ROTARY ENGINE PRESS INFORMATION 2007.05

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Mazda Motor Corporation.

May 2007

Preface

2007 marks the 40th anniversary of Mazda's first production car to be powered by a rotary engine, the Cosmo Sport. To date, Mazda has produced more than 1.96 million rotary engine vehicles and they have been driven throughout the world. Rotary engine technology continues to mature and steadily evolve towards the next generation thanks to the efforts of our engineers and their persistent determination to face challenges.

In today's automobile industry, the rotary engine is the sole preserve of Mazda Motor Corporation. As the world's only manufacturer of cars powered by rotary engines, our aim is to continue developing this singular form of internal combustion engine while familiarizing the car-buying public with its expanding potential. The publication of reports such as this is part of our commitment to promote public awareness and the accurate understanding of the latest rotary engine technologies, as well as its history and ongoing evolution.

This booklet contains a detailed description of the rotary engine's history and features. It also details the hydrogen rotary engine—a new possibility for the rotary engine which should play a significant role in the anticipated hydrogen-oriented society.

We hope that this booklet conveys Mazda's rotary engine spirit to one and all.

May 2007
Mazda Motor Corporation

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Introduction

The Rotary Engine Continues Its Evolution Backed by a Persistent Determination to Face Challenges

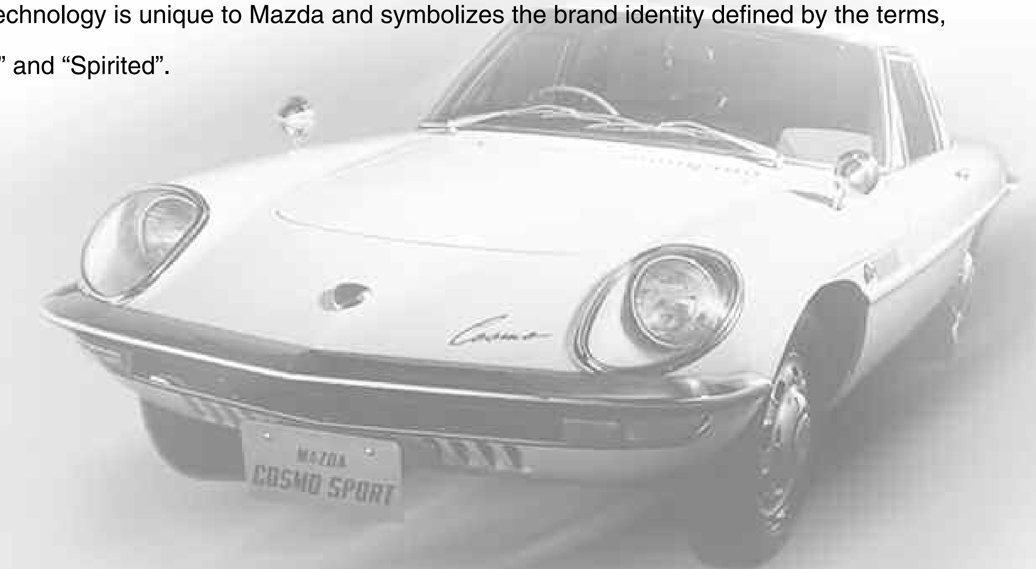
■ The Rotary Engine—the Symbol of Mazda's Brand Identity

With the dream of producing the ideal internal combustion engine, Mazda began development of the rotary engine in 1961. It is a unique powerplant that is lightweight and compact and far smoother than a reciprocating engine. Many scientists over the centuries have unsuccessfully attempted the development a practicable rotary engine.

At the time, not only Mazda but almost every major car maker in the world was involved in research and development aimed at the commercialization of the rotary engine. Finally however, Mazda became the only company to overcome the many technical problems and successfully achieve volume production. As a result, Mazda became well known the world over despite being a relatively new brand in the automobile industry.

By the mid-1970s, Mazda had become the world's sole remaining automaker involved with the rotary engine. Since that time, we have continued to refine the mechanisms and advance the development of vehicles which reap the benefits of this singular engine. It has resulted in globally renowned cars such as the Cosmo Sport, the RX-7 and the RX-8—a new concept sports car that capitalizes on the advantages of the compact rotary engine with its spacious interior and sporty design.

Rotary engine technology is unique to Mazda and symbolizes the brand identity defined by the terms, "Stylish", "Insightful" and "Spirited".



■ Declaration of "Sustainable Zoom-Zoom"—Part of Mazda's Initiative for a Sustainable Society

It is forty years since Mazda's first rotary engine car, the Cosmo Sport, was launched in 1967. In this commemorative year, Mazda has announced its long-term vision for technology development, "Sustainable Zoom-Zoom", which defines our aim to combine the pursuit of driving pleasure with a commitment toward realizing a sustainable society.

This marks the beginning of our initiative to promote Zoom-Zoom that harmonizes driving performance with environmental and safety performance. In line with this, we are seeking new possibilities for the rotary engine.

At Mazda we are developing and planning to introduce a new generation of gasoline rotary engines with dramatically improved power and fuel efficiency by the start of the decade beginning in 2010. At the same time we are ramping up efforts in the advancement of the hydrogen rotary engine as part of our goal of realizing a hydrogen-based society in the future. The rotary has been cited as the most suitable format for a hydrogen internal combustion engine and is drawing increased attention, especially since it employs existing technologies and components. Further, since the engine can alternate between hydrogen and gasoline fuel at the flick of a switch, we think it will play an important role during the transition period until a hydrogen infrastructure is in place.

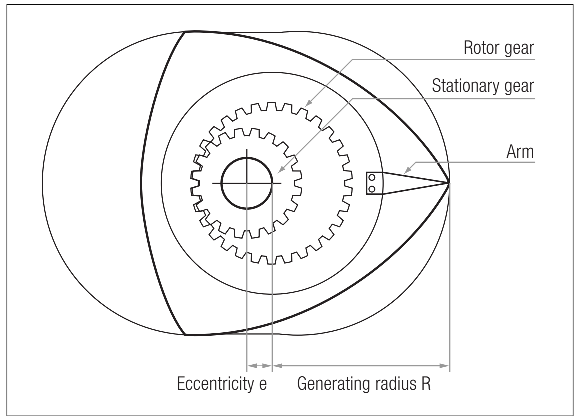
Hydrogen rotary engine cars retain the distinctive driving feel of a conventional combustion engine vehicle while producing absolutely none of the CO_2 emissions responsible for global warming. It is a next-generation alternative fuel technology that harmonizes excellent environmental compatibility with the sensational Zoom-Zoom experience that motorists have come to expect from Mazda.

As the sole automaker capable of manufacturing rotary engines, and as a brand that constantly promotes driving pleasure, Mazda will continue to look for new possibilities for the rotary engine as part of our plan to realize a sustainable society.

Structure and Working Principles of the Rotary Engine

■ Wankel-type Rotary Engine

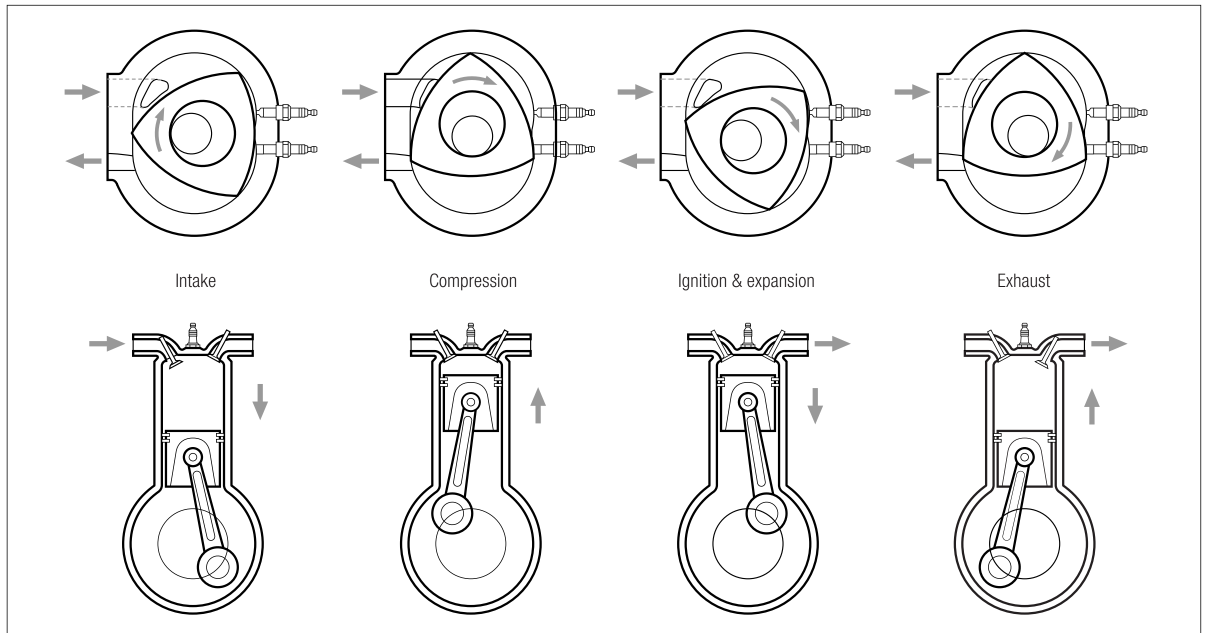
Over the past 400 years, many inventors and engineers have pursued the idea of developing a continuously rotating internal combustion engine. It was hoped that the reciprocating-piston internal combustion engine would be superseded by an elegant prime mover bearing a closer resemblance to the “wheel”, one of mankind’s greatest inventions.



Principle of Peritrochoid Curve
■ Dr. Wankel and his colleagues devised how to configure the trochoid curve as follows: First, fix an outer-toothed gear on a white sheet above a table and mesh an inner-toothed gear on it. Put a pen attached with an arm on the outside of the inner-toothed gear. The gear ratio between both gears is to be set as 2:3. When turning the inner-toothed gear on the other gear, the pen will generate the cocoon-shape trochoid curve.

It was late in the sixteenth century that the phrase, “continuous rotating internal combustion engine” first appeared in print. James Watt (1736~1819), the inventor of the connecting rod and crank mechanism, also took up research on a rotary-type internal combustion engine. For the last 150 years especially, a number of ideas on the rotary engine design have been set forth by inventors. It was in 1846, that the geometrical structure of the working chamber of current rotary engine designs was planned and the concept of the first engine using an epitrochoid curve was configured. However, none of those ideas had been put to practical use until Dr. Felix Wankel developed the Wankel-type rotary engine in 1957.

Dr. Wankel had researched and analyzed possibilities of various types of rotary engines and reached the optimum shape of the trochoid housing . His deep knowledge of the rotary valves used for aircraft engines, the airtight sealing mechanism for superchargers and the incorporation of these mechanisms into his design contributed to practical realization of Wankel-type rotary engine.



Comparison with Reciprocating Engine-1
■ With the rotary engine, the inside space of the housing is always divided into three working chambers and, as the rotor turns, those chambers also move. Four processes of intake, compression, combustion and exhaust are executed successively in a different place of the trochoid housing. This is significantly different from the reciprocating engine, where the four processes are carried out within a cylinder.

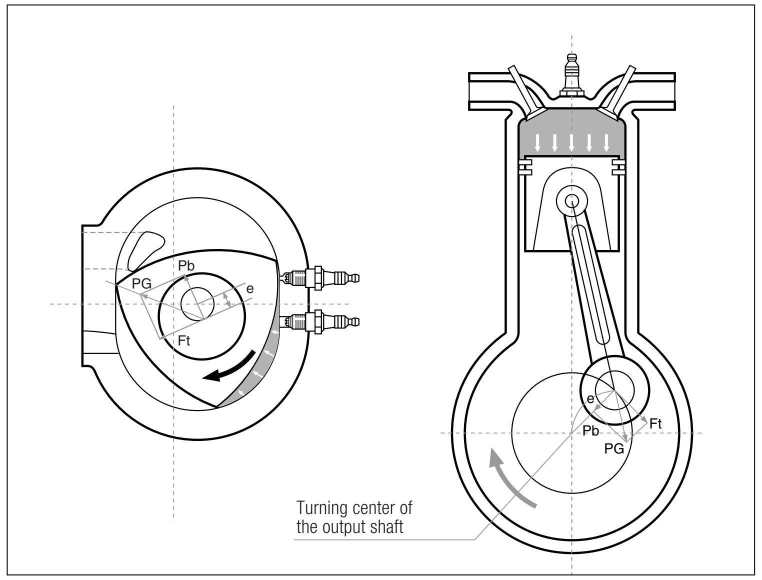
■ Structure and Operation of the Rotary Engine

The rotary engine is composed of a cocoon-shaped housing and a triangular-shaped rotor inside of it. The space between the rotor and the housing wall provides the chamber for internal combustion and the pressure of expanding gases serves to turn the rotor. In order to make the rotary engine work as an internal combustion engine, the four processes of intake, compression, combustion and exhaust had to be performed in succession in the working chamber. Suppose that the triangular-shaped rotor were concentrically placed inside a true circular housing. In this case, the working chamber would not vary in volume as the rotor turned inside the housing. Even if the fuel-air mixture were ignited there, the expansion pressure of combustion gas would merely work toward the center of the rotor and would not result in rotation. That was why the inner periphery of the housing was contoured as a trochoid-shape and assembled with the rotor installed on an eccentric shaft.

The working chamber changes in volume twice per revolution, thus the four processes of the internal combustion engine could be achieved. With the Wankel-type rotary engine, the rotor’s apices follow the oval contour of the inner periphery of the engine casing while remaining in contact with the gear on the output shaft which is also in eccentric orbit around the center point of the engine casing. A phase gear mechanism dictates the orbit of the triangular rotor. The phase gear consists of an inner-toothed gear ring fixed on the inside of the rotor and an outer-toothed gear fixed on an eccentric shaft. If the rotor gear were to have 30 teeth inside it, the shaft gear would have 20 teeth on its perimeter so the gear ratio is 3:2. Due to this gear ratio, the rate of turning speed between the rotor and the shaft is defined as 1:3. The rotor has a longer rotation period than the eccentric shaft. The rotor rotates one turn while the eccentric shaft rotates three turns. With the engine running at 3000rpm, the rotor will run at a mere 1000rpm.

■ Comparison with the Reciprocating Engine

In order to get the turning force, both the reciprocating engine and the rotary engine rely on the expansion pressure created by the combustion of the fuel-air mixture. The difference between the mechanisms of the two engines is in the way that the expansion pressure is used. In the reciprocating engine, the expansion pressure generated above the piston’s top surface forces the piston down and the mechanical force is transferred to the connecting rod that causes rotation of the crankshaft. In the case of the rotary engine, however, the



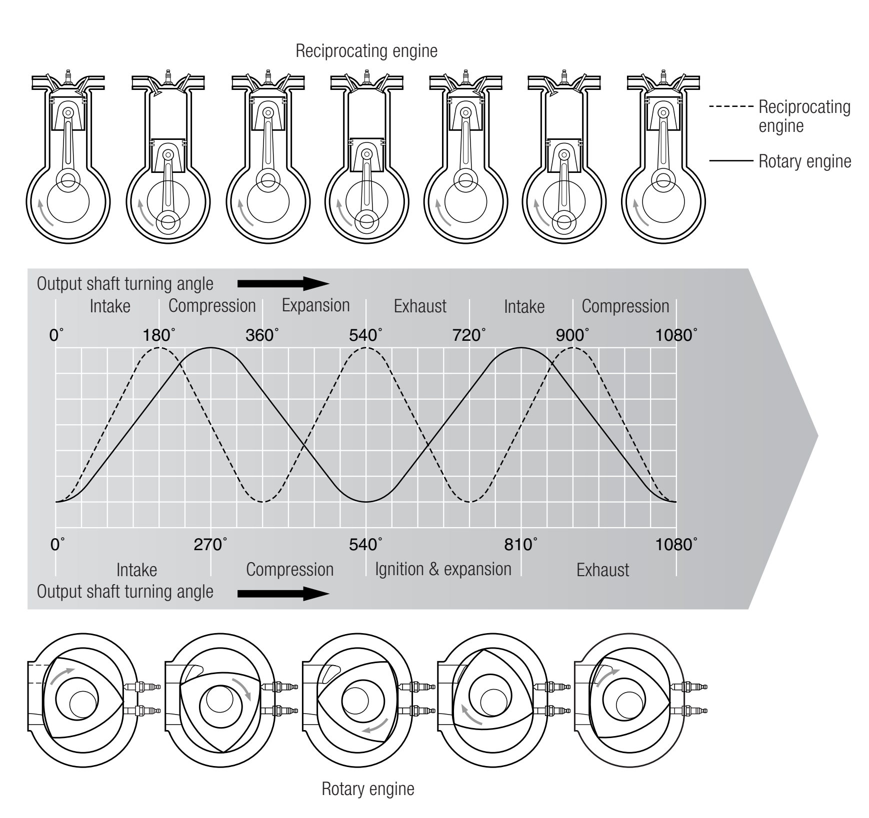
Principle of Generating Torque
■ With the reciprocating engine, the expansion pressure of the combustion gas is changed to turning motion through the connecting rod and transferred to the crankshaft. While, with the rotary engine, through the effect of the eccentric shaft, the expansion force directly turns the rotor and then the rotor turns the eccentric shaft.

expansion pressure is applied to the flank of the rotor. One of the three sides of a triangle is forced toward the center of the eccentric shaft as a result. (PG in the figure). This movement consists of two divided forces. One being the force toward the output shaft center (Pb in the figure) and the other is the tangential force (Ft) which rotates the output shaft.

The inside space of the housing (or the trochoid chamber) is always divided into three working chambers. Due to the turning of the rotor, those three working chambers are always in motion and successively execute the four processes of intake, compression, ignition (combustion) and exhaust inside the trochoid chamber. Each process is carried out in a different place in the trochoid chamber. This is significantly different from the reciprocating engine, where those four processes are carried out within each cylinder.

The displacement volume of the rotary engine is generally expressed by the unit chamber volume and by the number of rotors. For example, with the model 13B two-rotor rotary engine, the displacement volume is shown as “654cc $\times$ 2”.

The unit chamber volume means the difference between the maximum volume and the minimum volume of a working chamber, while the compression ratio is defined as the ratio between the maximum volume and the minimum volume. The same definitions are used for the reciprocating engine. In the figure shown on the next page, the changes of the working chamber volume of the rotary engine and the four-cycle reciprocating engine are compared. Although, in both engines, the working chamber volume varies smoothly in a wave shape, there are two distinctive differences between the two engines. One difference is the turning angle per



Comparison with Reciprocating Engine-2

■ The drawing here shows the volume change of the working chamber along with the working process, respectively for the reciprocating engine and the rotary engine. As seen here, the reciprocating engine runs two turns while completing the four processes, whereas the rotary engine runs three turns. When the output shaft speed is the same, the rotary engine can spend more time for one process than the reciprocating engine.

