digital Innovation) which allows the use of the same 3-D data from planning through to production, and the establishment of innovative measuring technology. One concrete example of a technical breakthrough achieved this way is the cut-off seal that prevents blow-by of gases between the intake and exhaust ports which are located on the same surface.

The name RENESIS stands for "the RE (rotary engine)'s GENESIS". The following account describes the inherent qualities of the new engine and the numerous innovative technologies by which they are realized.

* Figures are for the 6-port engine. Maximum power output is the specification for Japan and North America. Please see the table at right for details.

■ Side-Exhaust and Side-Intake Ports

A key innovation for the RENESIS is its side-exhaust and side-intake port configuration. Previous RE designs located the exhaust ports in the rotor housing (peripheral port), whereas the latest version has its exhaust ports in the rotor housing, where the intake ports are also located.

The chief advantage of this side-exhaust/side-intake port layout is that it permits elimination of intake/exhaust port timing overlap, eliminating the retention and carry-over of exhaust gas and encouraging more stable combustion. In addition, where the previous engine had one peripheral exhaust port per rotor chamber, RENESIS has two side ports, approximately doubling the port area. The new exhaust arrangement reduces exhaust gas flow-resistance, and while assuring ample exhaust port area, allows delay of the exhaust port opening for a longer expansion cycle, to raise thermal efficiency, power output and fuel economy.

Another major advantage of the side exhaust port is that it allows engineers more freedom to optimize port profiles. With RENESIS, both the 6-port engine and the 4-port engine have intake port cross-sectional area almost 30% greater than the previous engine. Additionally, the intake port closes later, resulting in increased intake volume and more power.

With the previous engine, unburned gases (hydrocarbons) were voided from the combustion chamber via the exhaust port. With the side-exhaust ports of the RENESIS, unburned gases are retained for burning in the next combustion cycle, further reducing regulated emissions.

■ **Engine performance**

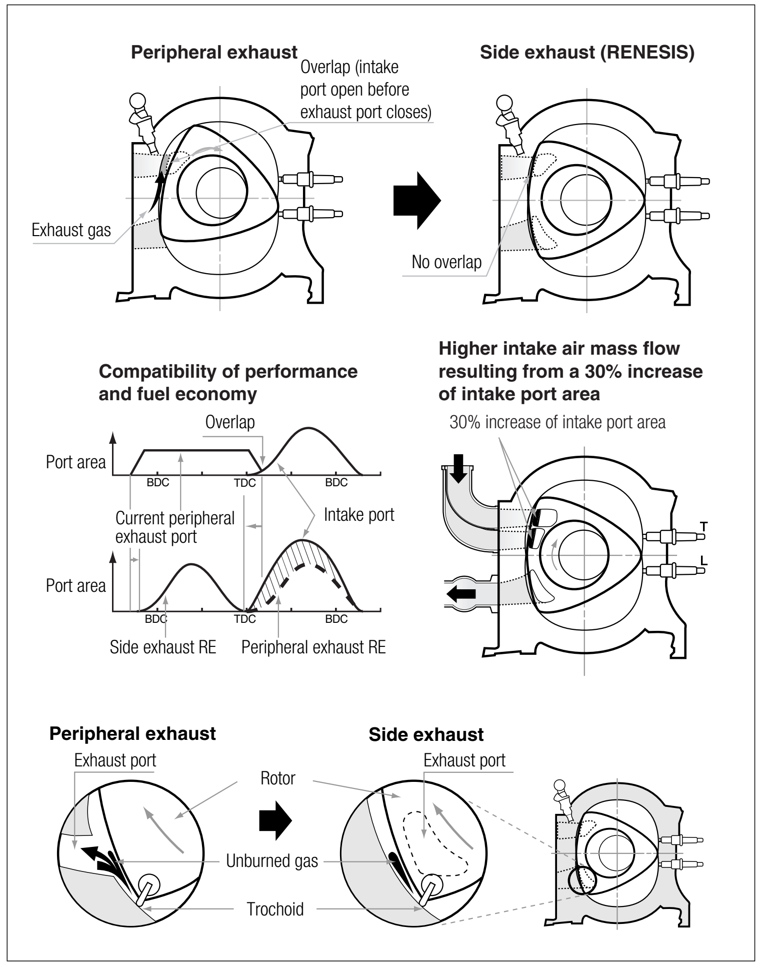
		Maximum Power	Maximum Torque	Rev Limit
6-port engine	Japan (6MT)	184kW(250PS) @8500rpm	216N-m(22.0kg-m) @5500rpm	9000rpm
	Japan (6AT)	184kW(215PS) @7450rpm	216N-m(22.0kg-m) @5500rpm	7500rpm
	NA (6MT)	232HP @8500rpm	159lb-ft @5500rpm	9000rpm
	NA (6AT)	232HP @7500rpm	216N-m(22.0kg-m) @5500rpm	7500rpm
	Australia (6MT)	170kW(231PS) @8200rpm	211N-m @5500rpm	9000rpm
	Australia (6MT)	170kW(231PS) @8200rpm	211N-m @5500rpm	
4-port engine	Japan (5MT)	154kW(210PS) @7200rpm	222N-m(22.6kg-m) @5000rpm	7500rpm
	Australia (4EAT)	141kW(192PS) @7000rpm	220N-m @5000rpm	
	EU (5MT)	141kW(192PS) @7000rpm	220N-m @5000rpm	

