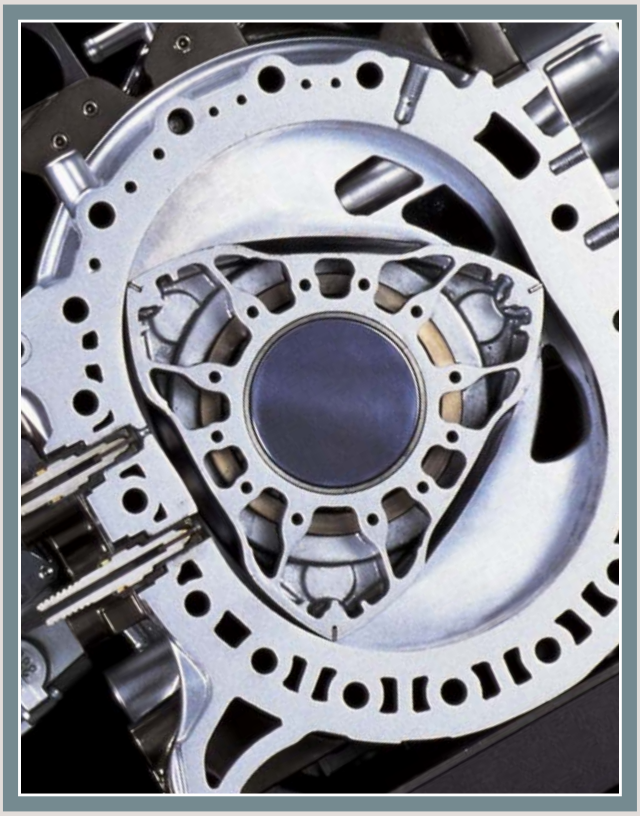
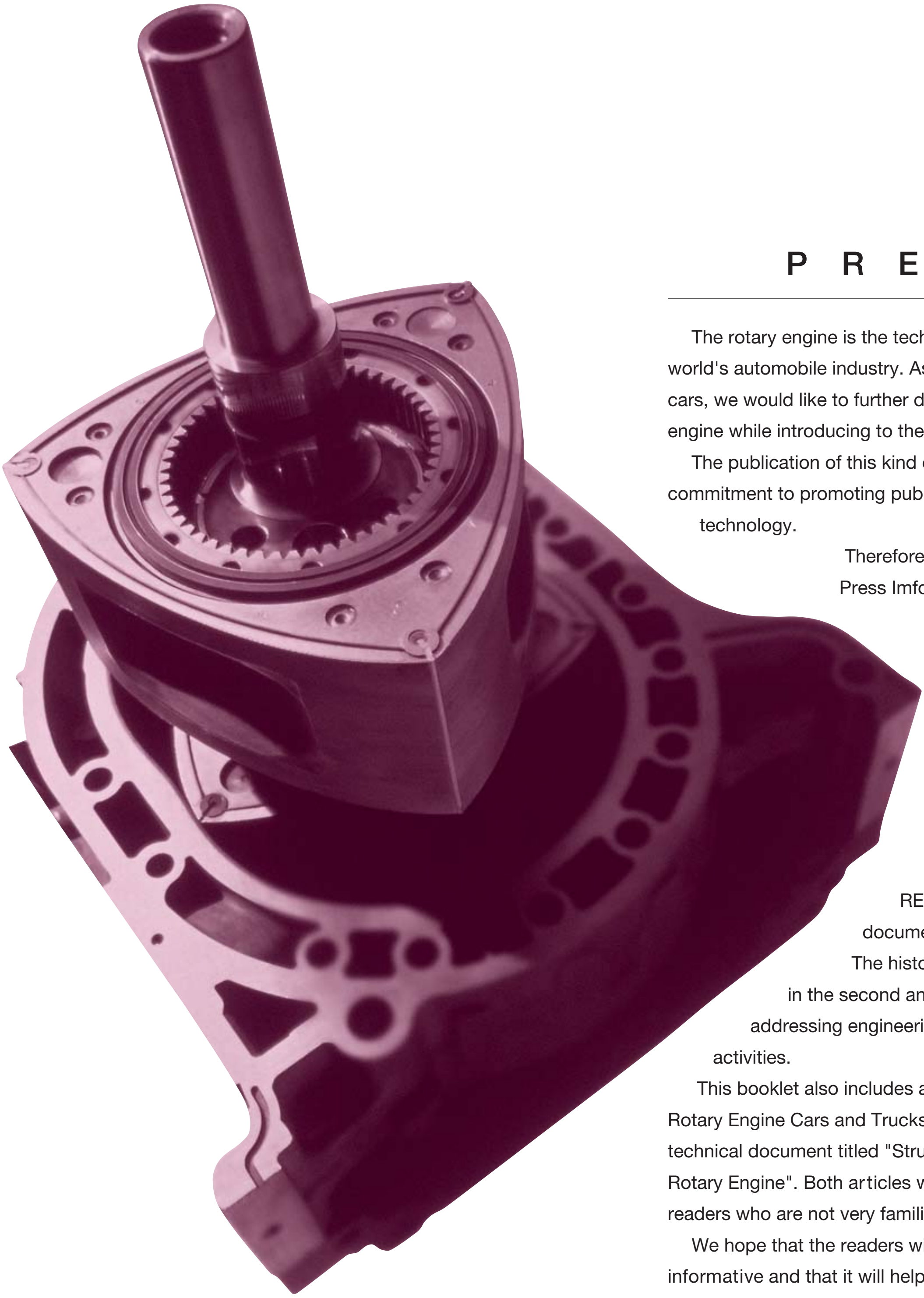
Press Information	October, 1999