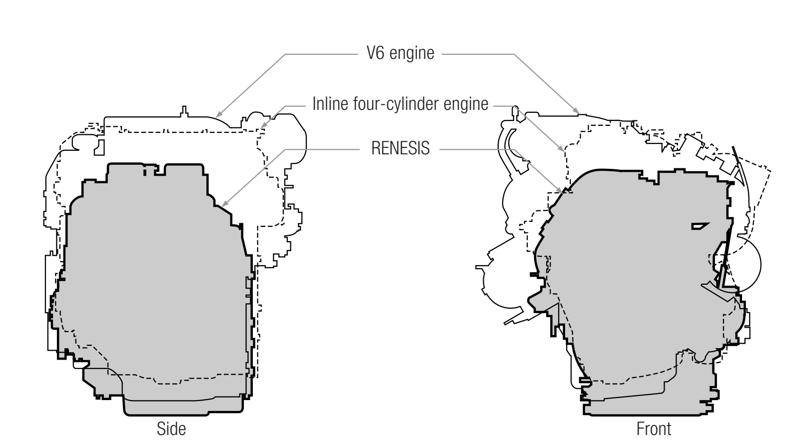
process. The reciprocating engine turns 180 degrees while the rotary engine turns 270 degrees, one and half times that of the reciprocating engine. In other words, in the reciprocating engine, the crankshaft (output shaft) makes two turns (720 degrees) during the four processes, while in the rotary engine, the eccentric shaft (output shaft) makes three turns (1080 degrees) while the rotor makes one turn. In this way, the rotary engine has a longer process time, causes less torque fluctuation and results in smooth operation. Furthermore, even in high speed running, the rotor's rpm is comparatively slower, thus, the more relaxed timing constraints of the intake and the exhaust processes facilitate the development of systems aimed at attaining higher performance.

■ Unique Features of the Rotary Engine

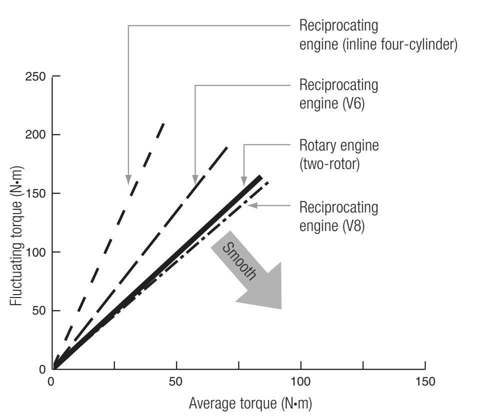
(1) Small Size and Light Weight

The rotary engine has several advantages but the most important ones are reduced size and weight. Where the two-rotor layout is considered equivalent to the inline six-cylinder reciprocating engine in quietness and smoothness of operation, the rotary engine can be designed to be two-thirds of the weight and size while achieving the same level of output. This advantage is very attractive to automobile designers especially in light of the recent trends toward stricter requirements in crashworthiness (collision safety), aerodynamics, weight distribution and space utility thus putting the rotary engine in the spotlight once again.

Comparison of Dimension



Comparison of torque fluctuation Rotary engine and reciprocating engine



(2) Flat Torque Characteristics

The rotary engine has a rather flat torque curve throughout the whole speed range and according to research results, torque fluctuations during operation are at the same level as an inline six cylinder reciprocating engine even with the two-rotor design, and a three-rotor layout is smoother than a V8 reciprocating engine.

(3) Less Vibration and Low Noise

With the reciprocating engine, piston motion itself could be a source of vibration, while the valvetrain generates unwanted mechanical noises. The smooth turning motions of the rotary engine generate considerably less vibration and the absence of a valve actuating mechanism contributes to smooth and quiet operation.

(4) Simple Structure

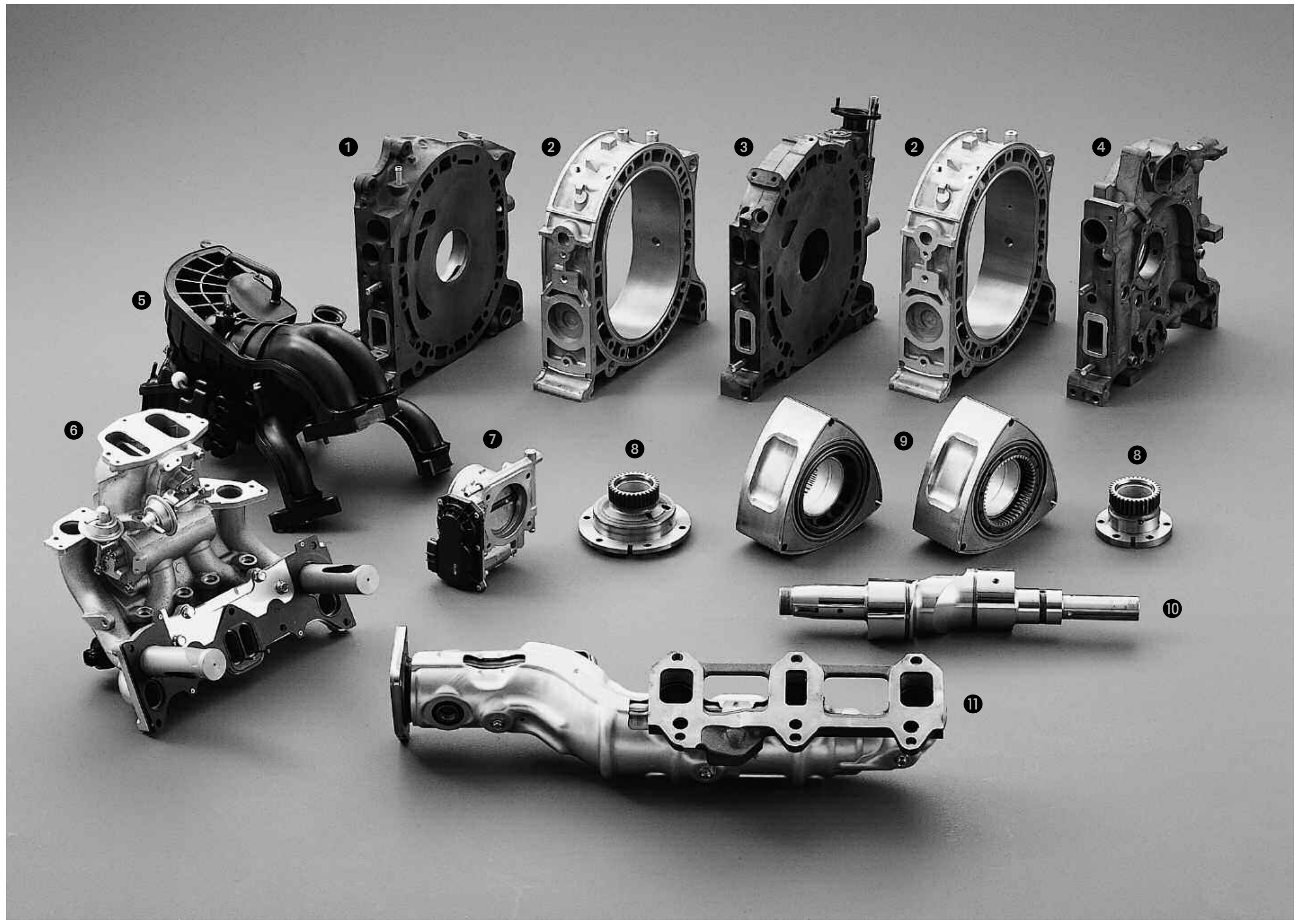
As the rotary engine converts the expansion pressure of the burnt fuel-air mixture directly into the turning force of the triangular rotor and the eccentric shaft, there is no need for connecting rods. The intake and exhaust ports are opened and closed by the rotor movement itself. The valve mechanism which includes the timing belt, the camshaft, the rocker arm, the valve, the valve spring, etc. required in the reciprocating engine is not required and a rotary engine can therefore be built with far fewer parts.

(5) Reliability and Durability

As mentioned before, the rotor turns at one-third of the engine speed. Therefore, when the rotary engine runs at speeds of 7000 or 8000rpm, the rotor is turning one-third that rate. In addition, since the rotary engine doesn't have such high-speed moving parts as rocker arms and conrods, it is more reliable and durable under high load operations. This was demonstrated by the overall win at Le Mans in 1991.

Major Components of the Rotary Engine

■ The rotary engine has no need of a valve actuating mechanism to open and close the intake and exhaust ports and, compared with the reciprocating engine, is composed of far fewer parts. The photo below shows the RX-8's RENESIS unit disassembled for reference. The major components are:
① rear housing, ② rotor housing, ③ intermediate housing, ④ front housing, ⑤ resinous intake manifold, ⑥ intake manifold, ⑦ electronic throttle, ⑧ stationary gear, ⑨ rotor, ⑩ eccentric shaft, ⑪ exhaust manifold



Chapter 2

RENESIS Technology

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
	EU (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

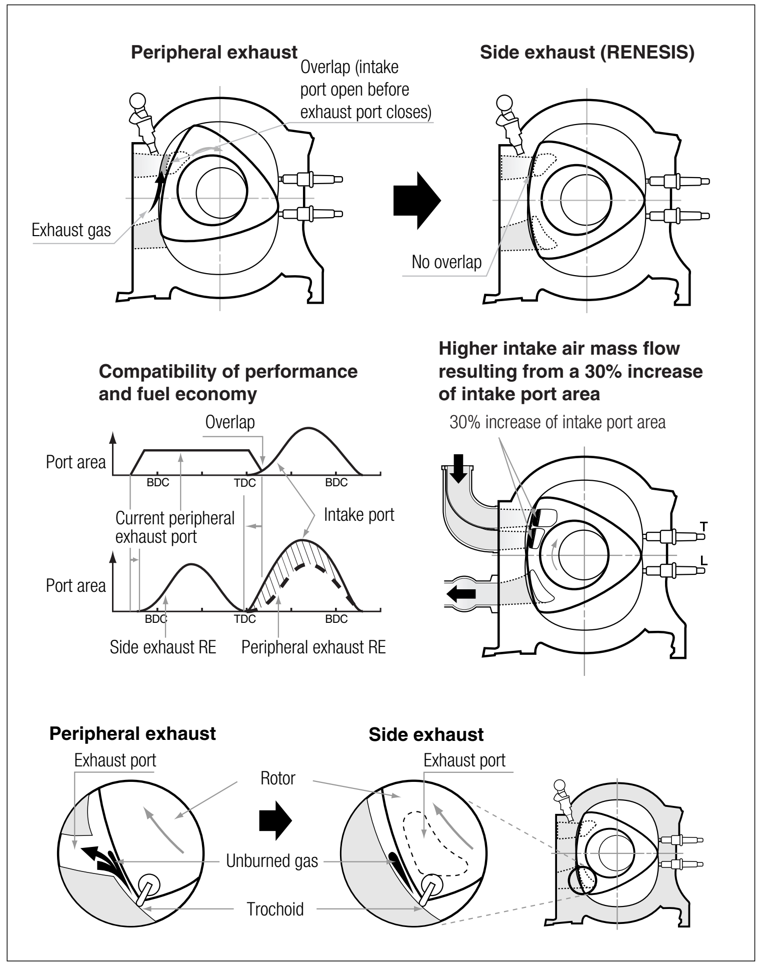
Thanks to the side-intake/side-exhaust port layout with its 30% increase in port area, and the later closing of the intake port, RENESIS receives a sizable increase in charging volume for higher power output. Additionally, the engine incorporates innovative technology designed to boost filling efficiency.

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.

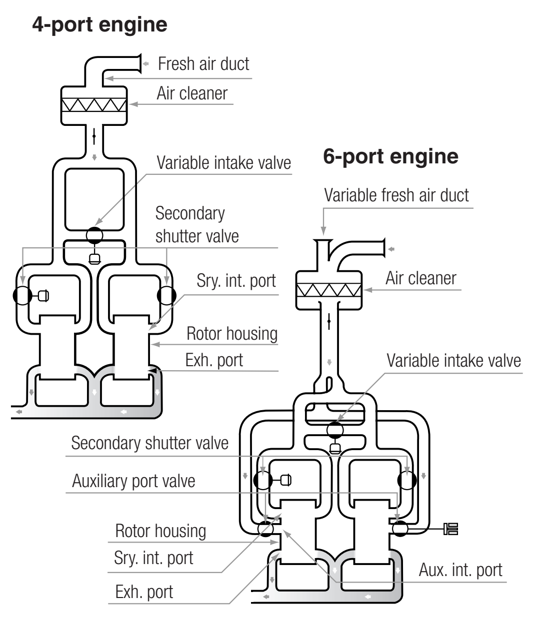
First, at low engine speeds, only the primary intake port is used, speeding intake flow for improved low-end torque. Next, the secondary port comes into operation at around 3750rpm through the opening of its shutter valve, slowing intake flow to increase low- and mid-range torque. In addition, the 6-port 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.

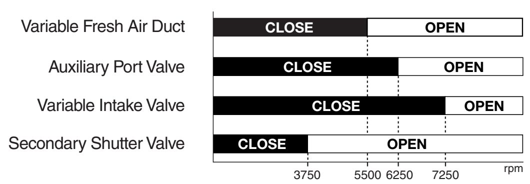
In addition, the naturally aspirated engine generates a suitably sports car-like engine note—one more way that RENESIS enhances driving enjoyment.



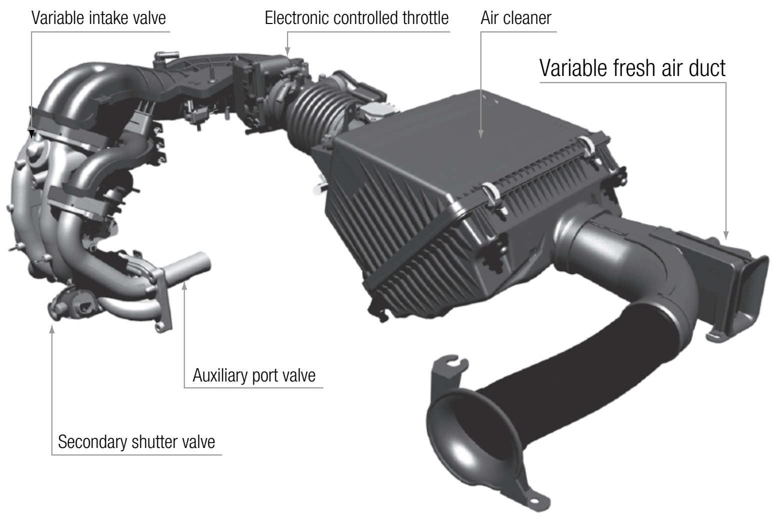
Sequential dynamic air intake system



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

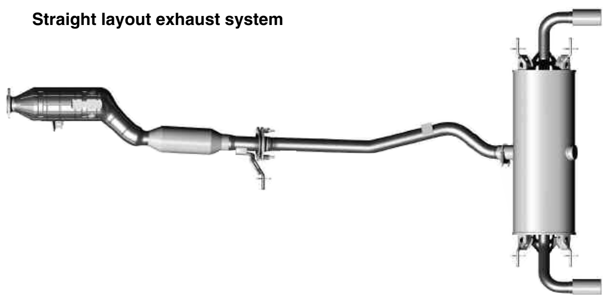


Variable Fresh Air Duct (FAD)
The 6-port engine incorporates a variable fresh air duct (FAD) in addition to the large, low flow-resistance air cleaner. The variable FAD has a shutter valve that opens at around 5500rpm to shorten the air intake manifold upstream of the air cleaner, and work in tandem 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.



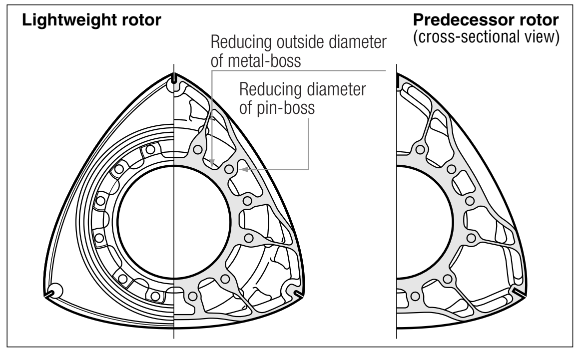
Straight Exhaust System Layout
To achieve a smooth flow of exhaust gases, the RENESIS exhaust system, including the exhaust manifold, was made as straight as possible. The system employs large diameter exhaust pipes and high capacity main silencer with the inlet pipe located straight through the center 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

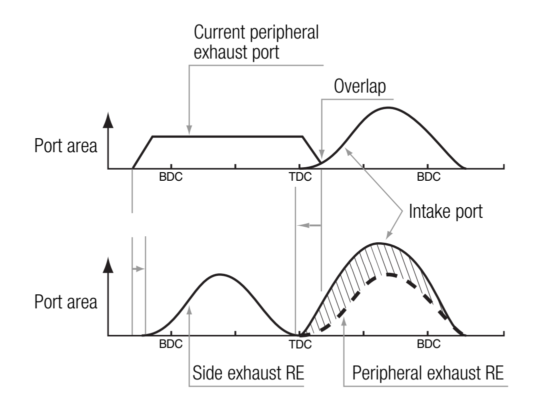
Dynamically balanced rotors
To further refine the superior balance afforded by the twin-rotor configuration, Mazda shifted from the previous static balance setting, and instead adopted dynamic balance calculated from the mass of oil entering the rotors, thereby achieving a further reduction in vibration 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

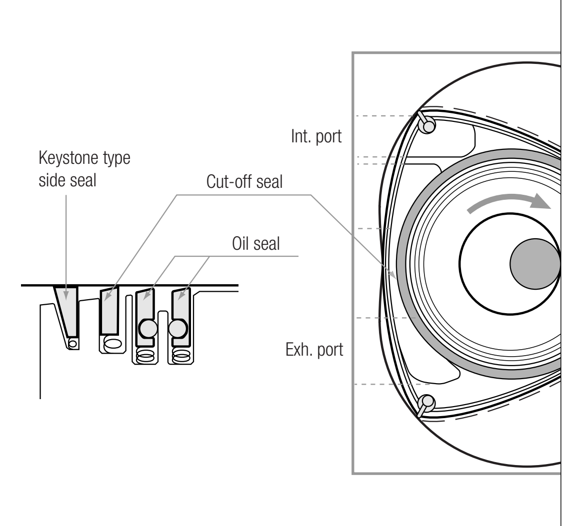
Eliminating intake/exhaust port timing overlap



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.

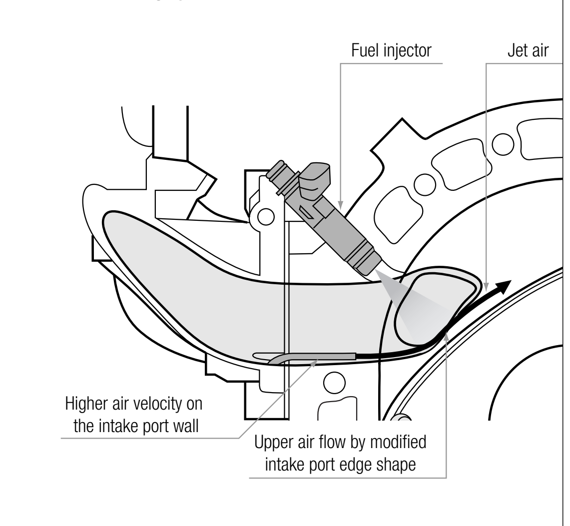
RENESIS oil and gas seals



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.