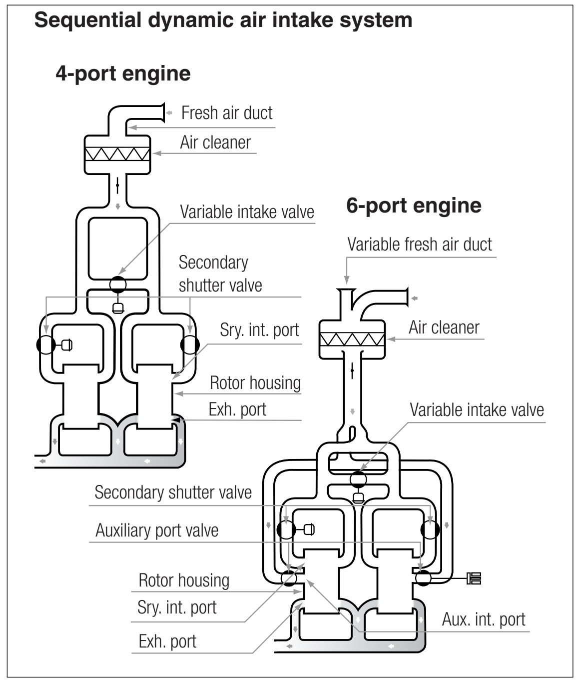
■ Technologies for Higher Output

Sequential dynamic air intake and electronic throttle

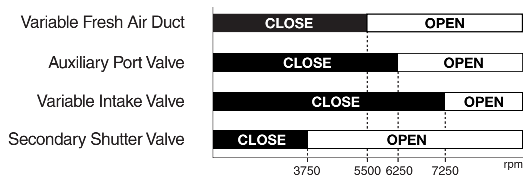
Thanks to the side-intake/side-exhaust port layout with its 30% increase in port area, and the later closing of the intake port, RENESIS receives a sizable increase in charging volume for higher power output. Additionally, the engine incorporates innovative technology designed to boost filling efficiency.

The 6-port engine has 3 intake ports per rotor chamber: primary, secondary and auxiliary (giving a total of 6 intake ports for the twin rotor RENESIS engine), with timing different for each port. The sequential dynamic air intake system (S-DAIS) operates in response to engine speed by controlling the secondary and auxiliary ports, and opening/closing the variable intake valve installed upstream of the secondary port's shutter valve. In this way, the system achieves optimal control of intake pressure propagation for each port. RENESIS also takes full advantage of the twin rotor's charging effect to boost intake for more substantial low-to-mid range torque as well as increased torque and power output at higher engine speeds. Since all valves are formed to streamline flow through the intake passage during valve opening/closing, intake resistance is substantially reduced. The intake system on the 4-port engine has 2 intake ports per rotor, for a total of 4. Intake ports are controlled by opening/ closing of a variable intake valve governing use of the secondary intake port.





■ **Sequential dynamic air intake system and variable fresh air duct switching timing (6-port engine)**