ROTARY ENGINE



P R E F A C E

The rotary engine is the technology that only Mazda owns in the world's automobile industry. As the sole producer of rotary engine cars, we would like to further develop this unique internal combustion engine while introducing to the public its potential and possibility.

The publication of this kind of materials is a part of our commitment to promoting public understanding of this innovative technology.

Therefore, we have revised the Rotary Engine Press Imformation for the first time since 1993.

The past 6 years of research and development witnessed several new findings and innovations. Some of them are already implemented into production engines.

The first chapter focuses on such innovations as well as future rotary engine technology.

Our latest experimental engine, the RENESIS, is highlighted here and documented in detail.

The history of the rotary engine is summarized in the second and third chapters, respectively addressing engineering development and motor sports activities.

This booklet also includes a list of Mazda's Series-Production Rotary Engine Cars and Trucks, in the second chapter, and a technical document titled "Structure and Working Principles of the Rotary Engine". Both articles will be of special interest to those readers who are not very familier with the rotary engine technology.

We hope that the readers will find this booklet interesting and informative and that it will help them to better understand the attractions of this unique internal combustion engine.

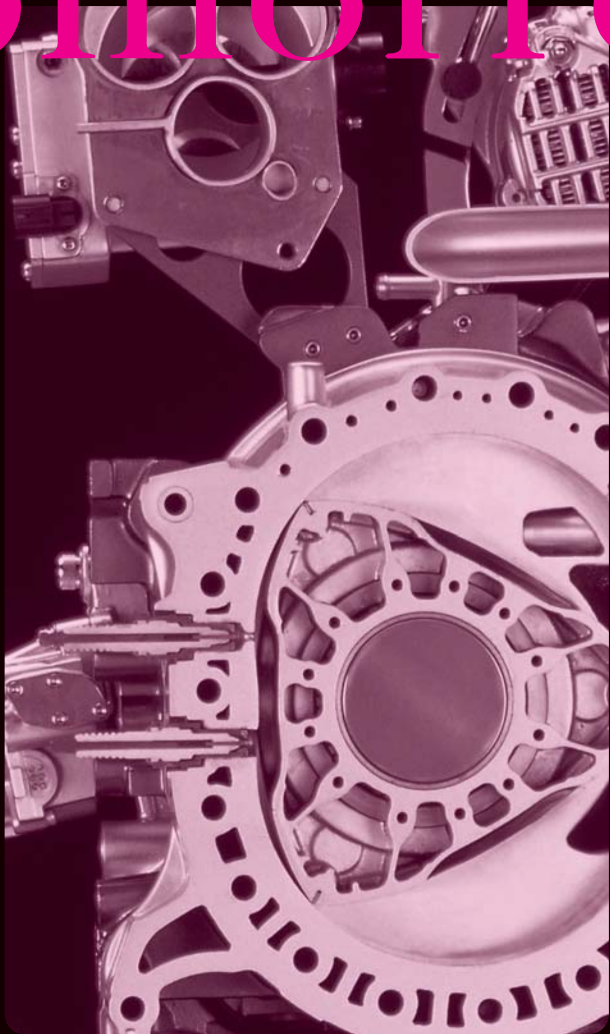
October 1999

Mazda Motor Corporation

C O N T E N T S

Rotary Engine Today and Tomorrow

Chapter 1



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

mazda

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

Mazda Rot

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

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

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

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

Introduction

ary Engine

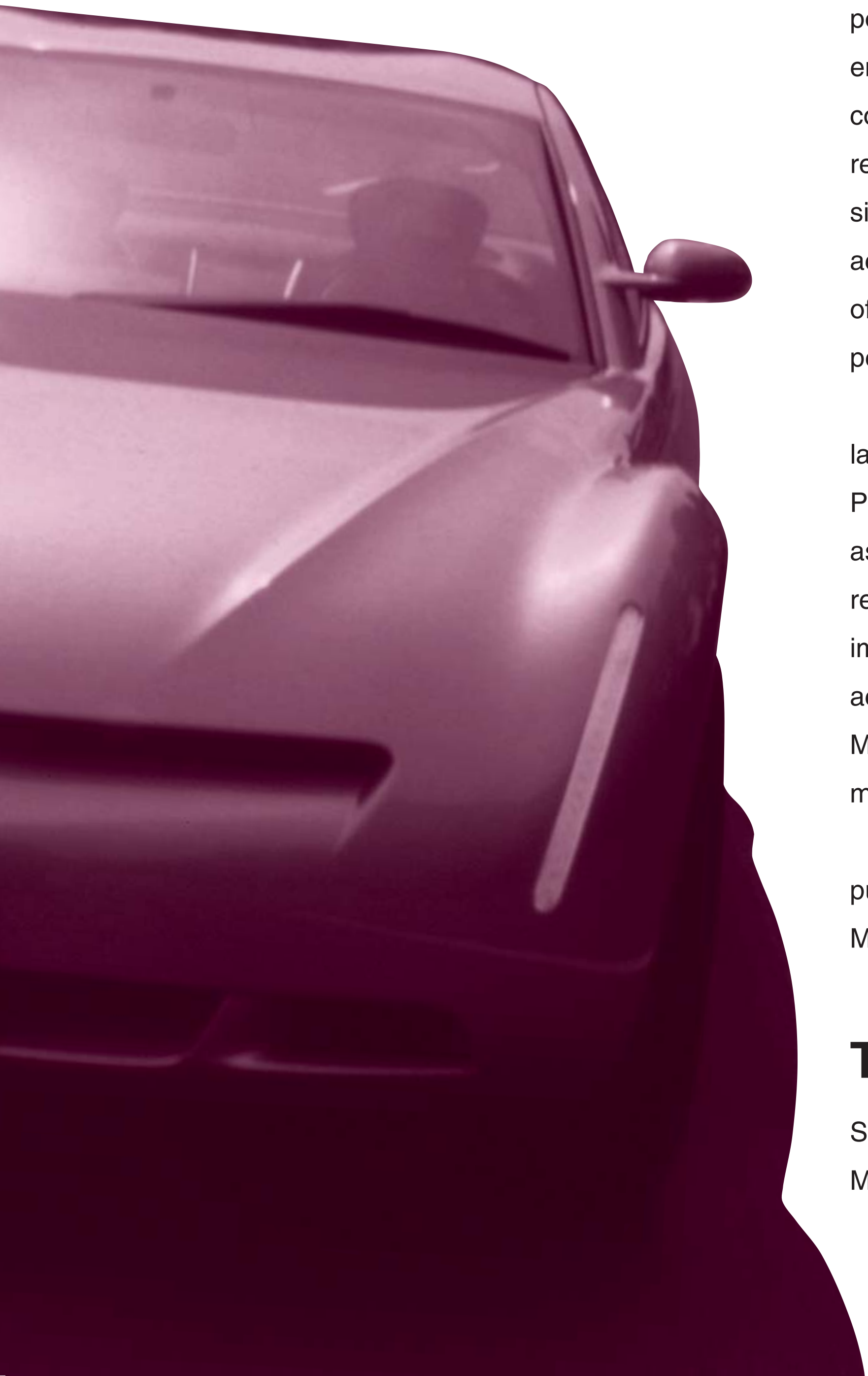
The rotary engine is a truly unique asset possessed exclusively by Mazda, and we regard it as a technology that symbolizes the personality of the Mazda brand—a personality which is Stylish, Insightful and Spirited.