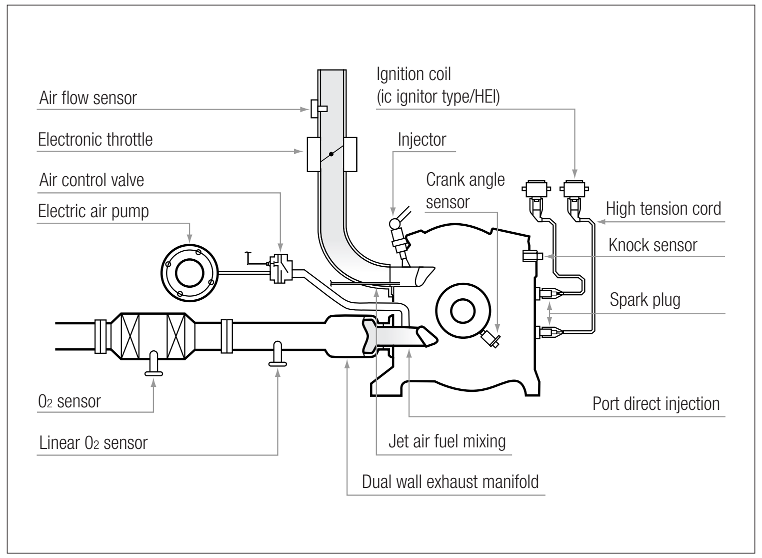
Jet Air-Fuel Mixing System
The primary intake port's injector is an ultra-fine atomizing, 12-hole type (the other injectors are 4-hole types), and in addition RENESIS is equipped with a new Jet Air-Fuel Mixing System that strongly promotes the dispersion and mixing of fuel. The system utilizes port air 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

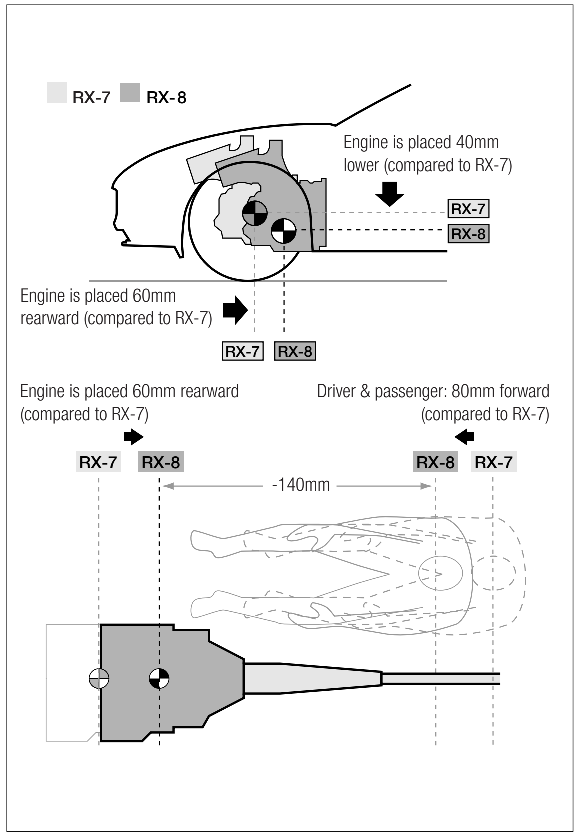
With RENESIS, Mazda has renewed its rotary engine fuel metering system. Firstly, instead of the previous intake manifold depression system of measuring air intake volume, RENESIS employs a hot wire flow volume meter. Additionally, whereas the previous engine used a single-loop air-fuel ratio feedback 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.

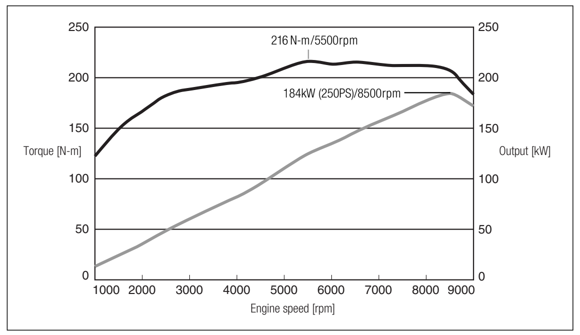


MAJOR ENGINE SPECIFICATIONS (Japanese version)

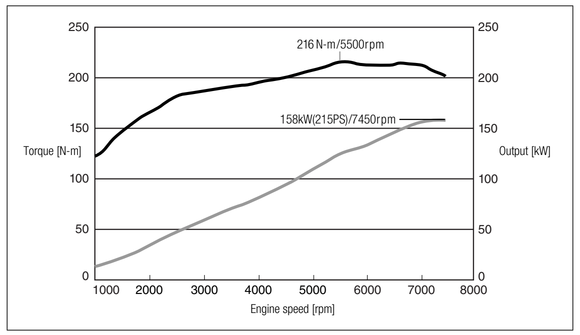
Tuning Level			6-port engine	4-port engine
Model Code			13B-MSP	
Type			Gasoline, Rotary Piston	
Total Displacement		L	0.654 × 2	
Number of Rotors			Inline 2-rotor Longitudinally-mounted	
Valve Mechanism			—	
Bore × Stroke (rotor housing size)		mm	240.0 (major axis), 180.0 (minor axis), 80.0 (width)	
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)
	Nozzle 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)

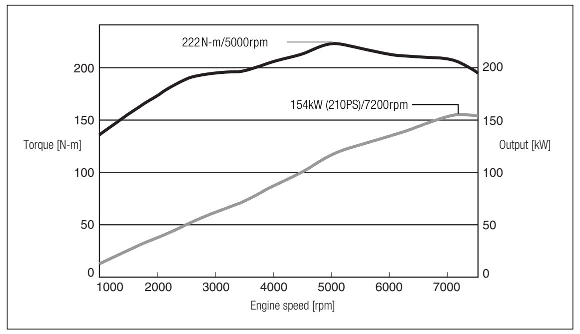
6-port engine (6MT)



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.

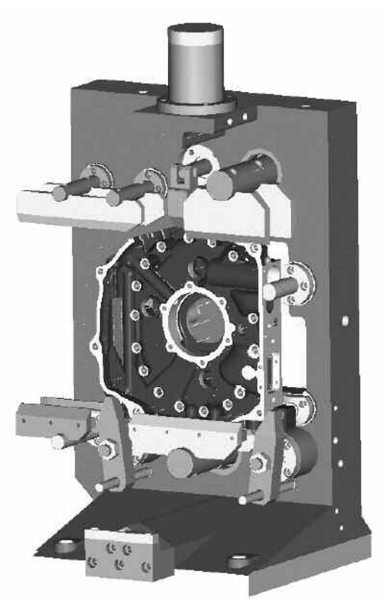
■ Positive Approaches to Improving Production Quality

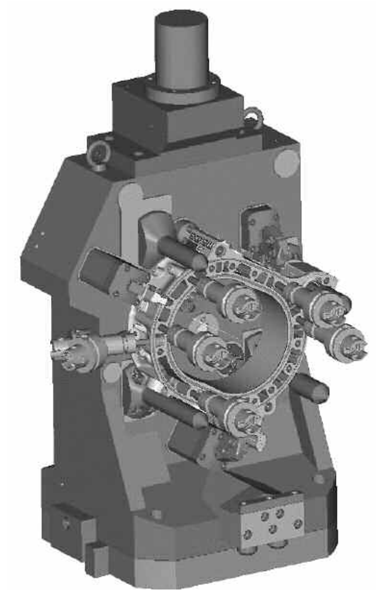
In 1994, Mazda introduced Total Productive Maintenance (TPM) operations, the brainchild of the Japan Plant Maintenance Association, to its manufacturing lines. Based on TPM concepts, Mazda strives to improve; the organization of its production department, initial management organization for new products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

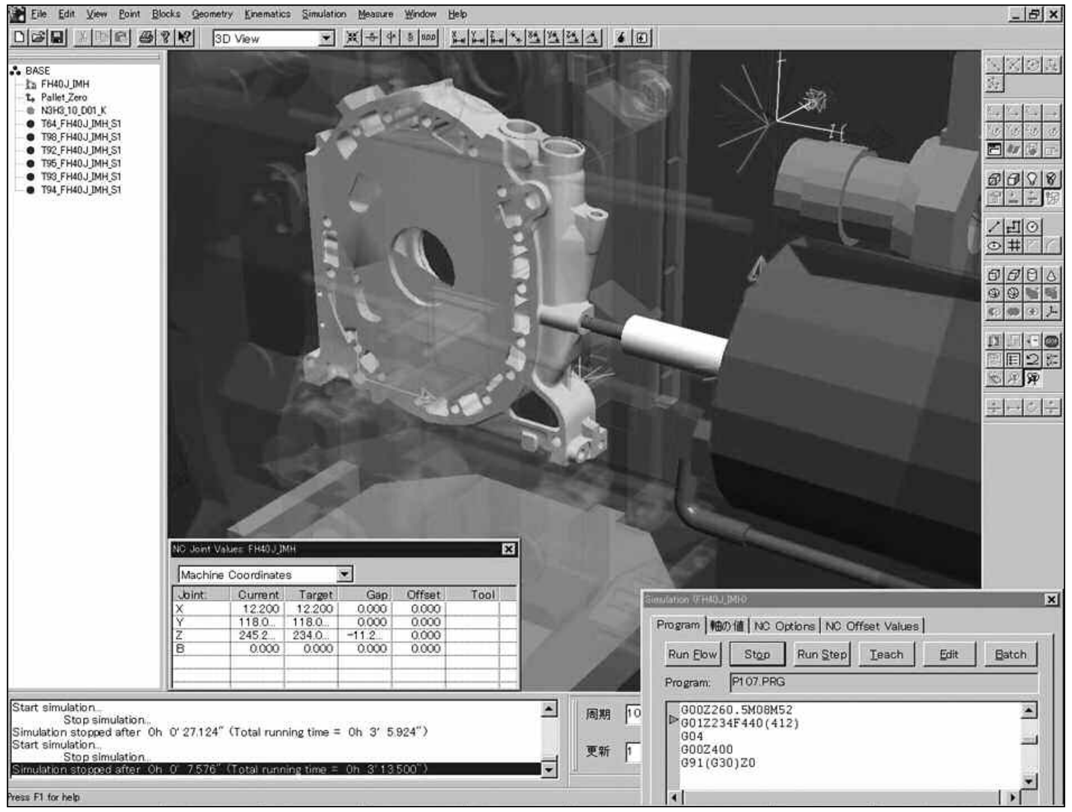
For promoting TPM activities now practiced by various manufacturers throughout the world, Mazda's 2nd Engine Production Department received the top-ranked TPM Special Award in 2001.

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.

The Birth of the Rotary Engine

■ Dream of the Young Wankel

Felix Wankel
■ In 1957, in cooperation with NSU, Dr. Wankel completed the type DKM engine. It was the world's first engine to generate power by rotating motion alone. In 1958, he completed a more practical type KKM that became the basis of the current rotary engine.

The rotary engine began with the improbable dream of a 17-year-old German boy named Felix Wankel in the summer in 1919. In the dream, he went to a concert in his own hand-made car. He even remembers boasting to his friends in the dream, "my car has a new type of engine: a half-turbine half-reciprocating engine. I invented it!" When he woke up in the morning, he was convinced that the dream was a premonition of the birth of a new type of gasoline engine.

At the time, he had no fundamental knowledge about internal combustion engines, but he intuitively believed that the engine could achieve four cycles—intake, compression, combustion, and exhaust—while rotating. This intuition actually triggered the birth of the rotary engine, which had been attempted countless times by people all over the world since the 16th century.

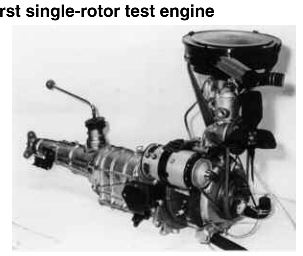
The rotary engine has an almost perfectly smooth operation; it also meets the most stringent technical standards. Wankel's dream and intuition went on to steer his entire life.

■ Research Starts

In 1924, at the age of 22, Felix Wankel established a small laboratory for the development of the rotary engine, where he engaged in research and development.

During World War II, he continued his work with the support of the German Aviation Ministry and large civil corporations, both of whom believed that the rotary engine would serve the national interest once it were fully developed. They held that the rotary engine, if fully exploited, could move the German nation and its industries toward greatness.

First single-rotor test engine



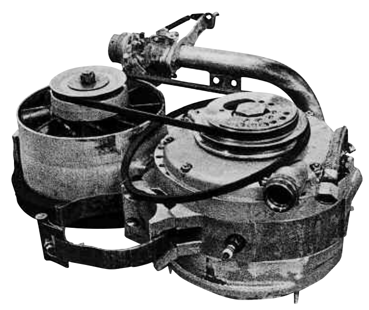
After the war, Wankel established the Technical Institute of Engineering Study (TES) and continued his work on the research and development of the rotary engine and the rotary compressor for commercial use.

One prominent motorcycle manufacturer, NSU, showed a strong interest in Wankel's research. NSU generated a great deal of enthusiasm among motorsports fans as they were repeat winners of many World Grand Prix championships. NSU was also attracted by the ideal concept of the rotary engine. After creating a partnership with Wankel, NSU promoted Wankel's research and focused on the rotary engine with trochoid housing as being most feasible.

■ First Wankel Engine

Before that, however, NSU completed development of the rotary compressor and applied it to the Wankel-type supercharger. With this supercharger, an NSU motorcycle set a new world speed record in the 50cc class, marking a top speed of 192.5 km/h (recorded at Bonneville salt lake flats). In 1957, Wankel and NSU completed a prototype of the type DKM rotary engine, which combined a cocoon-shaped housing with a triangular rotor. This was the birth of the rotary engine.

The DKM proved that the rotary engine was not just a dream. The structure, however, was complicated because the trochoid housing itself rotated; that made this type of rotary engine impractical. A more practical KKM with a fixed housing was completed a year later, in 1958. Although it had a rather complicated cooling system that included a water-cooled trochoid with an oil-cooled rotor, this new KKM was a prototype of the current Wankel rotary engine.



KKM 400
■ The NSU-built single-rotor prototype engine sent to Hiroshima from Germany with its technical drawings. This had a chamber volume of 400cc.

■ In Search of the Ideal Engine

In November 1959, NSU officially announced the completion of the Wankel rotary engine. Approximately 100 companies throughout the world scrambled to propose technical cooperation plans; 34 of them were Japanese companies.

Mazda's president, Mr. Tsuneji Matsuda, immediately recognized the great potential of the rotary engine, and began direct negotiations with NSU himself. Those negotiations resulted in the formal signing of a contract in July, 1961. The Japanese government gave its approval.

The first technical study group was immediately dispatched to NSU, while an in-house development committee was organized at Mazda. The technical study group obtained a prototype of a 400cc single-rotor rotary engine and related drawings, and saw that the "chatter mark" problem—traces of wavy abnormal wear on the rotor housing that caused the durability of the housing to significantly deteriorate—was the most critical barrier to full development. It remained a problem even inside NSU.

Chatter marks are score marks formed in the wall of the trochoid housing by apex seals at the three apices of a rotor, and are traces of juddering of the seals against the housing wall. With a maximum apex seal sway angle of 28 degrees and axial velocity of 7000rpm (twice the speed of a reciprocating engine's velocity of 37 m/s), these chatter marks are evidence of abnormal wear.

Mazda, while testing the NSU-built rotary engine, made its own prototype rotary engine, independently designed in-house, in November 1961. Both engines, however, were adversely affected by chatter marks. Practical use of the engine was not possible without solving that problem first.

■ Nail Marks of the Devil

In April, 1963, Mazda newly organized its RE (Rotary Engine) Research Department.

Under Mr. Kenichi Yamamoto, chief of the department, 47 engineers in four sections—investigation, design, testing, and materials-research—began exhaustive efforts in research and development. The main objective was the practical use of the rotary engine: namely, mass production and sales. However, this was dependent on solving the most critical engineering issue, the chatter mark problem.

These chatter marks occurred on the inner wall of the trochoid housing, where the apex seals on the triangular rotor juddered instead of sliding smoothly.

The RE Research Division called them Devil's Nail Marks and found that they were made when the apex seal vibrated at its inherent natural frequency.

To change the natural vibration frequency and damping capacity of the seal to prevent such abnormal vibration, Mazda engineers drilled a horizontal hole, 2.5 mm in diameter, in the metal seal to produce a cross-hollow seal which helped prototype engines to complete 300 hours of high-speed continuous operation.

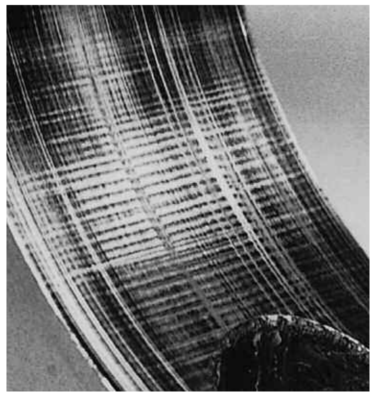
This breakthrough technology, however, was not adopted in the mass-produced rotary engines, but served to promote further research into the apex seal in the areas of materials and structure.

Moreover, in the initial stage of rotary engine development, another problem was thick white smoke caused by oil leaking into the combustion chamber. This also led to excessive oil consumption and was regarded as another barrier to commercialization.

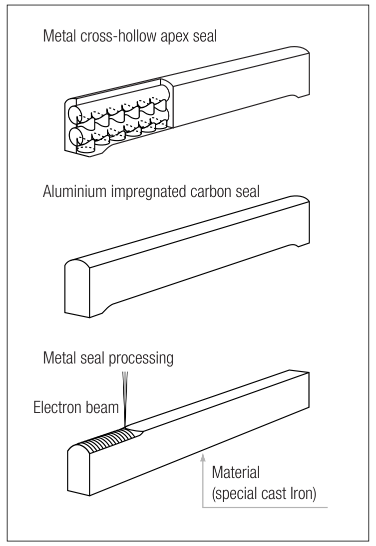
The cause of the problem was inadequate sealing, and with the cooperation of the Nippon Piston Ring Co., Ltd. and the Nippon Oil Seal Co., Ltd. Mazda designed a special oil seal which proved to be a solution.

Mr. Tsuneji Matsuda
■ As the President of Mazda, he took the initiative in proposing and obtaining the approval of a technical cooperation plan with NSU for the development of the rotary engine.

Mr. Kenichi Yamamoto
■ As the chief of the RE research department, he played a key role in developing Mazda's rotary engine. Later served as President and then Chairman of the company.



Chatter Marks
■ The durability of early rotary engines was severely affected by these wavy traces of abnormal wear on the inside surface of the trochoid housing.



Cosmo Sport, the Phoenix Project and Onward to the RX-7

■ Towards the Series-Production 2-Rotor Engine

In the early 1960s, during the initial development stage of the rotary engine, Mazda designed and investigated three types of rotary engine: those with two rotors, three rotors, and four rotors. The single-rotor version, prototypes of which were completed by NSU, could run smoothly at high speeds, but in the low speed range it tended to be unstable, with high levels of vibration and a lack of torque. This is due to the fact that a single rotor engine has only one combustion phase per revolution of the output shaft, resulting in a large torque conversion, which is a basic characteristic of this engine format.

Mazda then decided to develop a two-rotor engine, in which the torque fluctuations were expected to be at the same level as a 6-cylinder 4-stroke reciprocating engine.

The first two-rotor test engine, the type L8A (399cc single chamber volume), was an original Mazda design and was mounted in a prototype sports car (type L402A, an early prototype of the Cosmo Sport) designed specifically for the rotary engine.

In December 1964, another two-rotor test engine, type 3820 (491cc single chamber volume) was designed. It soon evolved into the mass-production trial-type L10A. The 60 Cosmo Sport prototype cars in which this engine was installed were driven for over 600,000 kilometers in Japan, during which Mazda collected critical data that was used in the preparation of the series production model. Once in production, the L10A designation given to the prototype became the type designation of the 1968 Cosmo Sport.