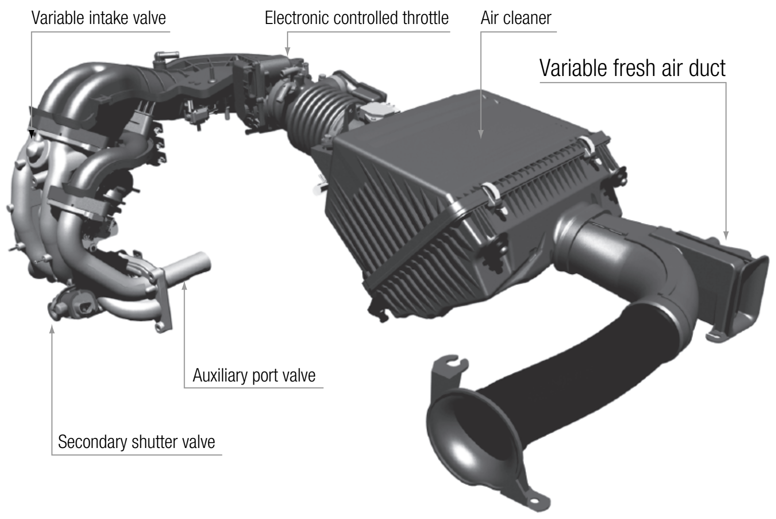


First, at low engine speeds, only the primary intake port is used, speeding intake flow for improved low-end torque. Next, the secondary port comes into operation at around 3750rpm through the opening of its shutter valve, slowing intake flow to increase low- and mid-range torque. In addition, the 6-port engine's auxiliary port opens at about 6250rpm to maximize intake port area and boost high-end torque and power output to the upper limit. Finally, with the 6-port engine, the variable intake valve opens at around 7250rpm (approximately 5750rpm in the 4-port engine), effectively lengthening the intake manifold for improved mid-range torque.

RENESIS also features an electronic throttle system to optimize response to signals generated by the degree and speed of accelerator pedal operation. The engine displayed at the 2001 Tokyo Motor Show had a twin type electronic throttle, but with the advent of the sequential dynamic system and variable fresh air duct, the twin throttle has been replaced with a single type for more accurate and reliable control.

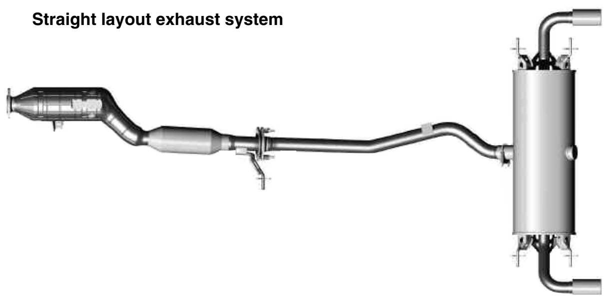
In addition, the naturally aspirated engine generates a suitably sports car-like engine note—one more way that RENESIS enhances driving enjoyment.

Variable Fresh Air Duct (FAD)
The 6-port engine incorporates a variable fresh air duct (FAD) in addition to the large, low flow-resistance air cleaner. The variable FAD has a shutter valve that opens at around 5500rpm to shorten the air intake manifold upstream of the air cleaner, and work in tandem with the variable intake valve to boost torque and power at high engine speeds. Also, an insulation plate is fitted just below the large air cleaner to isolate it from hot air from the radiator. This lowers the air temperature for improved torque in the regular engine speed range.



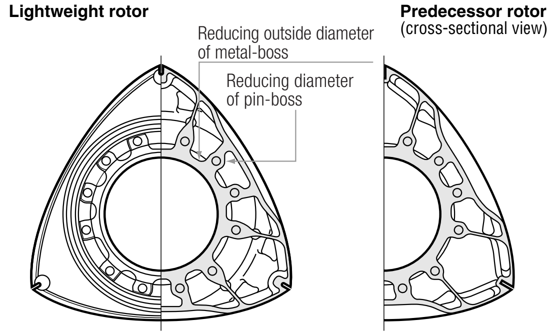
Straight Exhaust System Layout
To achieve a smooth flow of exhaust gases, the RENESIS exhaust system, including the exhaust manifold, was made as straight as possible. The system employs large diameter exhaust pipes and high capacity main silencer with the inlet pipe located straight through the center of the silencer body to reduce flow resistance. These measures contribute to the engine's high power output.

Straight layout exhaust system



■ Technology for Improved Engine Response

Lightweight rotors, lightweight flywheel and triple fuel injectors per rotor chamber
The previous 13B-REW engine generated its maximum power output at 6500rpm, whereas the power peak of the RENESIS rotary engine (6-port version) comes in at 8500rpm. This evolution to a higher revving engine was



achieved by virtue of a 5 percent reduction in rotor weight. Additionally, the flywheel weight has been reduced by some 15 percent compared with the previous engine. In combination, these weight-saving measures reduce inertia. In addition, RENESIS rotary engine's (6-port version's) triple fuel injectors, electronic throttle and 32-bit PCM (Powertrain Control Module) achieve more precise control of air-fuel metering and minimize throttle response lag, realizing the kind of engine response essential to a sports car.