The Potential of the Rotary Engine

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

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

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



Tadahiko Takiguchi

Senior Managing Director
Mazda Motor Corporation

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

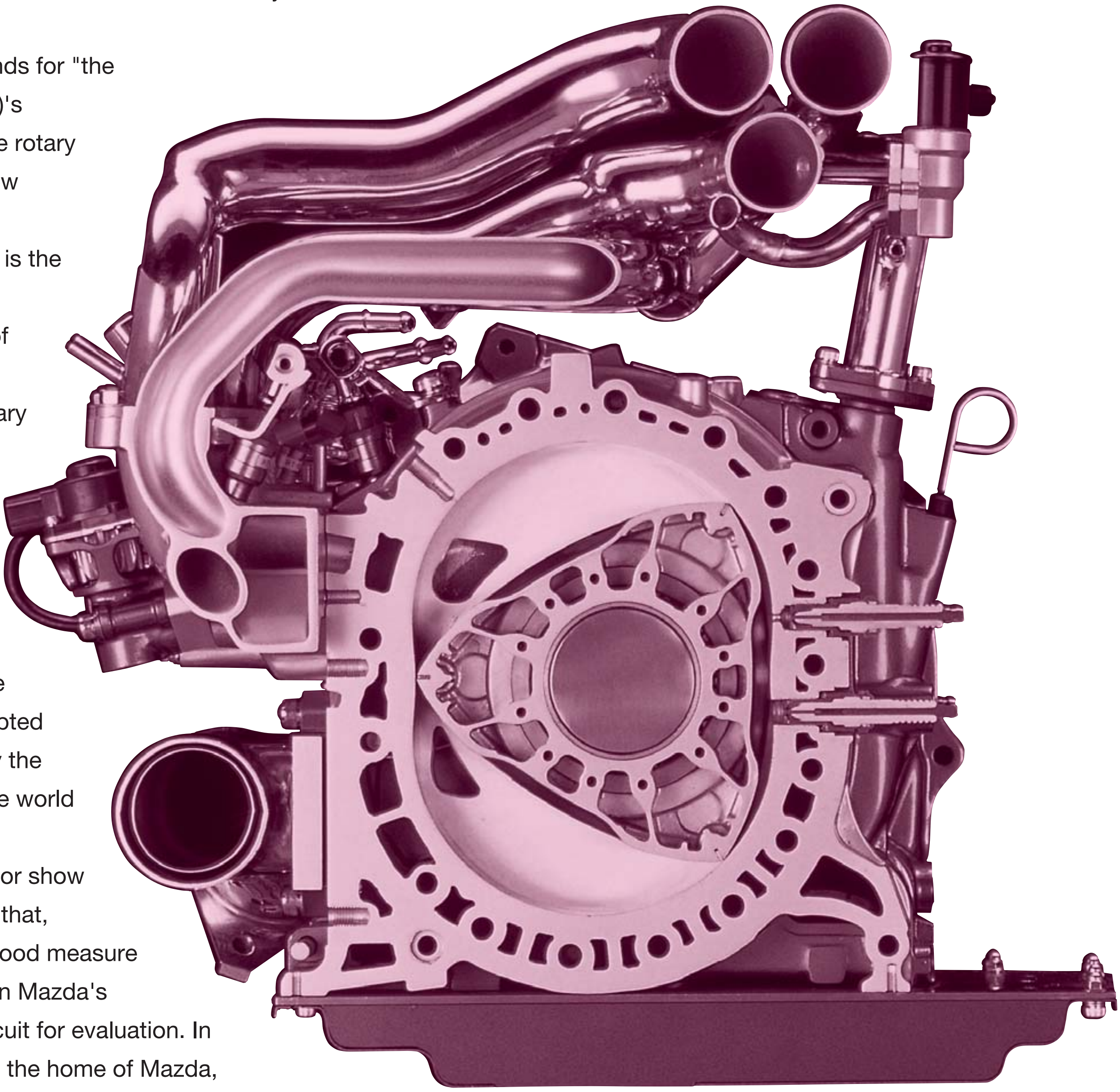
RENESIS stands for "the RE(rotary engine)'s GENESIS", or the rotary engine for the new millenium.

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

Highest Power Density for Naturally Aspirated Rotary Engine

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

The RENESIS' fuel efficiency has been further improved over its predecessor, the MSP-RE experimental engine, which had already improved idling consumption by 20 percent over the 13B-



REW unit powering the current Mazda RX-7. This gain has now been extended up to 40 percent.