Moreover, in recognition of the large potential of the rotary engine, Mazda invested heavily in imported and exclusive machine tools, and proceeded with the trial manufacturing of multi-rotor rotary engines, including three and four-rotor versions. Those prototypes were installed on a prototype mid-engine sports car, the Mazda R16A. Test drives were carried out on a high speed test circuit at Miyoshi Proving Ground, completed in 1965. The course was the most advanced in Asia at that time.

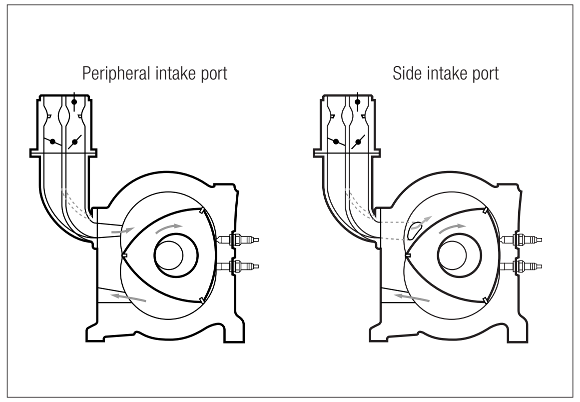
■ World's First Two-Rotor Rotary Engine

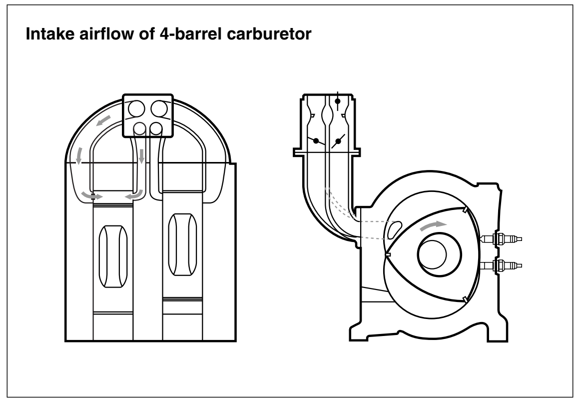
On May 30th, 1967, Mazda began selling the world's first two-rotor rotary engine car, the Cosmo Sport.

It featured a 110-horsepower type 10A engine (491cc single chamber volume) equipped with newly developed apex seals made with pyro-graphite, a high-strength carbon material, and specially processed aluminum sintering. This apex seal was the result of Mazda's independent development work and proved durable through 1,000 hours of continuous testing. Even after a 100,000 km test drive, it showed only slight wear of just 0.8 mm and an absence of chatter marks.

The intake system featured a side-port configuration coupled with a two-stage four-barrel carburetor, to keep combustion stable at all speeds. For the ignition system, each rotor was equipped with two spark plugs so that stable combustion could be maintained in cold and hot weather conditions alike, as well as on urban streets and expressways.

The Cosmo Sport was road-tested over a 6-year period and more than 3 million kilometers. The year after it went on sale, Mazda entered Cosmo Sport in the gruelling endurance race, "Marathon de la Route" of 1968. The car finished fourth in the race against formidable competition from Europe, and its futuristic styling and superb driving performance delighted car buffs throughout the world.





■ Development of Low-Emission Rotary Engines

After starting mass-production of the type10A two-rotor engine in 1967, Mazda decided to expand its application beyond the Cosmo Sport (which represented, after all, a relatively small market) and installed it in other sedan and coupe models for larger volume production, acquiring many new customers along the way.

Mazda also planned to export rotary engine cars to the world market.

In 1970, exports to the United States began. At the time, the U.S. government was actively preparing for the introduction of the Muskie Act, the most stringent automobile emissions standards the country had yet devised.

From the latter half of the 1960's, close attention was being paid to the severe smog problem in cities such as Los Angeles, and governments were beginning to take the issue of air pollution very seriously. In response, Mazda started research into the reduction of exhaust emissions in 1966, while continuing early-stage developmental work of the rotary engine itself.

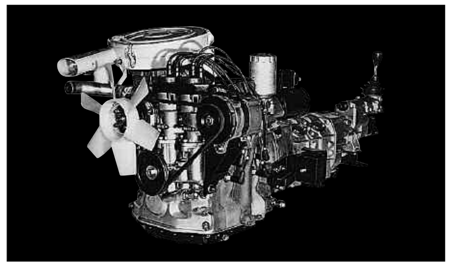
Compared with the reciprocating engine, the rotary engine tended to emit less NOx but more HC (Hydrocarbons).

To clear the emission standards of the Muskie Act, Mazda promoted the development of an advanced catalyst system, but as a more realistic solution also developed a thermal reactor system that could rapidly be introduced. The thermal reactor was a device that burned HC in exhaust gas to reduce HC emissions. This thermal reactor system was fitted to the first U.S.-bound export car with a rotary engine, the Model R100 (domestic name: Familia Rotary Coupe), which met the U.S. standards of that year. Later, while other car manufacturers all over the world stated that early compliance with the Muskie Law standards was impossible, Mazda reported in a public hearing with the U.S. government that the Mazda rotary engine could meet the standards.

In February 1973, the Mazda rotary engine cleared the U.S. EPA Muskie Act test, while shortly before, in November 1972, Mazda launched the Japanese market's first low-emission series-production car equipped with a Rotary Engine Anti-Pollution System (REAPS).

■ The Phoenix Project (The Fuel-Economy Challenge)

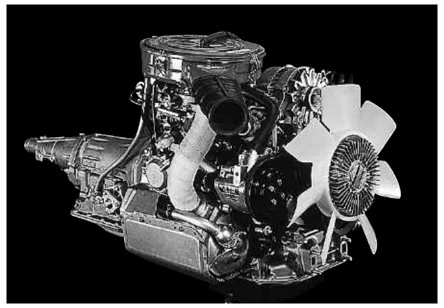
During the 1970s the world went through a stormy



First Two-Rotor Engine
■ In 1967 Mazda announced the world's first commercialized two-rotor unit, the type 10A with output of 110PS.

Cosmo Sport
■ Launched in 1967, the Cosmo Sport powered by a 10A rotary engine amazed people with its performance and unique design.

The Luce AP
■ The second generation Luce made its debut in 1973, with the first low emission version equipped with a 13B engine introduced the following year.



13B Rotary Engine
■ Mazda's largest twin rotor RE at 672cc per rotor chamber. The engine debuted in the Luce of 1973. At the time, it was the most powerful automobile engine in Japan.

period in international political relations, as many developing nations began to flex their muscles and use their oil resources as a political weapon. The “Oil Crisis” was the result.

With most Middle-Eastern oil-producing countries restricting their exports, global oil prices soared.

In response, car manufacturers began the development of mass-market cars with dramatically improved fuel efficiency. Mazda realized that a drastic reduction in fuel consumption had now become critical to the survival of the rotary engine and initiated the “Phoenix Project” targeting a 20 percent improvement in fuel economy for the first year of research and development, followed by a 40 percent improvement as the ultimate goal.

The company began by challenging the engineers to improve the fundamentals of the engines, including improving their combustion systems and carburetors, and concluded that fuel economy could be raised by 20 percent as targeted. Further development, including enhancing efficiency by incorporating a heat exchanger in the exhaust system, finally led to a 40 percent rise, the ultimate goal.

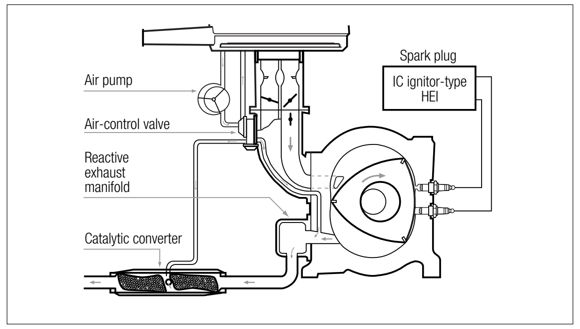
The success of the Phoenix Project was reflected in the sporty Savanna RX-7, launched in 1978, which proved once and for all that the rotary engine was here to stay. Thereafter, the world’s first catalytic converter system for the rotary engine was successfully developed, and fuel economy was even further improved. Soon afterward, fundamental engine improvements like the reaction-type exhaust manifold, the high-energy ignition system, the split secondary air control, and the two-stage pellet catalyst system, were developed in succession. The manifestation of all those developments was the lean-burn rotary engine that soon appeared on the market.

■ Six-port Induction System for Greater Fuel Economy and Power

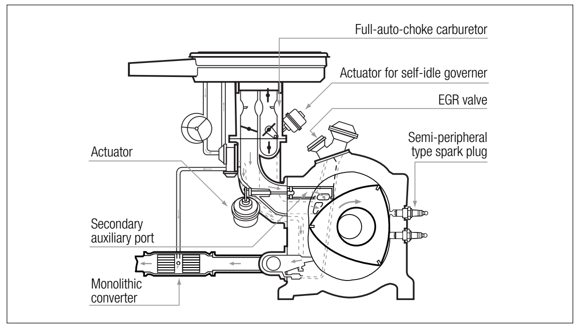
After its success in developing a low emission system and improving the rotary engine’s fuel economy, Mazda adopted a six-port induction system and two-stage monolithic catalyst for its type 12A engine (573cc single chamber volume).

The six-port induction system featured three intake ports per rotor chamber, and by controlling these intake ports in three stages fuel economy could be improved without sacrificing performance at high speeds.

This system, coupled with the two-stage monolithic catalyst would further the rotary engine’s advance.

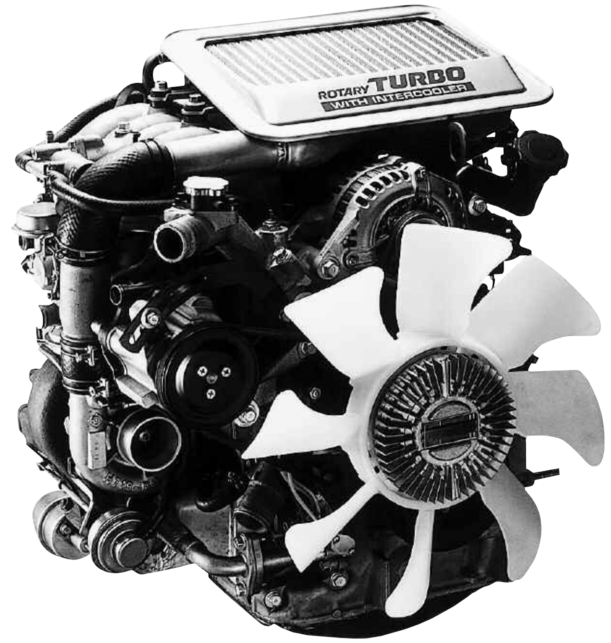


Lean-Burn Rotary Engine
By introducing a catalytic converter as a device to purify exhaust emissions, leaner mixture settings were achieved.



Six Port Induction System
A variable-intake system which utilized the design features inherent to the rotary engine to enhance power and fuel economy.

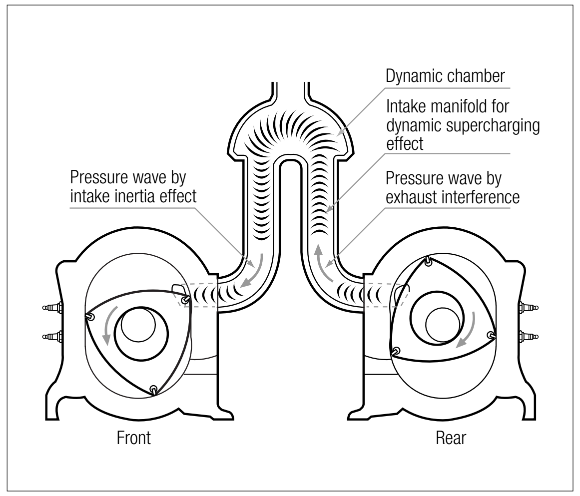
The Turbo Rotary Era



13B Rotary Turbo Engine
■ The second generation RX-7 made its debut in 1985, featuring a 13B rotary engine boosted by a Twin-Scroll Turbo. The engine produced a maximum output of 185PS.

■ RE Turbo and Dynamic Supercharger

The Cosmo RE Turbo, which went on sale in 1982, was the world’s first rotary engine car equipped with a turbocharger. Compared to a conventional reciprocating engine, the rotary engine’s exhaust system inherently offered more energy to drive a turbocharger; in short, the rotary engine was better suited to the turbocharger.



Dynamic Supercharging System
■ This system, with neither turbo nor supercharger, offers drastically improved charging efficiency over conventional designs by utilizing pressure waves generated inside the intake manifold by the sudden opening and closing of the ports.

Moreover, the Cosmo RE Turbo was the world’s first series-production rotary engine car equipped with an electronically controlled fuel injection system.

The Cosmo RE Turbo was the fastest commercial car in Japan at that time and it clearly demonstrated the attractiveness of the rotary engine. Shortly after came the debut of the “Impact-Turbo”, developed exclusively for the rotary engine and responsible for even further improvements in response and output.

The “Dynamic Supercharging” system was adopted in 1983 for the naturally aspirated (NA) rotary engine, type 13B. This system dynamically increased the intake air volume without turbo or mechanical supercharger, by utilizing the induction characteristics peculiar to the two-rotor rotary engine.

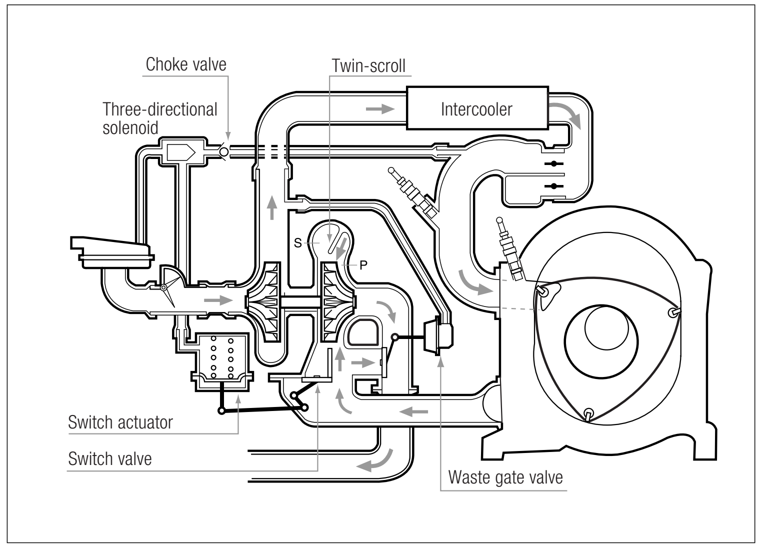
With the six-port induction system and a dual injector system with two fuel injectors per chamber, the 13B rotary engine came equipped with this dynamic supercharging system and achieved significant output increases regardless of the speed range. The dynamic supercharging system was further improved in 1985 through changes in the surge tank configuration.

Cosmo RE Turbo

■ Twin-Scroll Turbo

To improve the driving performance of the turbo rotary engine, the second generation Savanna RX-7 adopted the 13B engine with a Twin-Scroll Turbo to minimize turbo lag. The Twin-Scroll Turbo divided the exhaust intake scroll of the turbine into two passages so that exhaust could be supplied step-wise. With this configuration, the single turbocharger acted as a variable turbo and efficiently covered a wide range of speeds.

In 1989, the Twin-Scroll Turbo evolved into the Twin-Independent-Scroll Turbo, which had a more simplified configuration. When this new turbocharger was coupled with other improvements in the engine, it provided more outstanding low-speed torque, improved responsiveness, and upgraded driving performance.



Twin-Scroll Turbo System

■ This system helps to reduce turbo-lag, a traditional drawback of the turbo-engine. The duct feeding exhaust gas to the turbine was split into two, one of which was closed by a valve to accelerate exhaust gas flow at low speeds.

■ Dual Fuel Injector

Since 1983, Mazda's electronically-controlled fuel injection system for rotary engines has featured two injectors in each rotor chamber. Generally speaking, a larger nozzle is better for high-performance output as it can supply larger amounts of fuel. For more stable combustion at low speeds, however, a smaller nozzle is preferable as it can atomize fuel better.

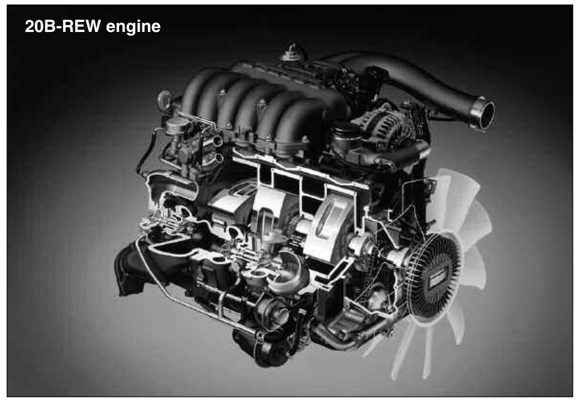
The dual injector was developed to cover the requirements of controlling fuel injection over a wide range of engine operations. The two-rotor 13B-REW and the three-rotor 20B-REW rotary engines were both equipped with air-mixture injectors, underwent further evolution of the dual fuel injectors, and achieved radical improvements in fuel atomization.

Today, the RENESIS engine powering the RX-8 has an ultra-atomizing system, and a description of the system is given earlier in this booklet.

■ Type 20B-REW Rotary Engine

In 1990, the Eunos Cosmo, with its three-rotor 20B-REW rotary engine, went on sale after a continuous quarter-century of research and development into the rotary engine. While the two-rotor engine produced a smooth operation equivalent to the 6-cylinder reciprocating engine, the three-rotor engine exceeded that of the V8 engine and even approached the level of a V12.

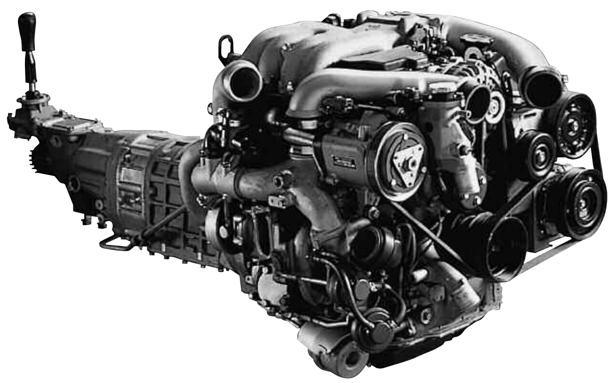
However, a difficult engineering problem stood in the way of mass-manufacturing the multi-rotor rotary engine. When the rotary engine was planned with an in-line multi-rotor configuration, only two choices in designing the eccentric shaft were feasible: coupling it through joints, or making one of the fixed gears on the rotors split-assembled. Since the early stages of development in the 1960s, Mazda had focused on the coupled eccentric shaft layout because the fixed gear split layout was considered too complicated for mass production., but now the company considered how to design the joints. The successful solution discovered in the 1980s was to use tapered joints in connecting the shafts. When the three-rotor engine was developed, extensive driving tests for performance and durability were carried out, including participation in international sports car racing activities like the famous Le Mans 24 Hours race.



20B-REW engine

■ Sequential Twin-Turbo

Development of the Sequential Twin-Turbo, first adopted in 1990 on the type 20B-REW and type 13B-REW rotary engines, was based on the unique engineering concept of utilizing two turbochargers in sequence. At low speeds, only the first turbocharger operates, and at higher speeds the second turbocharger kicks in. The use of two turbochargers enabled excellent forced-charging capacity and yielded high output. Running two turbochargers simultaneously also had the added benefit of reducing back-pressure on the exhaust, which in turn contributed to even higher performance.