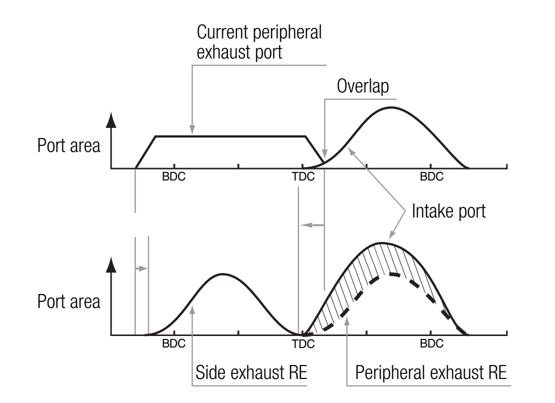
■ Technology for Low Vibration and Distinctive RE Sound

Dynamically balanced rotors
To further refine the superior balance afforded by the twin-rotor configuration, Mazda shifted from the previous static balance setting, and instead adopted dynamic balance calculated from the mass of oil entering the rotors, thereby achieving a further reduction in vibration at high engine speeds. This improvement, together with the effect of the long span engine mount system realizes extremely low vibration during acceleration.
Intake and exhaust sound tuning
RENESIS has a lower frequency exhaust note than the high-pitched tone of the previous rotary engine. The new rotary is characterized by a dry, clear exhaust sound. To achieve this distinctive exhaust note, Mazda engineers employed the exhaust silencer and intake resonator for intake/exhaust tuning. The result is a major feature of RENESIS—a visceral sound that directly communicates the character of the engine.

■ Technology for Fuel Economy

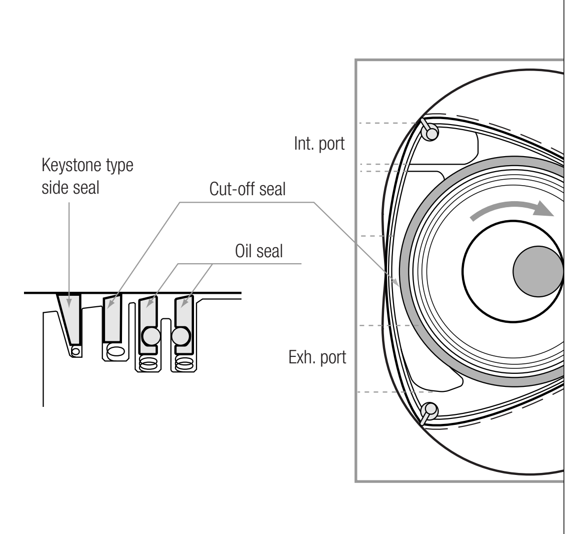
Eliminating Intake/Exhaust Port Timing Overlap
RENESIS eliminates intake/exhaust port timing overlap so that exhaust gas is not retained in the intake charge, thereby promoting more stable combustion. RENESIS has exhaust port area almost twice the size of the previous engine's, which means that the timing of the exhaust ports' opening can be retarded without sacrificing exhaust port area. This measure lengthens the

Eliminating intake/exhaust port timing overlap



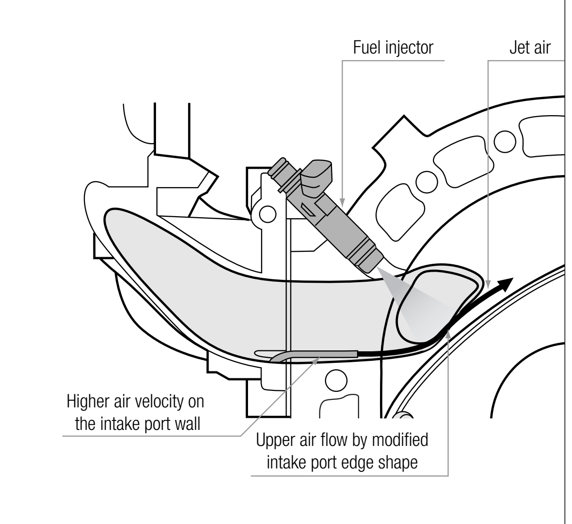
expansion cycle to improve thermal efficiency and fuel economy.
Cut-off Seals and other newly designed seals
The RENESIS engine has its intake and exhaust ports located in the side housing. With this configuration, blow-by of gases tends to occur between the intake and exhaust ports via the slight gap between the oil seals (corresponding to the piston rings in a reciprocating engine) and side seals on the rotor's side. Under these circumstances, even in the absence of timing overlap between intake and exhaust ports, retention of some exhaust gas for the next intake cycle cannot be prevented. To solve the problem, RENESIS employs an additional cut-off seal located between the oil seals, to ensure almost total elimination of blow-by owing to its tight sealing efficiency. This newly developed gas seal was the technological breakthrough needed to allow the successful design of the side exhaust port engine, and it was achieved through the use of MDI (Mazda Digital Innovation) which allows the use of the same 3-D data from planning through to production, innovative measuring technology for strict inspection and analysis, sophisticated systems aimed at high-quality manufacturing, and a flexible approach to problem-solving.