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

Side-Exhaust and Side-Intake Ports.

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

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

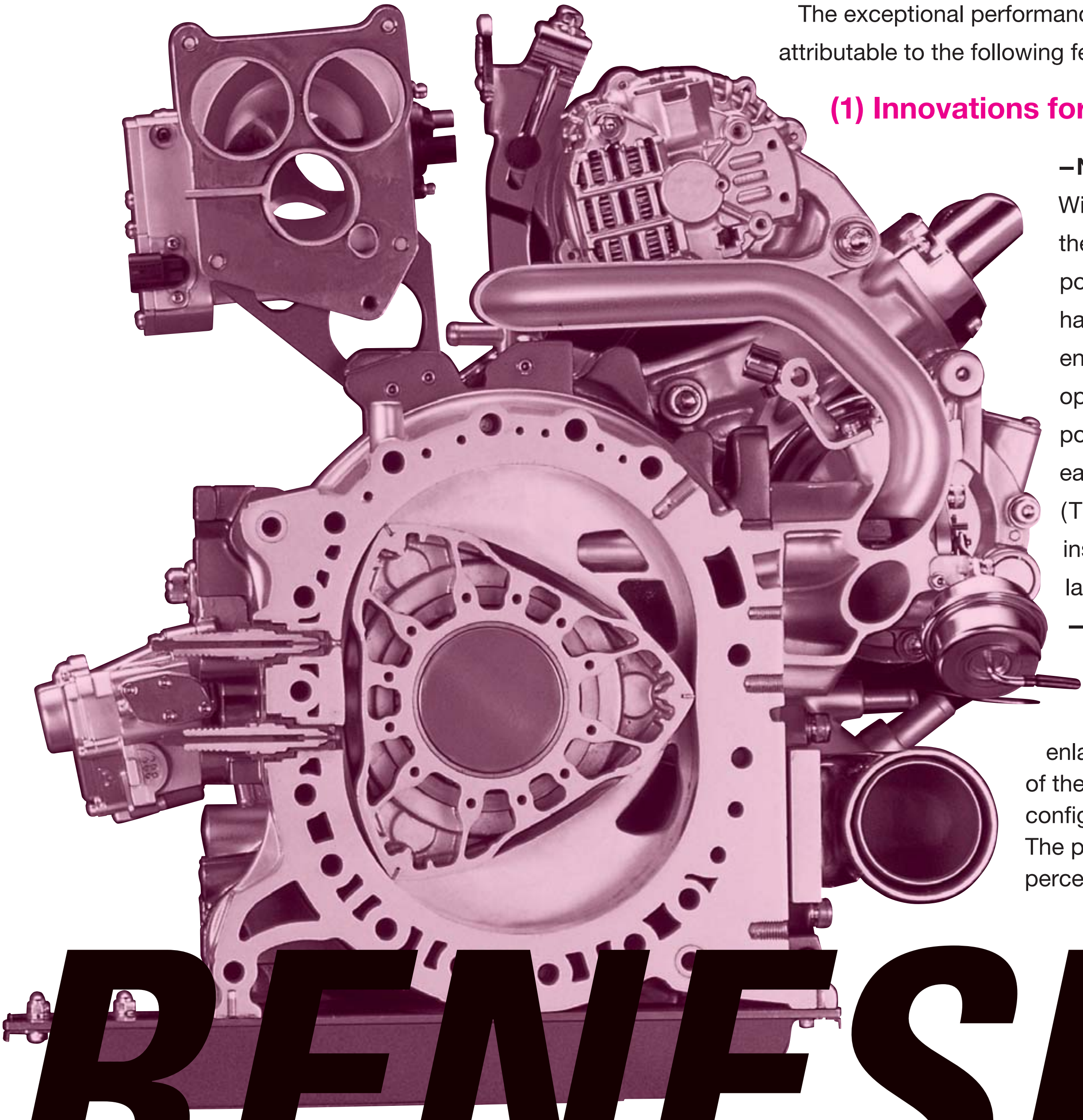
The exceptional performance of the RENESIS is attributable to the following features.