13B-REW engine with sequential twin turbo

■ The 13B-REW turbocharger employed abradable seals to minimize the gap between turbine blades and housing, producing an ultra-high-flow turbine that combined lower inertial mass with high flow volume to achieve an outstanding maximum power output of 280 PS (206 kW).

As mentioned previously, the rotary engine is inherently suited to use with a turbocharger thanks to characteristics that include a more dynamic exhaust flow caused by the sudden opening of the exhaust port, and a short and smooth manifold. To fully utilize these features, the uniquely shaped Dynamic Pressure Manifold was adopted to guide the exhaust gas into the turbocharger over the shortest distance.

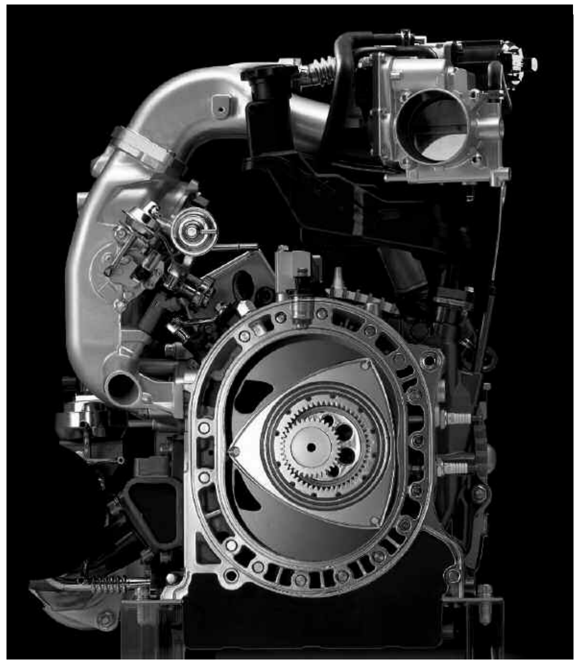
The 13B-REW engine with sequential twin turbochargers installed in the third-generation RX-7 was revised in 1998 to deliver 280 PS (206 kW) maximum power.

RX-7

A Cleaner Kind of *Zoom-Zoom* Performance Achieved by Exclusive Mazda Technologies

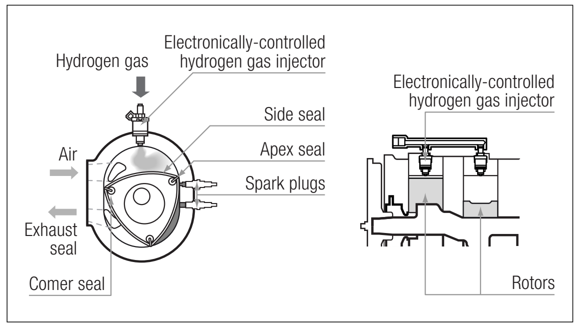
Mazda is pursuing development of the RENESIS hydrogen rotary engine with a view to producing cars that are not only thrilling to drive but also eco-friendly. This hydrogen rotary capitalizes on the advantages of the standard rotary engine through Mazda's exclusive technologies, achieving clean performance and the kind of comfortable ride people expect from a conventional car.

The engine is as easy-to-drive and reliable when running on hydrogen as it is when running on gasoline. And since hydrogen capability demands only minor engine and body modifications to the conventional gasoline-only model, it can be adopted at relatively low cost. A dual-fuel system enables the RENESIS hydrogen rotary engine to run on gasoline when necessary, which is highly convenient for long journeys and when traveling in areas that lack hydrogen supply facilities.



■ Technologies Used in the RENESIS Hydrogen Rotary Engine

An electronically controlled direct-injection system supplies the RENESIS hydrogen rotary engine with hydrogen gas. In each of the engine's two rotor housings, air is drawn through a side port and hydrogen is injected directly into the induction chamber by electronically controlled gas injectors located on top of the rotor housing. The benefits of the rotary engine in hydrogen-fuel mode are maximized by the following technologies:



Backfire suppression

In developing the hydrogen internal combustion engine, a major problem is avoiding early ignition of the hydrogen during the induction stroke (backfiring) due to the injected gas making contact with hot engine parts. Since the conventional reciprocating engine conducts intake, compression, expansion (combustion) and exhaust strokes in a single chamber, the spark plug and exhaust valves reach extremely high temperatures, which can easily cause backfiring during the intake stroke.

Unlike a reciprocating engine, the rotary engine, by virtue of its structure, has no intake valves, and induction and expansion occur in separate chambers. Hydrogen can therefore be injected into a comparatively cool induction chamber and backfiring is easily avoided. The rotary engine also generates a stronger flow of the air-fuel mixture than its reciprocating counterpart, and since its operating cycle time is longer, it promotes more thorough mixing of hydrogen and air. Owing to this, the rotary engine is capable of maintaining a homogeneous air-fuel mixture for combustion.

Combination of direct injection and pre-mixing

With the aim of achieving high power output in hydrogen-fuel mode, a direct injection system is adopted with electronically controlled hydrogen injectors mounted on top of the rotor housings. Since the hydrogen injectors use rubber seals, it is difficult to fit them in a reciprocating engine, where they are susceptible to the high temperature of the cylinder head. But the separate induction and combustion chambers of the rotary engine allow greater freedom of injector layout, thereby facilitating the application of direct injection in rotary induction.

Gas injectors for pre-mixing are also fitted in the intake manifold, enabling combined use of direct injection and pre-mixing to attain optimal hydrogen combustion characteristics while driving. Furthermore, during gasoline-fuel mode, gasoline is supplied from the same gasoline injectors as the base engine.

Lean combustion and EGR

Lean combustion and EGR (Exhaust Gas Recirculation) are used to reduce NOx emissions. Under low loads, NOx reduction is mainly achieved lean combustion settings, while EGR and a 3-way catalytic converter assist in lowering NOx under high loads. The 3-way catalytic converter is the same as that used in the gasoline engine base model.

Dual-fuel system

When the hydrogen fuel supply runs out, the system automatically switches to gasoline-fuel mode. The driver can also switch to gasoline manually, so there is no loss of convenience.

■ RX-8 Hydrogen RE

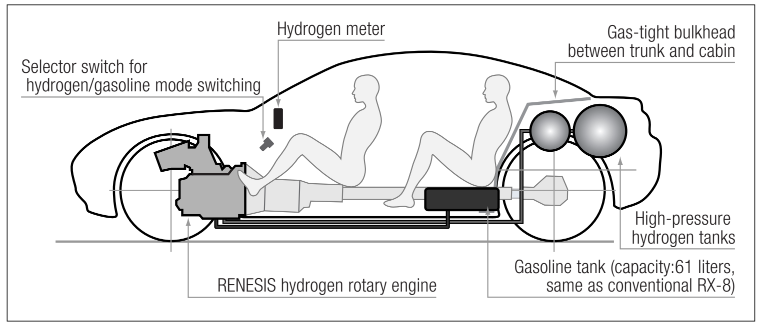
With the RX-8 Hydrogen RE, Mazda has successfully produced the world's first hydrogen rotary-engine vehicle that is viable for practical use. The hydrogen rotary engine realizes exceptional environmental performance, emitting zero CO_2 and minimal NOx without sacrificing the feeling of torque and acceleration or the exhaust note one expects from a conventional internal combustion engine. All of which makes the RX-8 Hydrogen RE the ultimate eco-car from Mazda, the company known for producing Zoom-Zoom fun-to-drive cars that people want to drive again and again.

In October 2004, Mazda received an approved number plate from the Ministry of Land, Infrastructure and Transport, and began testing the RX-8 Hydrogen RE on public roads in Japan. We subsequently carried out further improvements to the car, and began commercial leasing in February 2006. The RX-8 Hydrogen RE is currently being leased by government bodies, energy-related businesses and other organizations.

■ The RX-8 Hydrogen RE's Latest Technologies

Automatic transmission and increased driving range

In readiness for a market launch, Mazda recently equipped the RX-8 Hydrogen RE with an automatic transmission that enables more relaxed driving. We also enlarged the fuel tanks and adopted technologies to enhance the fuel economy, attaining a hydrogen-mode driving range of 100km (as measured by Japan's 10/15 mode standard).



Fuel selection

The dual-fuel system automatically switches to gasoline when the hydrogen supply runs out without the driver having to stop the car. A switch is also provided in the cabin which allows the driver to switch between gasoline-fuel and hydrogen-fuel while in motion (a useful feature for long journeys and for traveling in areas where there is no hydrogen supply infrastructure). The fuel selector switch is located at the bottom-right of the instrument panel (in front of the driver). When driving in hydrogen mode, the blue, rotor-shaped switch is illuminated. Switching from gasoline to hydrogen mode is only possible when the car is stationary.

Driver interface

A hydrogen-fuel gauge, fuel-mode indicator and warning lights are located in the center of the instrument panel to maximize visibility. The fuel-mode selector switch is lit only when the car is running in hydrogen mode. A chime also sounds before and after fuel switching to alert the driver.

Packaging

Even with two hydrogen fuel tanks located in the luggage compartment, the RX-8 Hydrogen RE assures the same cabin space for four occupants as the base model. The hydrogen tank pressure is 35MPa (currently the standard pressure for hydrogen stations in Japan). The hydrogen filler neck has the same type of adaptor that is widely used in fuel-cell electric vehicles. Two hydrogen filler necks are installed, one on either side of the gasoline filler neck.

RX-8 Hydrogen RE Major Specifications

Model		Mazda RX-8 Hydrogen RE
Body and chassis	Overall length	4435mm
	Overall width	1770mm
	Overall height	1340mm
	Wheelbase	2700mm
	Seating capacity	4
	Tires (front and rear)	225/55R16
Engine	Type	RENESIS hydrogen rotary engine with dual-fuel system
	Fuel	Hydrogen and gasoline
	Maximum output	Hydrogen mode: 80kW (109PS)
		Gasoline mode: 154kW (210PS)
	Maximum torque	Hydrogen mode: 140N-m (14.3kgm)
		Gasoline mode: 222N-m (22.6kgm)
Transmission 4AT		
Driving range: (10•15 mode)		Hydrogen mode: 100km
		Gasoline mode: 549km

Chapter 5

History of Motor Sports

The Challenge of Motor Sports—Germany's Nürburgring

■ The Racing Cosmo Sport 110S

After announcing the Cosmo Sport, the world's first mass-produced rotary engine car, Mazda was keen to participate in motor-sports activities, believing that motor sports enthusiasts would be extremely attracted to the high performance, reliability and durability of rotary engines. But in the initial stage of development, intensive efforts had to be focused on research for the completion of the rotary engine, and participation in motor-sports events was not a priority.

In 1964, however, a small scale Mazda racing team was organized, and began to compete in international races in Southeast Asia. Mazda quickly became known as one of the more enthusiastic car manufacturers in the sport.

Until Mazda's entry, no rotary-engine car had ever competed in an auto race, and an international meet held in Europe on August 21, 1968 was selected as the debut race for the Cosmo Sport. That 84-hour race was called the Marathon de la Route and was held at the Nürburgring Circuit in Germany, home country of the Wankel rotary engine. The race itself was exceedingly arduous: every car needed to keep running at full power for four full days.

Two Cosmo Sports modified for the endurance race were registered for entry. Their 10A rotary engines were modified to enhance reliability and durability, and maximum power was limited at a modest 130PS/7000rpm.

After the race started, two Porsches and one Lancia formed the top group, followed by the two Cosmo Sports. The Mazda racing team boldly fought on, even though one was forced to retire during the 81st hour after losing a tire due to rear axle trouble; the other completed the 84-hour race, and came in 4th overall. This result both shocked and moved racing enthusiasts throughout the world, and sealed the reputation of the rotary engine.

■ R-100 Takes up the European Touring Car Challenge

As the Familia Rotary Coupe (R100) made its debut in July 1968, the Mazda racing team started to compete in car races all over the globe. The 10A rotary engine mounted in the Familia Rotary Coupe generated around 200PS after special modifications for racing.

In April 1969, the Familia Rotary Coupe took first place overall in the Singapore Grand Prix. The team then moved on to Europe and in July of that year, competing against a fleet of Porsche 911s, finished 5th and 6th overall at the Belgium Spa-Francorchamps 24-hour race. In August, the second challenge in the Marathon de la Route 84-hour race resulted in a finish of 5th place overall.

In June of the following year, the team took 8th place overall in the RAC Tourist Trophy Race in England, followed by a 4th place showing overall in July at the West German Touring Car Grand Prix. Later that year, four Familia Rotary Coupes registered to compete in the Spa-Francorchamps 24-hour race with Mazda aiming to dominate the event. In the race, the Mazda team boldly confronted the BMW team, and finished in a dead heat. Although a pair of Japanese drivers (Yoshimi Katayama and Toshinori Takechi) held the lead at the 12th hour, the team encountered trouble and lost three cars. The lone surviving Mazda took 5th place overall, and the Familia Rotary Coupe earned the nickname "Small Giant" because of its strenuous efforts.

From Racing in Japan to IMSA and the WRC

■ 100 Wins for the Savanna RX-3

While the Familia Rotary Coupe was racing all over the world, the first race in Japan for the car took place in November 1969. Its debut was the All Japan Suzuka Automobile Grand Cup Race, where the Mazda team took first place overall. Touring car races in Japan at that time, however, were dominated by the Nissan Skyline GT-R (powered by a 2.0-liter DOHC inline 6-cylinder reciprocating engine). Although the Mazda racing team continued its challenge to the Skyline by switching their entry from the Familia to the more powerful Capella Rotary, with its 12A rotary engine, the team couldn't break the Skyline's domination. However, the first generation Savanna (with its 10A rotary engine), launched in September 1971, was very promising. In December of that year, three months after it went on sale, the Savanna defeated the Nissan Skyline GT-R in the Fuji 500-mile Tourist Trophy Race, just in time to prevent the Skyline's 50th victory.

In the following year, 1972, the Savanna RX-3 (Savanna GT in the market) with the long-awaited 12A rotary engine, made its debut, and dominated the Japan Grand Prix (TS-b Race) by taking the top positions after some fierce battles.

The Savanna chalked up its 100th victory in domestic race events when it won the JAF Grand Prix (TS/GTS-B Race) in 1976.

Mazda also manufactured "pure" race engines based on the 13B rotary engine and supplied them to racing teams in Japan. The 13B-powered racing prototypes came to dominate the Fuji Grand Champion Series.

■ Racing at IMSA Events

The Mazda RX-7 (Savanna RX-7 in the domestic market) made its debut in March 1978. It was a high-performance sports car that was praised by racing enthusiasts all over the world.

Mazda's activities in the International Motor Sports Association (IMSA) in the United States were especially extensive. At its debut race in 1979, Mazda won the GTU class (5th place overall) in the Daytona 24-hour race, and has never lost a race in the GTU class. For eight consecutive years (from 1980 to 1987), Mazda continued to win the IMSA series championship, a first in IMSA history.

In 1985, the RX-7 marked the IMSA winning record for a single model line, a distinction formerly held by the Porsche Carrera RSR. Thereafter, Mazda continued its activities in IMSA series and won the championship 10 times in the GTU class. From 1990, the RX-7 powered by a specially prepared four-rotor rotary engine officially began to compete in the GTO class, and in 1992 in the GTP class. By 1990, a total of 100 victories were chalked up, an IMSA series record. These astonishing results were largely due to the Mazda RE's proven high durability and reliability, and their ease of tuning and maintenance. RX-7 users were unanimous in their opinions. "The attraction of the rotary engine lies in its rugged endurance and reliability. We can use the time usually spent checking the engine on checking other parts of the car."

The RX-7 also won championships in the British Saloon Car Race, the Belgium Touring Car Race, and the Australia Touring Car Endurance Race. In 1981, the RX-7 won the Spa-Francorchamps 24-hour race. First place overall—the dream of the Familia Rotary Coupe 11 years earlier—was finally achieved by the RX-7.

■ WRC Challenges

Mazda also entered the World Rally Championship to demonstrate the high potential of the RX-7.

The first full-scale competition was the 1981 RAC Rally, where it finished 11th place overall. In 1982, entry in the New Zealand Rally resulted in 5th place overall.

In 1984, the RX-7 with a 13B rotary engine was specially developed for the World Rally Championship, where it was widely believed that only four-wheel-drive cars could compete. But the two-wheel-drive RX-7 took 9th place overall, proving its strong capabilities.

Rally activities all over the globe continued, and in 1985 Mazda's entry in the Acropolis Rally resulted in 3rd place overall. Thus, it was proven that the highly durable rotary engine could excel not only in races but also in rallies.

In December 1991, the third-generation Mazda RX-7 (with a turbocharged 13B rotary engine) was unveiled, and immediately began competing in motor-sports events in Japan, the United States, and Australia.

The car was particularly successful in Australia, winning the overall championship in the most popular touring car race, the Bathurst 12-hour Endurance Race, from 1992 through 1994. It also won the overall championship in the following year, 1995, when the venue was switched to the Eastern Creek circuit.

Le Mans and the Racing Rotary

■ The First Le Mans Challenge

Mazda's participation in motor-sports activities showcases the reliability, durability, and high performance of the rotary engine. So winning the world's most traditional endurance race—the Le Mans 24—stood as the most inspiring objective.

1970 marked the first time a rotary engine car competed at Le Mans, with a private team organized by Belgian drivers entering a car built in the U.K., the Chevron B16, powered by a Mazda-supplied 10A rotary engine. In 1973, the Japanese team Sigma Automotive made their debut in the race with a modified Sigma MC73 Mazda equipped with a 12A rotary engine. The car, however, had to retire after 11 hours due to trouble with the electrical system. The following year, a modified Sigma MC74 Mazda (with type 12A rotary engine) received the checkered flag after overcoming many troubles, but due to a shortage of laps, did not qualify.

In 1975, a private French team entered with a Mazda S124A (Savanna RX-3), but retired before completing the race. In 1979, the motor sports department of Mazda Auto Tokyo challenged the IMSA class race with a Silhouette Formula based on the Savanna RX-7, known as Mazda RX-7/252i, but regrettably retired in the trial phase of the race. In 1980, a private American team entered the race with an RX-7, and wound up in 21st place overall. It was the first rotary engine car to finish this historic endurance race.

In 1981, Mazda Auto Tokyo entered the race again with two Mazda RX-7/253s (modified versions of 1979's 252i), but failed to finish due to differential and transmission problems. The following year, two improved RX-7/254s were entered in the IMSA-GTX category with one of them finishing 6th in its category and in 14th place overall.

■ Repeated Trials

From 1983, Mazda Auto Tokyo targeted the newly defined Group C Junior category (renamed as Group C2 in 1984), developed a midship sports prototype car, the Mazda 717C and entered two in the race. The strategy worked taking first and second places in the C Junior category and winning several awards (12th and 18th overall). In June of that year, Mazda Auto Tokyo reorganized its motor sports department into what is now called MazdaSpeed, and began full-scale design and build work on a sports prototype car for Le Mans, as well as carrying on development of Mazda Racing Team activities.

In 1984, a total of four rotary engine cars entered the race. Two were Model 727C, modified from the 717C, and the other two were Lola T616 Mazdas (with 13B rotary engines) prepared by the BF Goodrich team, sponsored by the American tire manufacturer.

One of the Lolas took first place in the C2 category (10th place overall), and the other took third place in the same category (12th place overall). The two Mazda 727Cs took 4th place (15th place overall) and 6th place (20th overall). All four rotary cars finished the race, and the C2 category was dominated by them for two consecutive years. Such results were enough to prove the high reliability and performance of the rotary engines yet again.