RENESIS oil and gas seals



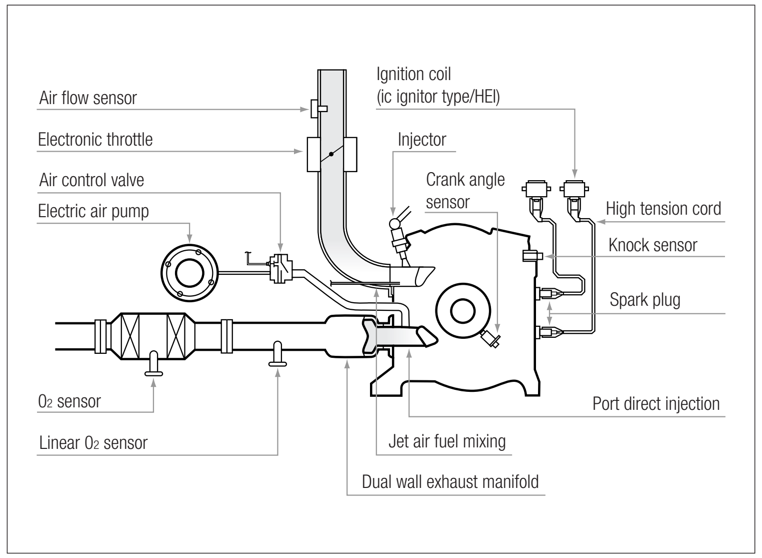
Side seals are a new keystone-type with wedge-shaped section. Exhaust gas build-up against the side seal can easily cause carbonization, but with the wedge-shaped or cuneiform side seal, the seal shape is optimized to remove carbon. The shape is also more congruent to its opposed frictional surface, achieving much better sealing proficiency.
Jet Air-Fuel Mixing System
The primary intake port's injector is an ultra-fine atomizing, 12-hole type (the other injectors are 4-hole types), and in addition RENESIS is equipped with a new Jet Air-Fuel Mixing System that strongly promotes the dispersion and mixing of fuel. The system utilizes port air bleed in the intake port to effectively speed the flow of air over the intake port walls and boost atomization of fuel particles adhering to them. The lower end of the intake port is also shape-optimized to promote movement of fuel along the air stream towards the spark plug, achieving ideal mixing conditions for air and fuel.

Jet air fuel mixing system



Micro-electrode spark plugs
The last technology employed in aid of fuel economy for the RENESIS engine is the micro-electrode spark plug. This spark plug uses a small side electrode and thick gauge central electrode with an extremely fine tip that promotes stable ignition of lean air-fuel mixtures. Also, by maintaining a lower temperature for side and central electrodes, the plug achieves high heat-resistance. The tip of the central electrode, which was previously platinum, is now made of longer-lasting iridium.

■ Technology for Lower Emissions



Emission table

Market	Model	Emission
Japan	6-port engine (6MT/6AT) 4-port engine (5MT)	2005 regulation
North America	6-port engine (6MT) 4-port engine (6AT)	Calif. LEV2-A Fed.T2 Bin5-A
Europe	6-port engine (6MT) 4-port engine (5MT)	Stage IV
Australia	6-port engine (6MT) 4-port engine (4EAT)	Stage III

Reduction of unburned gas emission and fast activating catalytic converter

The RENESIS engine retains unburned hydrocarbons from one cycle for combustion in the next—a process that vastly reduces emission of unburned gases in the exhaust. Also, when the engine starts, secondary air is introduced into the exhaust by an electric pump to promote re-burning of gases and cleaner emissions. Additionally, RENESIS has a dual skin exhaust manifold that maintains the temperature of burned gases and ensures that exhaust temperature rises sharply on starting, for fast activation of the latest, high-performance catalytic converter and consequently lower emissions.