(1) Innovations for Higher Output

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

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

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



RENESIS

Mazda's Rotary Engine for the Next Millennium

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

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

–Lightweight Rotor

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

–Higher Compression Ratio

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

(2) Innovations for Improved Fuel Efficiency

–Eliminated Overlap

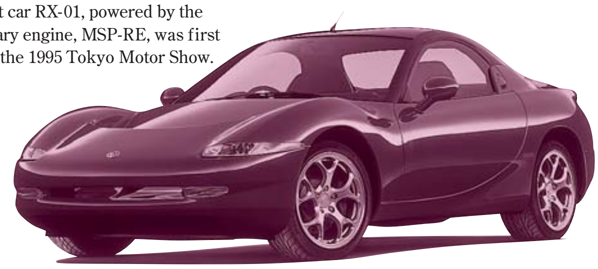
An improved exhaust port profile eliminates overlap and delays exhaust port opening, increasing the power (expansion) stroke and improving thermal efficiency, without exhaust gas diluting the incoming charge. The engine runs on leaner mixtures without the need for internal exhaust gas recirculation.

–Finer Fuel Atomization

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

–Lean Mixture Setting at High Speeds

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



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

Figure 1 : Compatibility of Performance and Fuel Economy

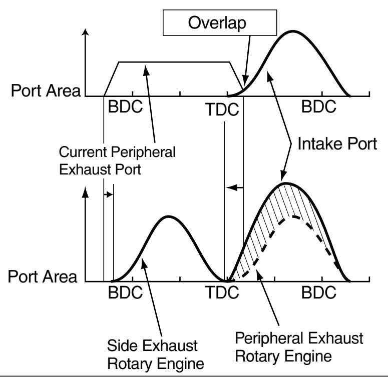


Figure 2 : Increased Intake Port Area

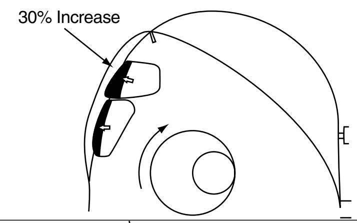
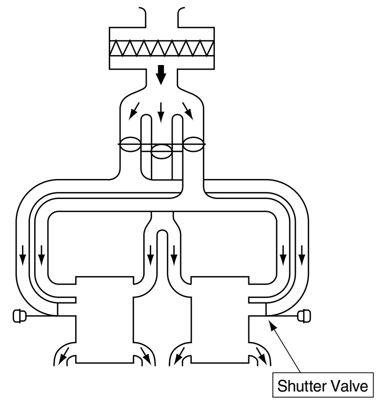


Figure 3 : 3-stage Intake System



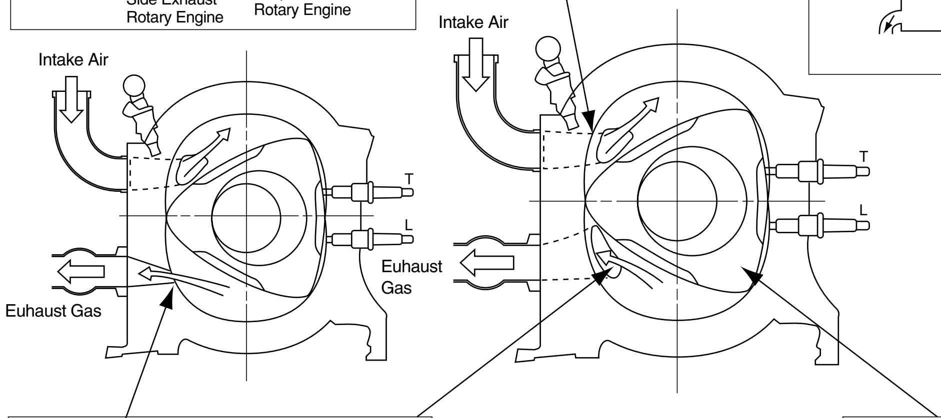


Figure 4 : Reduced Emission of HC

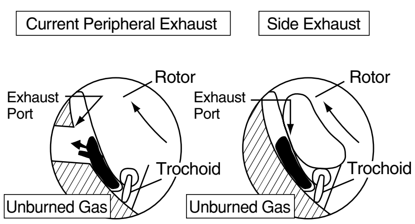
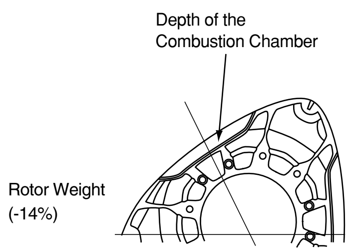