The following year, 1985, two Mazda 737Cs, modified from the 727C, entered the race, but ended up with disappointing third place (19th place overall) and sixth place (24th place overall) finishes in the C2 category due to transmission and other troubles.

■ Multi-Rotor Rotary Engine

In 1986, two newly developed Mazda 757s with type 13G three-rotor engines entered the race in the IMSA-GTP category, but both were forced to retire due to drive shaft problems. Two 757s, however, repeated the challenge the next year, and one of them triumphed in the GTP category (7th place overall). In 1988, in a bid to become the overall champion, two Mazda 767s, with newly developed type 13J-modified four-rotor engines, along with one proven Mazda 757, entered the race. The two 767s held the lead over other Japanese entries from the beginning, but due to exhaust manifold breakage, they finished the race in 17th and 19th places overall. The 757 also had rotor crack problems in the brakes, and finished 15th overall. They occupied the upper places of the IMSA-GTP category, including the top position, but could not capture top honors.

In 1989, two 767Bs and one 767 were entered in the race. Unfortunately two of them crashed in practice, jeopardizing their entry in the actual race, but the cars were restored by an extraordinary team effort, and all three cars finished the race. The results were seventh place (won the IMSA-GTP category), ninth place, and twelfth place overall, but still several steps short of the hoped-for overall victory.

In 1990 two new cars, the Mazda 787 with a newly developed R26B four-rotor engine, and one 767B entered the race. The Mazda 787s were fitted with full-carbon twin-tube chassis, and were regarded as most promising for victory. However, the two 787s had to retire due to abnormal fuel consumption and electrical system troubles. The 767B completed the race and won the IMSA-GTP category but finished in a disappointing 20th place overall.

■ Long Awaited Victory

The Mazda team challenge for the 1991 Le Mans 24 hours race featured two improved 787Bs and one 787. The R26B four-rotor unit now had greatly improved power and fuel efficiency. However, the organizers of this historic event had decided to restrict the race from the following year to machines powered by a 3.5-liter reciprocating engine, so this was the last chance for the four-rotor engine powering the 787B and 787.

From the very start, the three Mazdas competed successfully. At the 12th hour, the 787B with car number 55 took 3rd place and fought aggressively against Mercedes-Benz, Jaguar and other top contenders. After 21 hours, while a Mercedes-Benz machine had a pit stop, the 787B took the lead.

At 4 o'clock in the afternoon of June 23, 1991, the 787B passed the finish line, achieving Mazda's long awaited target as two hundred fifty thousand spectators cheered the car.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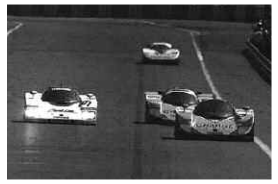
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1 ■ Car 55, the Mazda 787B, winner of the 1991 Le Mans 24 Hours and driven by V. Weidler (Germany), J. Herbert (UK) and B.Gachot (France).

2 ■ In 1983 MazdaSpeed's first entry, the 717C driven by three Japanese drivers (Katayama/Terada/Yorino), won the C Junior class and finished in 12th place overall.

3 ■ In 1989 the 767B, a racing prototype powered by a four-rotor rotary engine, took first, second, and third places in the IMSA-GTP class.

4 ■ The victory of the Mazda 787B was extremely valuable because it defeated the heavily favored Jaguar XJR12, Mercedes-Benz C11 and other tough contenders.

5 ■ Fine teamwork of the Japanese pit-crew members was a key element in the 787's victory. Mazda has learnt a great deal from the yearly challenges of the Le Mans 24-Hour race.

6 ■ Two 787Bs entered the 1991 Le Mans. One of them famously won the championship, while the other finished in sixth place overall.

An Album of Mazda's Rotary Engine Vehicles

Cosmo Sport/Mazda 110S — 1967 – 1972

The world's first twin-rotor rotary engine car was launched in May 1967. Its low, streamlined silhouette and futuristic body styling took advantage of the compact rotary engine, and defined the start of the rotary engine era, thrilling customers everywhere. In July of 1968, the improved version of the Cosmo Sport went on sale, featuring an uprated 128PS L10B rotary engine and wheelbase extended by 150mm. Maximum speed of 200km/h and acceleration that covered 400m from a standing start in 15.8sec. excited sports car fans all over the globe. A total of 1,176 units were produced over 5 years.

Major specifications:
■ Length×Width×Height: 4140×1595×1165mm ■ Wheelbase: 2200mm ■ Track (front/rear): 1250/1240mm ■ Vehicle Weight: 940kg ■ Seating Capacity: 2 ■ Engine Type: 10A ■ Displacement: 491cc×2 ■ Maximum Output: 110PS/7000rpm ■ Maximum Torque: 13.3kg-m/3500rpm (JIS gross) ■ Maximum Speed: 185km/h ■ Transmission: 4-speed Manual

Familia Rotary/Mazda R100 — 1968 – 1973

Development was based on the prototype Mazda RX-85, announced in 1967 at the 14th Tokyo Motor Show. It went on sale in July, 1968. The type 10A rotary engine, proven to be reliable and durable in the Cosmo Sport, was mounted in a fastback, two-door coupe style body designed as a high performance touring car, but with sufficient space to be used as a family car. In 1969, the sedan version—a high-performance family car called the Familia Rotary SS—was added to the lineup. A total of 95,891 units were produced over 5 years.

Major Specifications of the Familia Rotary Coupe:
■ Length×Width× Height: 3830×1480×1345mm ■ Wheelbase: 2260mm ■ Track (front/rear): 1200/1190mm ■ Vehicle Weight: 805kg ■ Seating Capacity: 5 ■ Engine Type: 10A ■ Displacement: 491cc×2 ■ Maximum Output: 100PS/7000rpm ■ Maximum Torque: 13.5kg-m/3500rpm (JIS gross) ■ Maximum Speed: 180km/h ■ Transmission: 4-speed Manual

Luce Rotary Coupe/Mazda R130 Coupe — 1969 – 1972

This highly refined personal coupe based on the prototype Mazda RX-87, was announced in 1968 at the 15th Tokyo Motor Show. It featured a front-engine, front-wheel-drive configuration and went on sale in October 1969. Its elegantly designed Italian-style body was graced with streamlined curves and shapely sculptured lines, without the then-popular front quarter windows. The type 13A rotary engine generating 126PS at 6000rpm boasted outstanding performance; it was extremely quiet and fit right into the trend of high-speed driving becoming popular at the time.

Major Specifications:
■ Length×Width×Height: 4585×1635×1385mm ■ Wheelbase: 2580mm ■ Track (front/rear): 1330/1325mm ■ Vehicle Weight: 1185kg ■ Seating Capacity: 5 ■ Engine Type: 13A ■ Displacement: 655cc×2 ■ Maximum Output: 126PS/6000rpm ■ Maximum Torque: 17.5kg-m/3500rpm (JIS gross) ■ Maximum Speed: 190km/h ■ Transmission: 4-speed Manual

* Data is taken from the first production models (Japan specification)

Capella Rotary/Mazda RX-2 — 1970 – 1978

Launched as a high-performance model in the mid-sized Capella series and went on sale in May 1970. A newly designed rotary engine, the 12A, was installed and the G series, the world's first rotary engine car with authentic automatic transmission, was added in 1971. The high-performance GSII with its 5-speed manual transmission, was introduced in 1972, and the AP, with its full anti-pollution package, came out in 1974. Winner of the 1972 Import Car-of-the-Year award from Road Test, a popular car magazine in the U.S. at the time.

Major Specifications of the Capella Rotary Coupe:
■ Length×Width×Height: 4150×1580×1395mm ■ Wheelbase: 2470mm ■ Track (front/rear): 1285/1280mm ■ Vehicle Weight: 950kg ■ Seating Capacity: 5 ■ Engine Type: 12A ■ Displacement: 573cc×2 ■ Maximum Output: 120PS/6500rpm ■ Maximum Torque: 16.0kg-m/3500rpm (JIS gross) ■ Maximum Speed: 190km/h ■ Transmission: 4-speed Manual

Savanna/Mazda RX-3 — 1971 – 1978

A sport sedan and coupe launched in September 1971, with the type 10A rotary engine. In 1972 the fully automatic transmission version, the Sport Wagon, was introduced as the world's first rotary engine wagon. The GT, with its 12A rotary engine and 5-speed manual transmission, was also added. A variety of sport-kits were prepared and contributed to many successful races. In 1973, the AP, with its anti-pollution package, was added. In 1975, the REAPS rotary engine, which achieved lower emissions and better fuel economy, was introduced.

Major Specifications of the Savanna Coupe:
■ Length×Width×Height: 4065×1595×1350mm ■ Wheelbase: 2310mm ■ Track (front/rear): 1300/1290mm ■ Vehicle Weight: 875kg ■ Seating Capacity: 5 ■ Engine Type: 10A ■ Displacement: 491cc×2 ■ Maximum Output: 105PS/7000rpm ■ Maximum Torque: 13.7kg-m/3500rpm (JIS gross) ■ Maximum Speed: 175km/h ■ Transmission: 4-speed Manual

Luce Rotary/Mazda RX-4 — 1972 – 1977

The second generation Luce, with its 12A rotary engine, was launched in October 1972 and was available in three body styles: hardtop, sedan, and custom. These models led the way into the top sport & luxury markets for rotary engine cars. In 1973, the Luce Wagon and the Grand Turismo with wood-grain panels on the sides, were added. At the same time, additional models with low emission AP versions and 13B rotary engines were prepared. They proved that low emissions and high performance could be compatible.

Major Specifications of the Luce Sedan:
■ Length×Width×Height: 4240×1670×1410mm ■ Wheelbase: 2510mm ■ Track (front/rear): 1380/1370mm ■ Vehicle Weight: 1035kg ■ Seating Capacity: 5 ■ Engine Type: 12A ■ Displacement: 573cc×2 ■ Max. Output: 130PS/7000rpm ■ Max. Torque: 16.5kg-m/4000rpm (JIS gross) ■ Max. Speed: 185km/h ■ Transmission: 5-speed Manual/3-speed Automatic

Rotary Pickup

1973 – 1977

Marketed exclusively in North America where pick-up trucks enjoyed great popularity, this was the world’s first pick-up truck and utility vehicle with a rotary engine. The lightweight and compact rotary engine was durable and fit well in this type of vehicle. Massive front grill, boxy body, large mirrors, extruded fenders, and wide tires were well-suited to the tastes of American pickup buyers. This was a unique rotary engine vehicle, not sold in Japan.

Major Specifications:
Not available, vehicle marketed exclusively in North America.

Parkway Rotary 26

1974 – 1976

The world’s first rotary engine bus, launched in July 1974 and equipped with the 135PS maximum power 13B rotary engine, offered a cruising speed of 120km/h with a pleasantly smooth ride, low noise and little vibration, thanks to the inherent benefits of the rotary engine. Two models were available: a 26-passenger Deluxe version with optional air-conditioning operated by a sub-engine, and the 13-passenger Super-Deluxe version, with full luxury equipment. This was a unique model that showed the rotary engine was not solely for passenger cars.

Major Specifications:
■ Length×Width×Height: 6195×1980×2290mm ■ Wheelbase: 3285mm ■ Track (front/rear): 1525/1470mm ■ Vehicle Weight: 2885kg ■ Seating Capacity: 26 ■ Engine Type: 13B ■ Displacement: 654cc×2 ■ Maximum Output: 135PS/6500rpm ■ Maximum Torque: 18.3kg-m/4000rpm (JIS gross) ■ Maximum Speed: 120km/h ■ Transmission: 4-speed Manual

Roadpacer AP

1975 – 1977

A full-size sedan launched in March 1975, with some body parts and mechanical components supplied by GM-Holden of Australia. The engine was Mazda’s 13B RE. Anticipating the era of international joint operations, this project aimed at lowering costs and raising quality through shortened development periods; it saved its tooling investment for the small-volume, premium market. The Roadpacer AP was mainly sold as a chauffeur-driven saloon for company executives, but was also attractive as a high-class personal car. 800 units were produced over three years.

Major Specifications:
■ Length×Width×Height: 4850×1885×1465mm ■ Wheelbase: 2830mm ■ Track (front/rear): 1530/1530mm ■ Vehicle Weight: 1575kg ■ Seating Capacity: 5 ■ Engine Type: 13B ■ Displacement: 654cc×2 ■ Maximum Output: 135PS/6000rpm ■ Maximum Torque: 19.0kg-m/4000rpm (JIS gross) ■ Maximum Speed: 165km/h ■ Transmission: 3-speed Automatic

Cosmo AP/Mazda RX-5

1975 – 1981

This highly refined specialty car was launched in October 1975. Named after the Cosmo Sport, Mazda’s first commercialized rotary engine car, the Cosmo AP was available with both the 12A and 13B rotary engines with low-emissions package, and 10 optional variations were offered to customers. In 1977, Cosmo L, the Japan-first Landau-top model, was added. A commercial film, “Red Cosmo,” became wildly popular, and this model became an image leader for developing the high-performance specialty car market in Japan.

Major Specifications of the Cosmo AP:
■ Length×Width×Height: 4545×1685×1325mm ■ Wheelbase: 2510mm ■ Track (front/rear): 1380/1370mm ■ Vehicle Weight: 1220kg ■ Seating Capacity: 5 ■ Engine Type: 13B ■ Displacement: 654cc×2 ■ Maximum Output: 135PS/6000rpm ■ Maximum Torque: 19.0kg-m/4000rpm (JIS gross) ■ Transmission: 5-speed Manual/3-speed Automatic

Luce Legato/Mazda 929L

1977 – 1981

Launched in October 1977 as the top of the Luce series. The Luce Legato’s development concepts were high quality, grace, and distinction. Two rotary engine options, type 13B with 135PS and 12A with 125PS, were available. Two body styles, the 4-door Pillared Hardtop and the 4-door Sedan, were also offered. To meet various market segments, Mazda offered 3 versions and 10 types for the Pillared Hardtop, 4 versions and 10 types for the Sedan, and 3 types (with manual, automatic, and column-shift automatic transmission) for the top version, the 13B-powered Limited.

Major Specifications of the Luce Legato 4-door Hardtop:
■ Length×Width×Height: 4625×1690×1385mm ■ Wheelbase: 2610mm ■ Track (front/rear): 1430/1400mm ■ Vehicle Weight: 1225kg ■ Seating Capacity: 5 ■ Engine Type: 13B ■ Displacement: 654cc×2 ■ Maximum Output: 135PS/6000rpm ■ Maximum Torque: 19.0kg-m/4000rpm (JIS gross) ■ Transmission: 5-speed Manual/3-speed Automatic

Savanna RX-7/Mazda RX-7

1978 – 1985

The first generation RX-7 was launched in March 1978. The front mid-ship layout with an improved 12A engine and the then-unique retractable headlights helped realized an aerodynamic body design. This model became extremely popular not only in Japan but also in North America. A face-lift was made in 1980, the new 6PI engine was installed in 1981, and the 12A turbo rotary engine, which developed 165PS added in 1983.

Major Specifications:
■ Length×Width×Height: 4285×1675×1260mm ■ Wheelbase: 2420mm ■ Track (front/rear): 1420/1400mm ■ Vehicle Weight: 1005kg ■ Seating Capacity: 4 ■ Engine Type: 12A ■ Displacement: 573cc×2 ■ Maximum Output: 130PS/7000rpm ■ Maximum Torque: 16.5kg-m/4000rpm (JIS gross) ■ Transmission: 5-speed Manual/3-speed Automatic

Cosmo — 1981 – 1990

The third-generation Cosmo, launched in October 1981, was developed as a high-end personal car to meet the requirements of the day. Three body variations were offered: 2-door and 4-door hardtops, and saloon. The 6PI type 12A rotary engine was originally installed; type 13B, with its electronically controlled super-injection system, and type 12A with the Impact-Turbo, the world's first turbo rotary engine, were added later. Equipped with four-wheel independent and electronically controlled suspension, the Cosmo was fast and a pure pleasure to drive.

Major Specifications of the Cosmo 2-door Hardtop:
■ Length×Width×Height: 4640×1690×1340mm ■ Wheelbase: 2615mm ■ Track (front/rear): 1430/1425mm ■ Vehicle Weight: 1170kg ■ Seating Capacity: 5 ■ Engine Type: 12A ■ Displacement: 573cc×2 ■ Maximum Output: 130PS/7000rpm ■ Maximum Torque: 16.5kg-m/4000rpm (JIS gross) ■ Transmission: 5-speed Manual/3-speed Automatic

Luce/Mazda 929 — 1981 – 1986

The 3rd generation Luce was launched in October 1981, at the same time as the Cosmo. The series included a 4-door sedan and a hardtop, powered by a 2.0-liter reciprocating or a 12A rotary engine. Like the Cosmo, the rotary engine model employed Mazda's first 4-wheel independent suspension system. Later, the Luce underwent a major face-lift and got an extensively modified nose and rear end. The new top range models, powered by a turbochaged 12A or dynamic supercharger-equipped 13B rotary engine, became popular in the market as a luxury car with performance and elegance.

Major Specifications of the Luce 4-door Hardtop:
■ Length×Width×Height: 4640×1690×1360mm ■ Wheelbase: 2615mm ■ Track (front/rear): 1430/1420mm ■ Vehicle Weight: 1165kg ■ Seating Capacity: 5 ■ Engine Type: 12A ■ Displacement: 573cc×2 ■ Maximum Output: 130PS/7000rpm ■ Maximum Torque: 16.5kg-m/4000rpm (JIS gross) ■ Transmission: 5-speed Manual/3-speed Automatic

Savanna RX-7/Mazda RX-7 — 1985 – 1992

The second-generation RX-7 was launched in October 1985, with further upgraded styling and dynamic performance. The 13B rotary engine with Twin-Scroll Turbo and intercooler developed maximum power of 185PS. Mazda's unique multi-link rear suspension with toe-control capability also came as standard. The interior was designed with a perfect blend of harmony, beauty, and sportiness; the result was a "matured" sports car. In 1987, the Cabriolet was added; in 1989, the engine's maximum output was raised to 205PS.

Major Specifications:
■ Length×Width×Height: 4310×1690×1270mm ■ Wheelbase: 2430mm ■ Track (front/rear): 1450/1440mm ■ Vehicle Weight: 1240kg ■ Seating Capacity: 4 ■ Engine Type: 13B turbo ■ Displacement: 654cc×2 ■ Maximum Output: 185ps/6500rpm ■ Maximum Torque: 25.0kg-m/3500rpm (JIS net) ■ Transmission: 5-speed Manual/4-speed Automatic

Luce — 1986 – 1991

The fifth-generation Luce, launched in September 1986, was designed to couple the luxury of the top-end sedan with the sportiness of the rotary engine. The powerful turbocharged 13B rotary engine, with its 180PS maximum power, was installed. Combined with a newly developed automatic transmission, it realized smoother and quicker acceleration. The highly rigid monocoque body featured struts for the front and Mazda's unique E(Multi)-link suspension for the rear. It thus resulted in a high level of compatibility between performance and comfort as a luxury saloon.