Latest control technology for more precise air-fuel metering

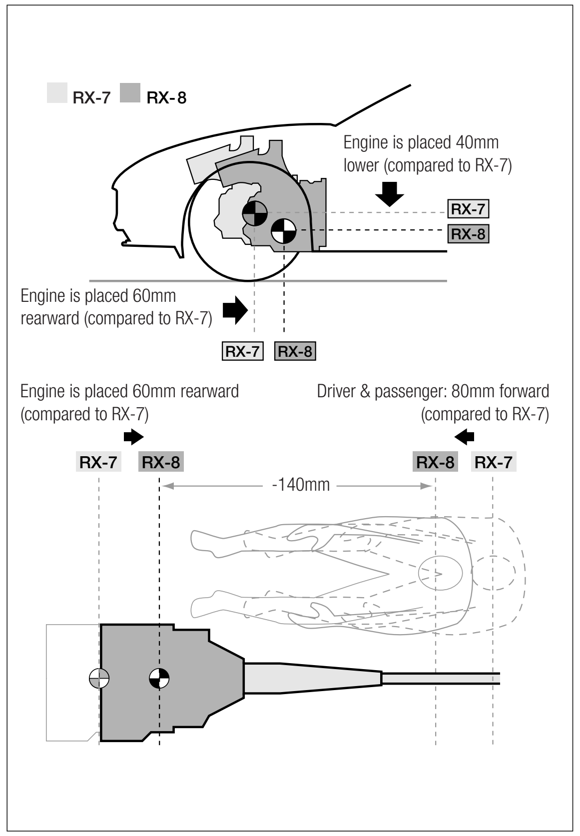
With RENESIS, Mazda has renewed its rotary engine fuel metering system. Firstly, instead of the previous intake manifold depression system of measuring air intake volume, RENESIS employs a hot wire flow volume meter. Additionally, whereas the previous engine used a single-loop air-fuel ratio feedback control system equipped with an O_2 sensor located upstream of the catalytic converter, RENESIS is equipped with O_2 sensors fore and aft of the catalytic converter in a double loop feedback control system. The O_2 sensor upstream of the catalyst is a highly linear O_2 type that responds in a linear manner over a wide range of air-fuel ratios, achieving precise fuel control from idling to top engine speed. In combination with the exhaust gas re-burning system mentioned previously, the new air-fuel metering system helps to achieve 1/10 or lower exhaust gas emissions compared with the previous RE.

As a result, RENESIS meets the latest exhaust emission regulations in each country.

■ Technology for Compact Size and Lighter Weight

Thinner engine ribs, wet sump lubrication system and resin inlet manifold

Mazda engineers employed a supercomputer for structural analysis to assure excellent rigidity while reducing the thickness of ribs in the side housing and other areas of the engine. Approximately half of the parts used in the ultra-long inlet manifold are made of rasin to make use of the RE's characteristic pulse charging effect. In addition, the air conditioner and other auxiliaries are mounted directly without brackets, further contributing to lower weight and compact size. Despite the use of a wet sump system, the oil pan has only about half the depth of the previous RE at approximately 40 mm. Such meticulous attention to size and weight reduction in the design of this naturally aspirated engine—already intrinsically lighter and more compact than a turbo charged unit—has achieved light weight approximately the same as inline-4 all-aluminum engine, and enabled a front midship layout with the engine mounted 60 mm further to the rear and about 40 mm lower than the RX-7's engine.

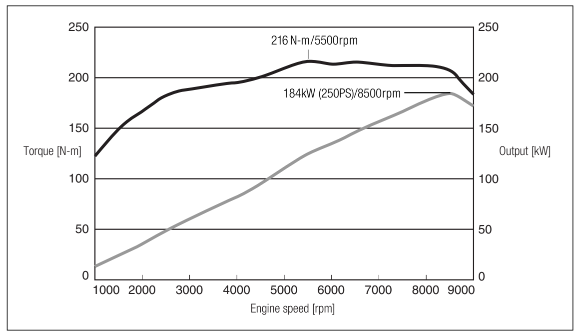


MAJOR ENGINE SPECIFICATIONS (Japanese version)

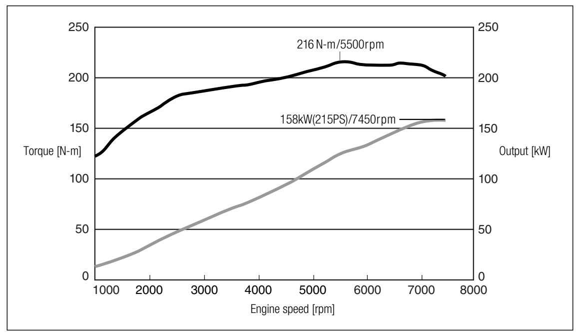
Tuning Level				6-port engine	4-port engine
Model Code				13B-MSP	
Type				Gasoline, Rotary Piston	
Total Displacement			L	0.654 × 2	
Number of Rotors				Inline 2-rotor Longitudinally-mounted	
Valve Mechanism				—	
Bore × Stroke (rotor housing size)			mm	240.0 (major axis), 180.0 (minor axis), 80.0 (width)	
Compression Ratio				10.0 : 1	
Maximum output (Net)			kW (PS)/rpm	6MT: 184 (250)/8500 6MT: 184 (250)/8500	154 (210)/7200
Maximum torque (Net)			N-m/rpm	216/5500	222/5000
Port Timing	Intake	Opening	ATDC	3° (primary) 12° (secondary) 38° (auxiliary)	3° (primary) 12° (secondary)
		Closing	ABDC	65° (primary) 36° (secondary) 80° (auxiliary)	60° (primary) 45° (secondary)
	Exhaust	Opening	BBDC	50°	40°
		Closing	BTDC	3°	
Idling Speed			rpm	750 – 850	
Lubrication System	Type			Forced Supply	
	Oil Pump			Trochoid Type	
	Oil Cooler			Independent, Air-cooled	
Cooling System	Type			Water-cooled, Electric-powered	
	Radiator			Sealed-type	
Air Purifier	Type			Paper Filters	
	Number			1	
Fuel Pump				Electric	
Fuel Injection				Electronic	
Jet Nozzle	Type			Plate-nozzle-type	
	Nozzle	Number		12 (primary) 4 (primary 2) 4 (secondary)	12 (primary) 4 (secondary)
		Diameter	mm	0.21 (primary) 0.41 (primary 2) 0.41 (secondary)	0.21 (primary) 0.41 (secondary)
	Injection Pressure		kPa	392	