Figure 5 : Lightweight Rotor



TECHNICAL HIGHLIGHTS OF THE RENESIS

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

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

(3) Innovations for Lower Emission

–Reduced Emission of Hydrocarbon

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

–Improvement in the Catalyst System

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

(4) Other Innovations

– Tighter Sealing and New Management System

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

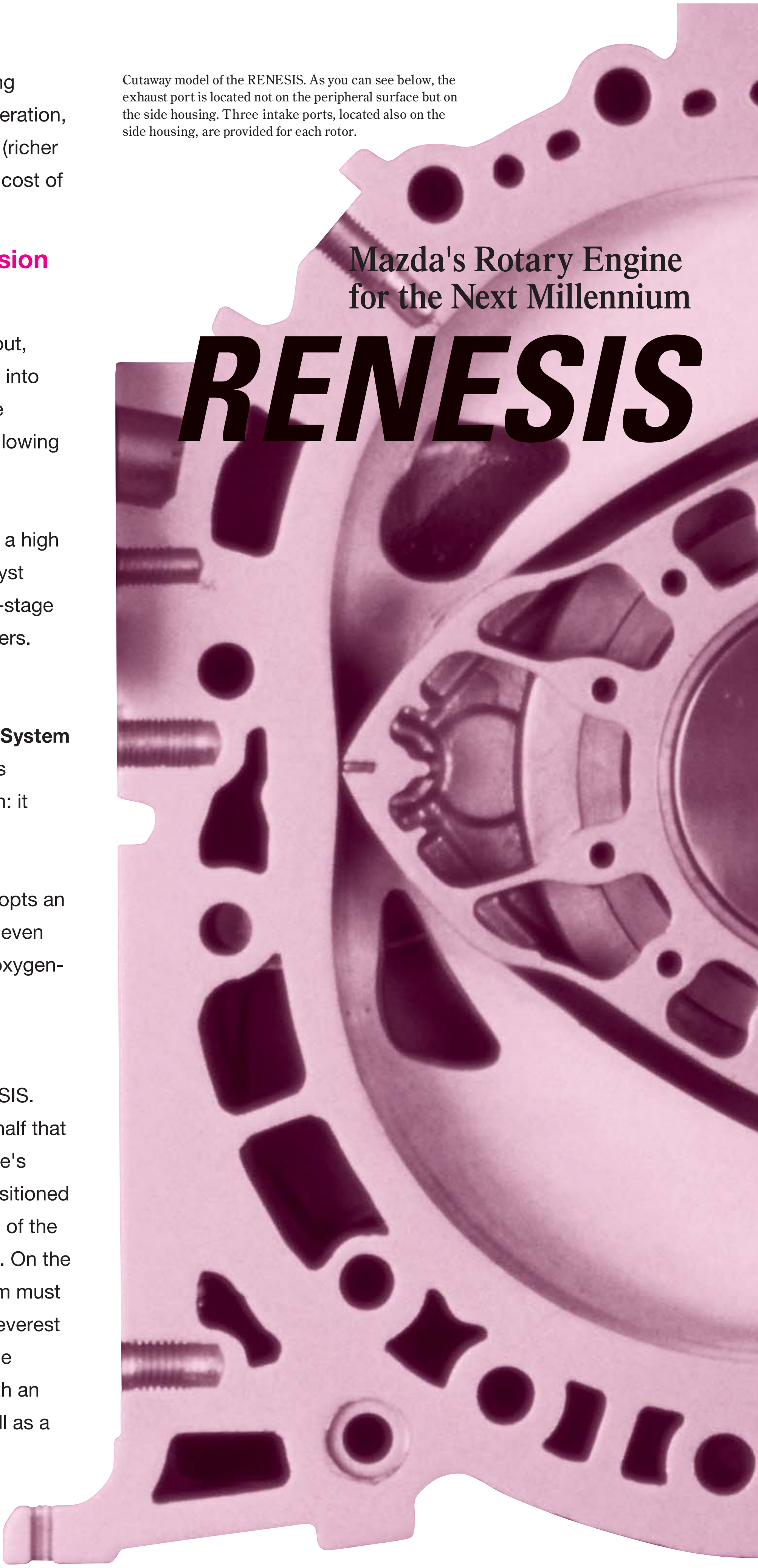
– New Wet-Sump Lubrication System

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

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

Mazda's Rotary Engine for the Next Millennium

RENESIS



13B-REW

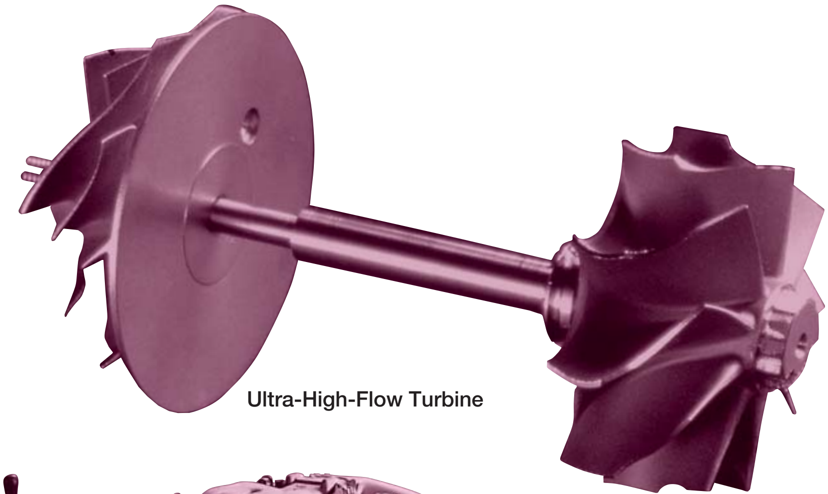