Major Specifications:
■ Length×Width×Height: 4690×1695×1395mm ■ Wheelbase: 2710mm ■ Track (front/rear): 1440/1450mm ■ Vehicle Weight: 1500kg ■ Seating Capacity: 5 ■ Engine Type: 13B turbo ■ Displacement: 654cc×2 ■ Maximum Output: 180PS/6500rpm ■ Maximum Torque: 25.0kg-m/3500rpm ■ Transmission: 4-speed Automatic

Eunos Cosmo — 1990 – 1995

The Eunos Cosmo, launched in April 1990, was the world's first series-production car with a 3-rotor rotary engine, the type 20B-REW with Sequential Twin Turbo system, developing maximum power of 280PS in a smooth and responsive manner. The body was exclusively designed for the "full-size" category in Japan, The cabin was spaced as a luxury 2 plus 2, and interior materials—leather and wood—were carefully selected at the raw material stage. The engine, suspension automatic transmission, and air-conditioning system were all electronically controlled.

Major Specifications:
■ Length×Width×Height: 4815×1795×1305mm ■ Wheelbase: 2750mm ■ Track (front/rear): 1520/1510mm ■ Vehicle Weight: 1610kg ■ Seating Capacity: 4 ■ Engine Type: 20B-REW ■ Displacement: 654cc×2 ■ Maximum Output: 280PS/6500rpm ■ Maximum Torque: 41.0kg-m/3000rpm (JIS net) ■ Transmission: 4-speed Automatic

Mazda RX-7 — 1991 – 2002

The third-generation RX-7, launched in December 1991, featured a powerful and responsive 13B-REW rotary engine with Sequential Twin-Turbo and a superbly beautiful body silhouette. All-wheel double-wishbone suspension with newly developed dynamic geometry control mechanism was standard on all models. Developed as a pure sports car, it pursued the ultimate in driving pleasure. Face lifts came in 1996 and in 1998, and the maximum output of the 13B REW was boosted to 280PS for enhanced sports-car pleasure.

Major Specifications:
■ Length×Width×Height: 4295×1760×1230mm ■ Wheelbase: 2425mm ■ Track (front/rear): 1460/1460mm ■ Vehicle Weight: 1250kg ■ Seating Capacity: 4 ■ Engine Type: 13B-REW ■ Displacement: 654cc×2 ■ Maximum Output: 255PS/6500rpm ■ Maximum Torque: 30.0kg-m/5000rpm (JIS net) ■ Transmission: 5-speed Manual/4-speed Automatic

RX-8

2003 – present

The RX-8, which debuted in April 2003, comes equipped with the new-generation RENESIS rotary engine. Though naturally aspirated, the new RENESIS maximizes the benefits of the rotary engine, while being more compact, lighter and higher performing than its predecessors. It also provides more cabin space, accommodating up to four adults in comfort. The RX-8 is a 4-door, 4-seat sports car with innovative styling. As a new-concept genuine sports car with high levels of environmental and safety performance, the RX-8 has garnered many awards, including the 2004 RJC Car of the Year Award, and enjoys considerable popularity among the car-buying public.

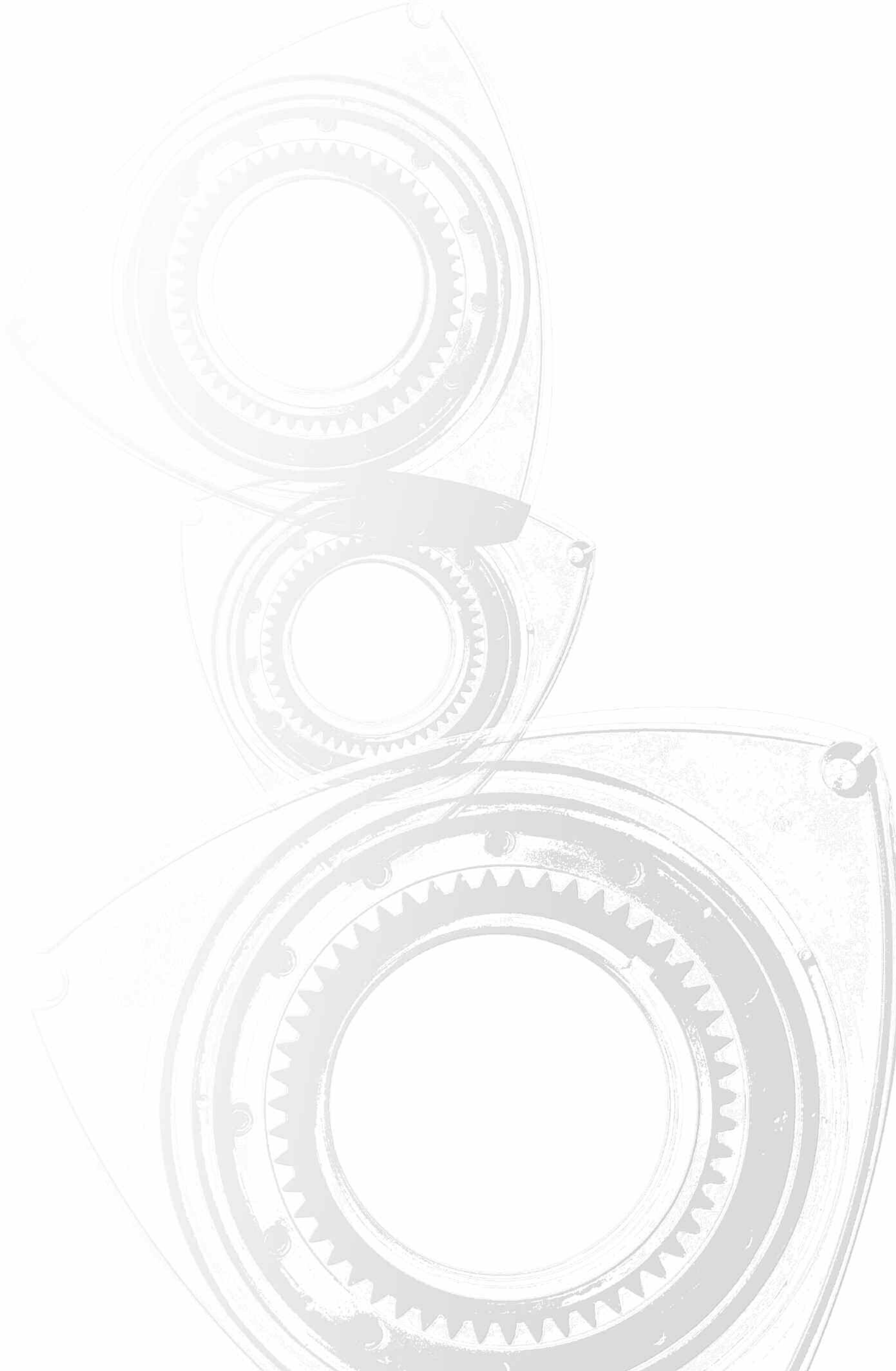
Major Specifications:
■ Length×Width×Height: 4435×1770×1340mm ■ Wheelbase: 2700mm ■ Track (front/rear): 1500/1505mm ■ Vehicle Weight: 1310kg ■ Seating Capacity: 4 ■ Engine Type: 13B-MSP ■ Displacement: 654cc×2 ■ Maximum Output (Net): 250PS/8500rpm ■ Maximum Torque (Net): 22.0kg/3000rpm ■ Transmission: 6-speed Manual

RX-8 Hydrogen RE

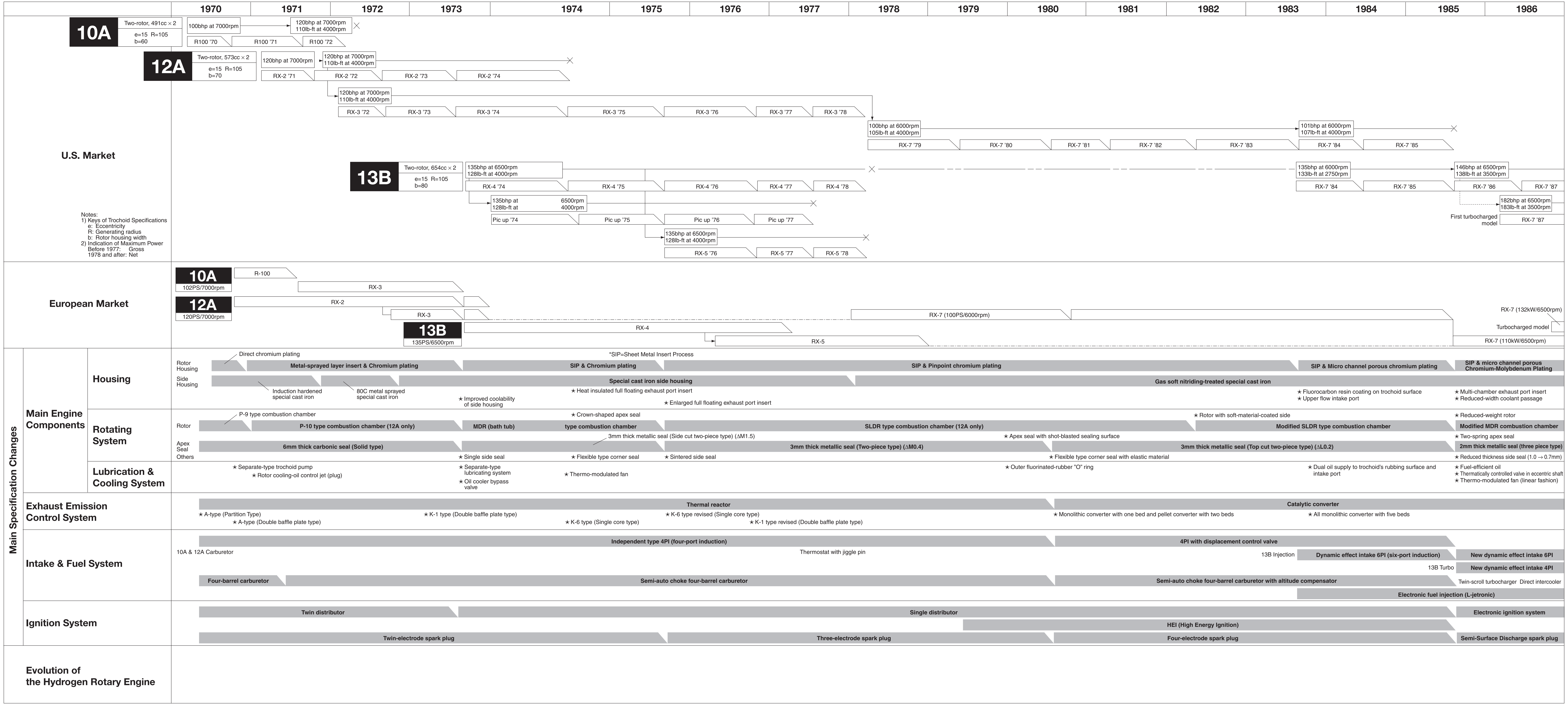
2004 – present

The hydrogen-fuelled RX-8 Hydrogen RE started running on public roads in Japan on receiving approval from the Ministry of Land, Infrastructure and Transport in October 2004. With zero CO_2 emissions, the hydrogen rotary engine exhibits exceptional environmental performance while retaining the characteristic-driving feel of an internal combustion engine. To enable the RX-8 Hydrogen RE to run in areas not yet provided with hydrogen filling stations, the engine uses a dual-fuel system that switches between hydrogen and gasoline fuel modes. The base model RX-8 remains unchanged, assuring seating capacity for four as well as highly practical on-board equipment. The RX-8 Hydrogen RE, which is leased to businesses and local governments, is gaining a favourable reputation and spurring research and development towards the realization of a hydrogen energy society.

Major Specifications:
■ Length×Width×Height: 4435×1770×1340mm ■ Wheelbase: 2700mm ■ Track (front/rear): 1500/1505mm ■ Vehicle Weight: 1460kg ■ Seating Capacity: 4 ■ Engine Type: 13B ■ Displacement: 654cc×2 ■ Maximum Output (Net): Hydrogen 109PS, Gasoline 210PS ■ Maximum Torque (Net): Hydrogen 14.3kg-m, Gasoline 22.6kg-m ■ Transmission: 4-speed Automatic ■ Fuel: Hydrogen/gasoline dual-fuel system



History of Mazda's Rotary Engine Development



1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
U.S. Market
160bhp at 7000rpm
140lb-ft at 4000rpm
RX-7 '87
RX-7 '88
RX-7 '89
RX-7 '90
RX-7 '91
200bhp at 6500rpm
196lb-ft at 4000rpm
255bhp at 6500rpm
217lb-ft at 5000rpm
RX-7 '87
RX-7 '88
RX-7 '89
RX-7 '90
RX-7 '91
RX-7 '93
RX-7 '94
RX-7 '95
Notes:
1) Keys of Trochoid Specifications
e: Eccentricity
R: Generating radius
b: Rotor housing width
2) Indication of Maximum Power
Before 1977: Gross
1978 and after: Net
RENESIS 6-port engine
184kW (250PS)/8500rpm
216N-m (22.0kg-m)/5500rpm
RENESIS 4-port engine
154kW (210PS)/7200rpm
222N-m (22.6kg-m)/5000rpm
RENESIS 6-port engine
158kW (215PS)/7450rpm
216N-m (22.0kg-m)/5500rpm
RX-8 '03
European Market
RX-7 (132kW/6500rpm)
RX-7 (147kW/6500rpm)
RX-7 (176kW/6500rpm)
RX-7 (110kW/6500rpm)
RENESIS 6-port engine
RX-8 (170kW/8200rpm)
RENESIS 4-port engine
RX-8 (141kW/7000rpm)
Main Specification Changes
Main Engine Components
Housing
SIP & micro channel porous Chromium-Molybdenum Plating
Gas soft nitriding-treated special cast iron
★ Ion-nitrided stationary gear
★ Graphite coating on trochoid surface
Rotating System
★ Ion-nitrided rotor gear, thin and light rotor
Improved precision in bearing clearance ★
Modified MDR combustion chamber
High-precision and compression MDR combustion chamber
Lightweight rotor with MDR combustion chamber
Laser beam hardening of rotor apex seal groove ★
2mm thick metal seal (three piece type)
2mm thick metal seal (two piece type)
Lubrication & Cooling System
★ Electronically-controlled metering oil pump
★ Direct oil injection to trochoid's rubbing surface
★ Thin oil pan with inner bulge
★ Three-stage controlled electric fan
★ 2-stage electronically controlled M.O. oil supply system
★ High response metering oil nozzle
★ Twin direct oil supply system
★ Ultrathin oil pan with inner bulge
Exhaust Emission Control System
Catalytic converter
★ Double layered catalytic converter
★ Metal catalytic converter
★ Electric secondary air pump
Intake & Fuel System
New dynamic effect intake 6PI
Variable dynamic effect intake 6PI
Sequential Dynamic Air Intake 6PI
New dynamic effect intake 4PI
★ Independent twin-scroll turbo system
★ Sequential twin turbo system
★ EGI-HS
★ Independent air intake
Electronic fuel injection (L-jetronic)
Electronic fuel injection (D–jetronic)
EGI (L-jetronic)
Ignition System
Electronic ignition system
★ Crankshaft angle sensor
★ Platinum-tip spark plug
(Microcomputer control)
★ 16bit
★ 32bit
Semi-Surface Discharge spark plug
Super air-gap spark plug
Single-electrode spark plug
★ Iridium-tip
Evolution of the Hydrogen Rotary Engine
HR-X concept car (equipped with hydrogen rotary engine)
October 1991
Roadster (MX-5/Miata experimental vehicle equipped with hydrogen rotary engine)
HR-X2 concept car (equipped with hydrogen rotary engine)
October 1993
Capella Cargo (experimental vehicle equipped with hydrogen rotary engine)
RX-8 Hydrogen RE (development vehicle)
RX-8 Hydrogen RE launched on limited release basis
★ Development of first hydrogen rotary engine car, the HR-X
★ Development of second hydrogen rotary engine car, the HR-X2
★ Start of Hydrogen RE car tests on public roads
★ RX-8 Hydrogen RE trials begin on public roads with approval from the Ministry of Land, Infrastructure and Transport.

Mazda Rotary Engine: Chronological Table

Date	
1588	Ramelli invented the first rotary piston type water pump.
1636	Pappenheim invented a gear type pump.
1769	James Watt invented the first rotary steam engine.
1799	Murdock also invented a rotary steam engine and succeeded in generating power.
1901	Cooley manufactured a rotary steam engine in which both inner and outer rotors rotate.
1908	Umpleby advanced Cooley's steam engine into a rotary type internal combustion engine.
1923	Wallinder, Skoog, and Lundby announced their joint research on the rotary engine.
1938	Sensaud de Lavou further advanced the rotary theory.
1943	Maillard devised a compressor by applying the rotary theory.
1951	Felix Wankel collaborated with NSU to promote his rotary engine research and development.
1957	Wankel/NSU built a prototype DKM rotary engine.
1958	Wankel/NSU built a prototype KKM rotary engine.
Jul. 1959	Wankel completed the type KKM250 rotary engine.
Jan. 1960	Wankel/NSU tested their rotary engine in public.
Jul. 1961	Mazda made a technical contract with NSU and Wankel.
Nov. 1961	Mazda completed its own first prototype rotary engine.
Apr. 1963	Mazda organized Rotary Engine Research Department.
Sep. 1964	A prototype sports car powered by a rotary engine is unveiled at the Tokyo Motor Show.
May 1967	Mazda announced the completion of the rotary engine. The Cosmo Sport was introduced into the domestic market.
Jul. 1968	The Familia Rotary Coupe was introduced.
Sep. 1969	Mazda exported rotary engine cars for the first time (to Australia and Thailand).
Oct. 1969	The Luce Rotary Coupe (front-wheel-drive) was introduced. Mazda's rotary engine car cleared the US Federal Government emissions test.
Apr. 1970	Mazda received award from Japanese Mechanical Engineering Society for the commercialization of the rotary engine.
May 1970	Export of rotary engine cars to Europe (Switzerland) started. The Capella Rotary (powered by 12A unit) was introduced.
Jun. 1970	Export of rotary engine cars to the United States started.
Dec. 1970	Cumulative production of rotary engine cars reached 100,000 units.
Sep. 1971	The Savanna Rotary was introduced.
Oct. 1971	Cappella G, the first rotary-powered automobile with an automatic transmission, was introduced. Cumulative production of rotary engine cars reached 200,000 units.
Jan. 1972	The Capella Rotary Coupe completed 100,000km endurance run, through eleven European countries and with its engine fully sealed.
Oct. 1972	The first series production car with full emission control package, the Luce Rotary was introduced.