Main engine specifications and performance curves (Japanese version)

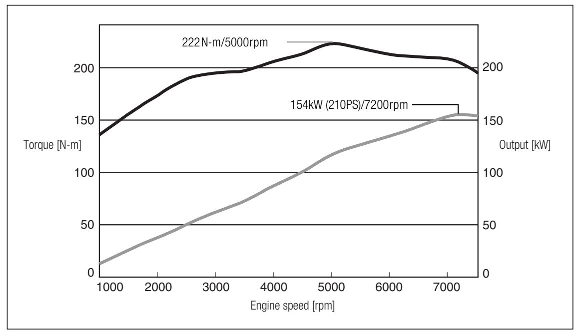
6-port engine (6MT)



6-port engine (6AT)



4-port engine (5MT)



Craftsmanship-Based Engine Production Line for the RENESIS Rotary Engine

Mazda began its development of the rotary engine in 1961. At the time, many of the world's automakers were involved in rotary engine research and development, but by the latter half of the '70's Mazda was the only car company with a rotary engine R & D program. This places Mazda in a unique position among today's automakers, forcing the company to capitalize on its unique strengths and competences to make progress in rotary development. At the same time, Mazda also produces much of its own manufacturing technology and equipment to build these unique engines.

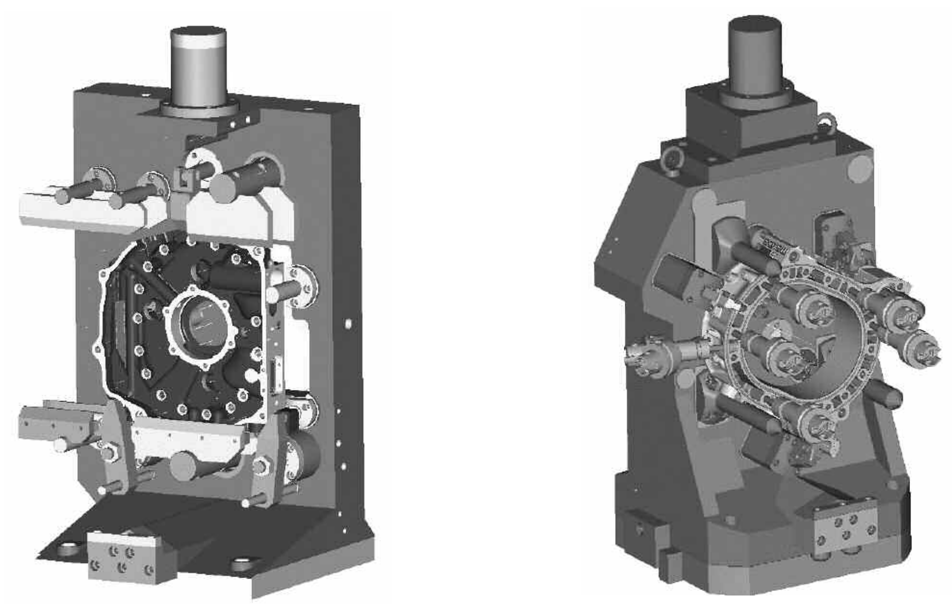
■ Positive Approaches to Improving Production Quality

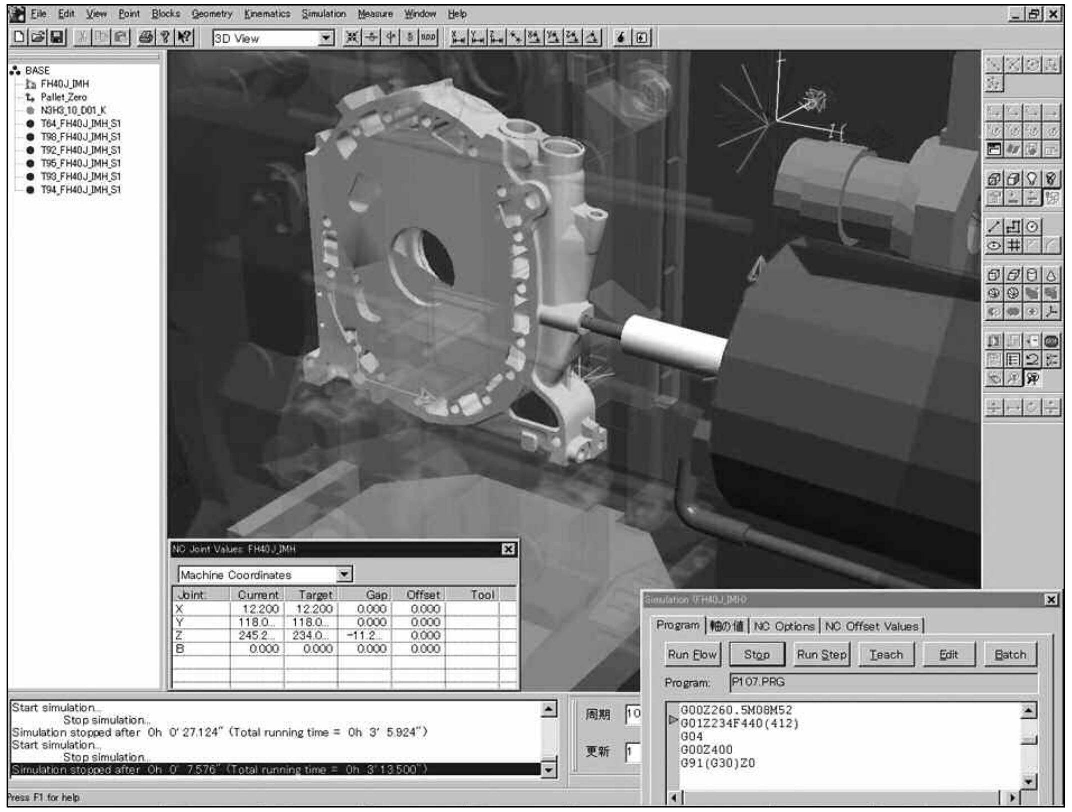
In 1994, Mazda introduced Total Productive Maintenance (TPM) operations, the brainchild of the Japan Plant Maintenance Association, to its manufacturing lines. Based on TPM concepts, Mazda strives to improve; the organization of its production department, initial management organization for new products and equipment, quality maintenance organization, etc. Factories dedicated to high quality, technology and skill levels,

For promoting TPM activities now practiced by various manufacturers throughout the world, Mazda's 2nd Engine Production Department received the top-ranked TPM Special Award in 2001.

Since 1996, the company has been pursuing what it calls the Mazda Digital Innovation (MDI) project. The project involves integration of CAD/CAM systems ranging from design through production. By employing the most advanced 3-dimensional information system, Mazda has revolutionized its entire research and development organization. In the case of the RENESIS project, Mazda used MDI's 3-D data to implement virtual simulations of machining processes in production engineering, allowing the construction of a high-quality, stable production line in a very short time.

3-D jig design





Simulation for numerical control machining process

■ Reliable Quality—a Product of the Most Advanced Digital Technology and Human Skill

Mazda will take machining of the lightweight rotor adopted for the RENESIS as an example of processes involved in engine production. Three dimensional design data is received from the engine development team, and employed to create 3-dimensional metal die data for casting. Based on this 3-D data, Mazda conduct analyses and checks through computer simulations to assess the precision, quality, efficiency and other attributes of various approaches to rotor casting and machining. Also, with regard to cutting and other machining processes, Mazda run 3-D simulations that help us check whether the design of cutting tools and holders, and resulting product quality, is optimal throughout the entire manufacturing process.

To achieve the critical finish quality of side seals, cut-off seals and related components of the rotary chamber, Mazda capitalize on the unique skills of our production staff, honed through years of experience in rotary engine building, as they painstakingly build and check each and every item to achieve trustworthy quality.

Mazda has renewed its development system through intelligent use of a wealth of accrued experience and technology in car manufacturing, as well as the outstanding skill and quality symbolized by our TPM activities and our advanced MDI project. By merging tradition with our vision of future technologies, Mazda has secured enormous gains in both the precision and efficiency of the equipment used in the production of its rotary engines, realizing yet another signal advance in performance and quality with the innovative RENESIS.

The exceptional skills of Mazda' s rotary engine production staff hone the quality to a critical finish.