Date	
Feb. 1973	Mazda's rotary engine car cleared the U.S. 1975 emission standards, and this fact was confirmed by EPA test.
May 1973	Luce AP (REAPS-2) was the first vehicle approved under the anti-pollution incentive tax in Japan.
Jun. 1973	Cumulative production of rotary engine cars reached 500,000 units.
Dec. 1973	The Luce AP Grand Tourismo powered by 13B engine was introduced.
Jul. 1974	The Parkway Rotary 26 was introduced.
Mar. 1975	The Roadpacer was introduced.
Oct. 1975	The Cosmo AP was introduced featuring a low emission rotary engine with 40% improved fuel-efficiency.
Jul. 1977	Cosmo L Landau top was introduced.
Oct. 1977	Luce Legato was introduced.
Mar. 1978	The Savanna RX-7 was introduced.
Nov. 1978	Cumulative production of rotary engine cars reached 1,000,000 units.
Oct. 1981	The New Cosmo and Luce Rotary were introduced.
Aug. 1982	The world's first turbo-charged rotary engine model was added to the Luce/Cosmo (929) series.
Sep. 1983	The RX-7 was face-lifted and the world-first turbo rotary engine model was added.
Oct. 1985	The RX-7 was entirely redesigned.
Apr. 1986	Cumulative production of rotary engine cars reached 1,500,000 units.
Sep. 1986	The Luce was entirely redesigned.
Apr. 1990	The Eunos Cosmo debuted featuring the world's first three-rotor rotary engine (20B-REW).
Jun. 1991	The Mazda 787B achieved overall win at the 59th Le Mans 24 Hours race.
Oct. 1991	The HR-X concept car (with hydrogen RE) was unveiled at the Tokyo Motor Show.
Dec. 1991	The RX-7 was completely redesigned (with a 255PS 13B-REW unit).
Oct. 1993	The HR-X2 concept car (with hydrogen RE) was unveiled at the Tokyo Motor Show.
May 1995	First public road trials of a hydrogen RE vehicle in Japan.
Oct. 1995	The RX-01 concept car (powered by a type MSP-RE experimental engine) was unveiled at the Tokyo Motor Show.
Jan. 1996	The RX-7 was face-lifted (engine output increased to 265PS).
Dec. 1998	The RX-7 was face-lifted (engine output increased to 280PS).
Oct. 1999	The RX-EVOLV concept car with the RENESIS experimental engine was unveiled at the Tokyo Motor Show.
Oct. 2001	A design prototype of the Mazda RX-8 (powered by the RENESIS) was unveiled at the Tokyo Motor Show.
Apr. 2003	The Mazda RX-8 (with the RENESIS) introduced.
Oct. 2003	RX-8 Hydrogen RE (development vehicle) was unveiled.
Oct. 2004	RX-8 Hydrogen RE trials began on public roads with approval from the Ministry of Land, Infrastructure and Transport.
Feb. 2006	RX-8 Hydrogen RE launched on limited release basis

History of Mazda's Motor Sports Activities

Date		Event	Model	Result
1968	Aug.	Marathon de la Route 84-hour	Cosmo 110S	4th overall
1969	Apr.	Singapore Grand Prix (Touring car race)	R 100 coupe	1st overall
	Jul.	Spa-Francorchamps 24-hour	R 100 coupe	5th, 6th overall
	Aug.	Marathon de la Route 84-hour	R 100 coupe	5th overall
	Nov.	All Japan Suzuka Automobile race (Grand Cup)	R 100 coupe	1st overall
1970	Jun.	RAC Tourist Trophy	R 100 coupe	8th, 10th, 12th overall
	Jul.	West Germany Touring-car Grand Prix	R 100 coupe	4th, 5th, 6th overall
	Jul.	Spa-Francorchamps 24-hour	R 100 coupe	5th overall
1971	Jul.	Fuji 1000km	RX-2	1st class, 3rd overall
	Dec.	Fuji Tourist Trophy	RX-3	1st overall
1972	May	Japan Grand Prix (T-b race)	RX-3	1st, 2nd, 3rd overall
	Aug.	All Japan Suzuka 300km Touring car	RX-3	1st overall
	'72	Fuji Grand Champion series (super touring car class)	RX-3	Champion
1973	May	Japan Grand Prix (TS-b race)	RX-3	1st overall
	Aug.	Suzuka Great 20 Drivers (T-race)	RX-3	1st overall
	'73	Fuji Grand Champion series (super touring car class)	RX-3	Champion
1974	Sep.	Fuji Inter 200 mile	Sigma GC73•Mazda	2nd overall
	Dec.	Fuji Tourist Tropy	RX-3	1st overall
1975	May	Japan Grand Prix (TS/GTS-B race)	RX-3	1st overall
	Oct.	Fuji Masters 250km race (Super T & GT-B race)	RX-3	1st overall
	'75	Fuji Grand Champion series (super T & GT class)	RX-3	Champion
1976	May	Japan Grand Prix (TS/GTS-B race)	RX-3	1st overall (RX-3's 100th win in domestic races)
	Sep.	Fuji Inter 200 mile (super T & GT race)	RX-3	1st overall
	'76	Fuji Grand Champion series (super T & GT class)	RX-3	Champion
1977	May	Fuji 1000km	March 75S•Mazda	1st overall
	Sep.	Fuji Inter 200 mile	March 76S•Mazda	1st overall
	Dec.	Fuji 500 mile	March 75S•Mazda	1st overall
	'77	Fuji Grand Champion Series (ST race)	RX-3	Champion
		Fuji Long-distance series	March 75S•Mazda	Champion
1978	May	Japan Grand Prix (TS/GTS-B race)	RX-3	1st overall
	Jul.	Fuji 1000km	March 75S•Mazda	1st overall
	Sep.	Fuji Inter 200 mile	March 76S•Mazda	1st overall
	Nov.	Fuji Victory 200km	March 75S•Mazda	1st overall
	'78	Fuji Long-distance series	March 75S•Mazda	Champion
1979	Feb.	IMSA Daytona 24-hour	RX-7	1st, 2nd in GTU (5th, 6th overall)
	Apr.	Fuji 500km	March 76S•Mazda	1st overall
	Sep.	Fuji Inter 500 mile	MCS•Mazda	1st overall
	Oct.	Fuji Masters 250km	KR-1•Mazda	1st overall
	'79	British Saloon Car Championship (1600 ~ 2300cc)	RX-7	Champion

● WEC=World Endurance Championship ● WRC=World Rally Championship ● ERC=European Rally Championship ● WSPC=World Sport Prototype Car Championship ● SWC=Sportcar World Championship ● (shaded) =series champion

Date		Event	Model	Result
1980	**Mar.**	Fuji 300km Speed	MCS-Mazda	1st overall
	Sep.	Fuji Inter 200 mile	KR-1-Mazda	1st overall
	'80	IMSA series GTU class	RX-7	Champion (Manufacturers' & Drivers')
		IMSA series RS class	RX-3	Champion (Manufacturers')
		British Saloon Car Championship (1600 ~ 2300cc)	RX-7	Champion
1981	**Apr.**	Suzuka 500km	KR-1-Mazda	1st overall
	'81	IMSA series GTU class	RX-7	Champion (Manufacturers' & Drivers')
		SCCA Pro Rally series	RX-7	Champion (Manufacturers' & Drivers')
		British Saloon Car Championship (1600 ~ 2300cc)	RX-7	Champion
		Belgium Touring Car Championship	RX-7	Champion
1982	**Feb.**	IMSA Daytona 24-hour	RX-7	1st in GTO (4th overall), 1st in GTU (6th overall)
	Jun.	WEC Le Mans 24-hour	RX7-254	14th overall
	Jun.	WRC New Zealand Rally	RX-7	1st in class (5th overall)
	Oct.	WEC Fuji 6-hour	RX-7-254	1st in class (6th overall)
	'82	IMSA series GTU class	RX-7	Champion (Manufacturers' & Drivers')
		Australian Endurance championship	RX-7	Champion (Manufacturers' & Drivers')
1983	**Feb.**	IMSA Daytona 24-hour	RX-7	1st in GTO (3rd overall), 1st in GTU (12th overall)
	Jun.	WEC Le Mans 24-hour	Mazda 717C	1st, 2nd in Gp. C-junior (12th, 18th overall)
	Jun.	Fuji Inter 200 mile	MCS III-Mazda	1st overall
	'83	IMSA series GTU class	RX-7	Champion (Manufacturers' & Drivers')
		Australian Endurance championship	RX-7	Champion (Manufacturers' & Drivers')
1984	**Feb.**	IMSA Daytona 24-hour	RX-7	1st in GTU (12th overall)
	Jun.	WRC Acropolis Rally	RX-7	9th overall
	Jun.	WEC Le Man 24-hour	Mazda Lola T616	1st, 3rd in Gp. C-2 (10th, 12th overall)
			Mazda 727C	4th, 6th in Gp. C-2 (15th, 20th overall)
	Jul.	ERC Poland Rally	RX-7	1st overall
	Jul.	Fuji 1000km	Taku Mazda 83C	1st overall
	'84	Fuji JSS series	RX-7	Champion
		IMSA series GTU class	RX-7	Champion (Manufacturers' & Drivers') (Fifth consecutive champion—new record in IMSA series)
		IMSA series GTU class	RX-7	Champion (Drivers')
		Australian Endurance championship	RX-7	Champion (Manufacturers' & Drivers')
1985	**Feb.**	IMSA Daytona 24-hour	RX-7	1st in GTU (12th overall)
			RX-7	2nd in GTO (11th overall)
			Mazda Argo JM16	1st in Camel Light (10th overall)
	May	WRC Acropolis Rally	RX-7	3rd, 6th overall
	Jun.	WEC Le Mans 24-hour	Mazda 737C	3rd, 6th in Gp. C-2 (19th, 24th overall)
	Aug.	IMSA series	RX-7	67th win in IMSA series (Breaking Porsche's record of 66 wins)
	Nov.	WRC RAC Rally	RX-7	9th, 10th overall
	'85	IMSA series GTU class	RX-7	Champion (Manufacturers' & Drivers')
		IMSA series Camel Light class	Mazda Argo JM16	Champion (Engine Manufacturers' & Drivers')
		SCCA Pro Rally series	4WD RX-7	Champion (Manufacturers')

Date		Event	Model	Result
1986	**Feb.**	IMSA Daytona 24-hour	RX-7	1st in GTU (8th overall)
			Mazda Argo	1st in Camel Light (7th overall)
	Feb.	Suzuka 500 km	Mazda 757	6th overall (Three-rotor rotary-powered Mazda 757 debuted)
	Aug.	A specially prepared Mazda RX-7 established a new C/Grand Touring Class land speed record of 238.442 miles per hour in the 38th annual Bonneville National Speed Trials held on the Bonneville Salt Flats in Utah, U.S.A.		
	'86	IMSA series GTU class	RX-7	Champion (Manufacturers' & Drivers')
		IMSA series Camel Light class	Mazda Argo	Champion (Engine Manufacturers' & Drivers')
1987	**Feb.**	IMSA Daytona 24-hour	RX-7	1st in GTU (10th overall)
	Jun.	WSPC Le Mans 24-hour	Mazda 757	7th overall
	Sep.	WSPC Fuji 1000 km	Mazda 757	7th overall
	'87	IMSA series GTU class	RX-7	Champion (Manufacturers' & Drivers')
		IMSA series Camel Light class	Mazda Argo	Champion (Engine Manufacturers' & Drivers')
1988	**Feb.**	IMSA Daytona 24-hour	RX-7	1st in GTU (15th overall)
	Apr.	Suzuka 500 km	Mazda 767	7th overall (Four-rotor rotary-powered Mazda 767 debuted)
	Jun.	WSPC Le Mans 24-hour	Mazda 757	15th overall
			Mazda 767	17th, 19th overall
1989	**Feb.**	IMSA Daytona 24-hour	Mazda 767B	5th overall
			RX-7	1st in GTU (12th overall)
	Jun.	WSPC Le Mans 24-hour	Mazda 767B	7th, 9th, 12th overall
	'89	IMSA series GTU class	RX-7/MX-6	Champion (Manufacturers')
1990	**Feb.**	IMSA Daytona 24-hour	RX-7	2nd in GTO (7th overall)
			Mazda Argo	1st in Camel Light class (9th overall)
			RX-7	1st in GTU (12th overall) (Nine-year consecutive winner in GTU since 1982)
	May	IMSA Heartland Park 2-hour	RX-7	1st overall (1st in GTO) (First time for four-rotor rotary-powered GTO race car)
	Sep.	IMSA San Antonio 300km	RX-7	1st overall (100 victories overall in IMSA series)
	'90	IMSA series GTU class	RX-7/MX-6	Champion (Manufacturers')
1991	**Feb.**	IMSA Daytona 24-hour	RX-7/MX-6	1st in GTU (13th overall)/2nd in GTU (15th overall)
	Jun.	SWC Le Mans 24-hour	Mazda 787B/787	1st, 6th, 8th overall
	'91	IMSA series GTO class	RX-7	Champion (Manufacturers' & Drivers')
1992	**Feb.**	IMSA Daytona 24-hour	RX-7/MX-6	1st in GTU (7th overall)/2nd in GTU (12th overall) (11 consecutive wins in GTU at the Daytona 24-hour)
	Apr.	Bathurst 12-hour	RX-7	1st, 5th overall
	May	IMSA GTP class	Mazda RX-792P	3rd, 4th
	Jun.	IMSA GTP class	Mazda RX-792P	2nd
1993	**Jan.**	IMSA Daytona 24-hour	RX-7	1st in GTU (12-year consecutive winner in GTU since 1982)
	Apr.	Bathurst 12-hour	RX-7	1st overall
1994	**Apr.**	Bathurst 12-hour	RX-7	1st overall (3-year consecutive winner overall)
1995	**Aug.**	Intercreek 12-hour	RX-7	1st overall (Race site was changed to Intercreek from Bathurst. 4-year consecutive winner overall, succeeding results in Bathurst.)

Production Units of Rotary Engine Vehicles by Model

Year	110S (Cosmo Sport)	R110 (Familia)	R130 Coupe/RX-4 (Luce)	RX-2 (Capella)	RX-3 (Savanna)	Rotary Pickup	Parkway	Roadpacer	RX-5 (Cosmo)	RX-7	Eunos Cosmo	RX-8	Total units	Cumulative production units
1967	343												343	343
1968	172	6,925											7,097	7,440
1969	159	28,041	542										28,742	36,182
1970	258	31,238	431	34,242									66,169	102,351
1971	126	21,907	3	63,389	33,004								118,429	220,780
1972	118	5,720	10,903	58,433	79,719								154,893	375,673
1973		2,060	77,028	54,962	105,819	2							239,871	615,544
1974			66,998	7,656	29,678	14,364	18						118,714	734,258
1975			41,668	5,960	26,236	113	18	491	12,014				86,500	820,758
1976			13,284	553	9,825	632	8	183	43,792				68,277	889,035
1977			13,480	253	1,606	1,161		126	25,273				41,899	930,934
1978			6,484	240					1,561	72,692			80,977	1,011,911
1979			5,705						5,896	71,617			83,218	1,095,129
1980			4,213						1,108	56,317			61,638	1,156,767
1981			2,292						2,785	55,321			60,398	1,217,165
1982			2,046						4,170	59,686			65,902	1,283,067
1983			1,402						3,026	57,864			62,292	1,345,359
1984			1,349						3,477	63,959			68,785	1,414,144
1985			506						1,062	63,105			64,673	1,478,817
1986			2,533						265	72,760			75,558	1,554,375
1987			633						60	52,204			52,897	1,607,272
1988			1,048						22	34,592			35,662	1,642,934
1989			395						8	37,624			38,027	1,680,961
1990			318							29,411	4,325		34,054	1,715,015
1991										16,623	1,700		18,323	1,733,338
1992										26,899	1,373		28,272	1,761,610
1993										6,801	711		7,512	1,769,122
1994										5,962	435		6,397	1,775,519
1995										5,202	331		5,533	1,781,052
1996										4,762			4,762	1,785,814
1997										3,556			3,556	1,789,370
1998										1,423			1,423	1,790,793
1999										4,151			4,151	1,794,944
2000										2,611			2,611	1,797,555
2001										2,589			2,589	1,800,144
2002										3,903			3,903	1,804,047
2003												60,100	60,100	1,864,147
2004												50,813	50,813	1,914,960
2005												27,837	27,837	1,942,797
2006												23,363	23,363	1,966,160
Cumulative production units	1,176	95,891	253,261	225,688	285,887	16,272	44	800	104,519	811,634	8,875	162,113	1,966,160	1,966,160

List of Awards Related to Mazda's Rotary Engine

Awards (Country)	Date	Awarded by	Awarded for or as
Masuda Award (Japan)	Jan. 1968	The Daily Industrial News	Development of the rotary engine
Foreign Car Award for 1968 (U.S.A.)	Feb. 1968	Motor Trend	Putting the world's first 2-rotor rotary engine into mass production
Chugoku Cultural Award (Japan)	Nov. 1968	The Chugoku Shimbun	Ditto
Commendation by Minister of State for Science & Technology (Japan)	Apr. 1969	Science and Technology Agency	Ditto
Japan Society for the Promotion of Machine Industries Awards (Japan)	Oct. 1969	Japan Society for the Promotion of Machine Industries	Development of the rotary engine
JSME MEDAL (Japan)	Apr. 1970	The Japan Society of Mechanical Engineers (JSME)	Ditto
RX-2 (Capella) '1972 Car of the Year' (Japan)	Jan. 1972	Motor Fan	The best Japanese passenger car in 1972
RX-2 (Capella) '1972 Car of the Year' (U.S.A.)	Jan. 1972	Road Test	The best American passenger car in 1972
The Mainichi Industrial Technology Award (Japan)	Dec. 1972	Mainichi Newspapers	Development of the carbon-based apex seal
Invention Prize (Japan)	1974	Japan Institute of Invention and Innovation	Development of the forced air-cooled Thermal Reactor
Environmental Prize of Merit (Japan)	Jun. 1976	Environment Agency	Contribution to reduction of exhaust pollutants
RX-7 (Savanna RX-7) '1979 Car of the Year' (Japan)	Jan. 1979	Motor Fan	The best passenger car in 1979
RX-7 (Savanna RX-7) 'Car of the Decade' (Japan)	1980	Motor Fan	The best Japanese passenger car in the last 10 years
Nakagawa Award (Japan)	May 1982	Society of Automotive Engineers of Japan, Inc.	Research and development of the rorary engine with 6PI
Grand Prize of Local Commendation for Invention (Japan)	Nov. 1984	Japan Institute of Invention and Innovation	Development of the rotary engine with 6PI
Japan Society for the Promotion of Machine Industries Award (Japan)	Nov. 1984	Japan Society for the Promotion of Machine Industries	Development of the rotary engine with Super Injection, a combination between 6PI and electronically-controlled gas injection (EGI)
JSAE Technological Contribution Prize (Japan)	Oct. 1985	Society of Automotive Engineers of Japan, Inc.	Putting the rotary engine into practical use
RX-7 1986 'Import Car of the Year' (U.S.A.)	Jan. 1986	Motor Trend	The 1986 best import passenger car in the U.S.
Commendation by Minister of State for Science & Technology (Japan)	Apr. 1989	Science and Technology Agency	Development and improvement of a new intake system for the rotary engine
RX-7 (Anfini RX-7) 'RJC Car of the Year' (Japan)	Dec. 1991	RJC (Automotive Researcher's & Journalists' Conference of Japan)	Best Domestic Vehicle of 1991
Kenichi Yamamoto, Chairman of the Board 'RJC Man of the Year' (Japan)	Dec. 1991	RJC (Automotive Researcher's & Journalists' Conference of Japan)	Automotive Industry Figure of 1991
RX-7 (Anfini RX-7) 'Import Car of the Year' (U.S.A.)	Jan. 1993	Motor Trend	Best Import Car of 1993 in the U.S.
Fiscal 1996 Award for Young Engineers (Japan)	Apr. 1996	The Japan Society of Mechanical Engineers (JSME)	Numerical Study of the Flow Field Inside Rotary Engines
RENESIS 'International Engine of the Year'	May 2003	Engine Technology International	The world's best engine in 2003
RX-8 'RJC Car of the Year' (Japan)	Nov. 2003	RJC (Automotive Researchers' & Journalists' Conference of Japan)	Best Domestic Vehicle of 2003
RENESIS 'RJC Technology of the Year' (Japan)	Nov. 2003	RJC (Automotive Researchers' & Journalists' Conference of Japan)	Best Automotive Technology of 2003
RENESIS 'JSME (Japan Society of Mechanical Engineers) Medal (Technology)' (Japan)	May 2004	Japan Society of Mechanical Engineers	Development of automobile rotary engine with side-exhaust port system