The Latest Version of Mazda's Series Production Rotary Engine Developing 280 PS, the Highest Power Available in the Domestic Cars.

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

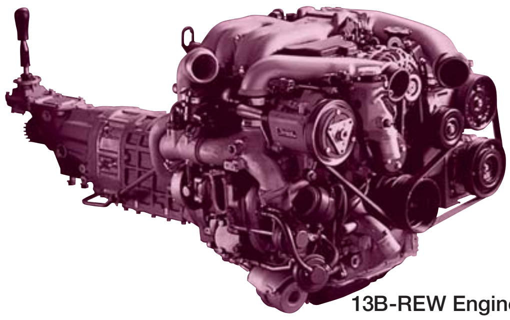
Late last year, the engine was comprehensively improved and its maximum power increased up to 280PS, the highest mark of any automobile engine available in Japan. The components then modified include the turbocharger, lubrication system, exhaust system and the cooling system. As a result, torque in the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

Improved Efficiency and Greater Air Flow

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

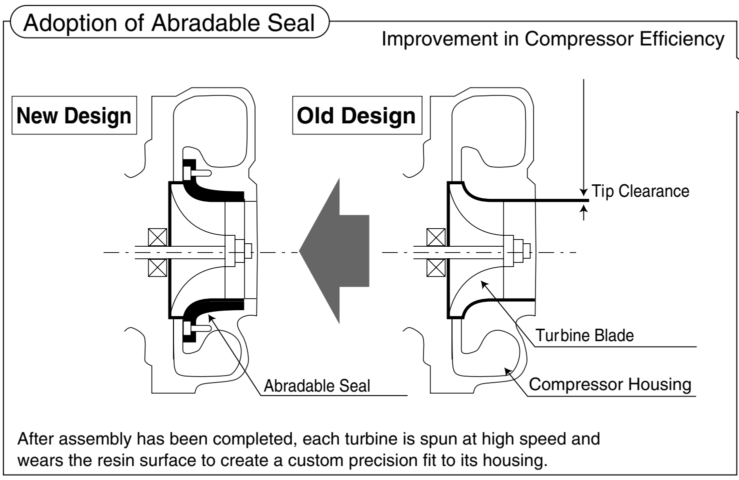


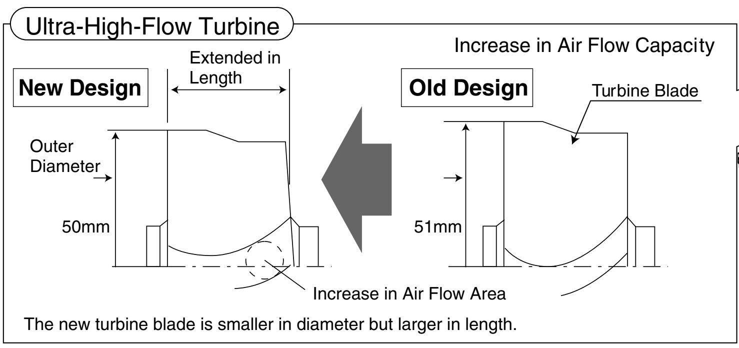
Ultra-High-Flow Turbine



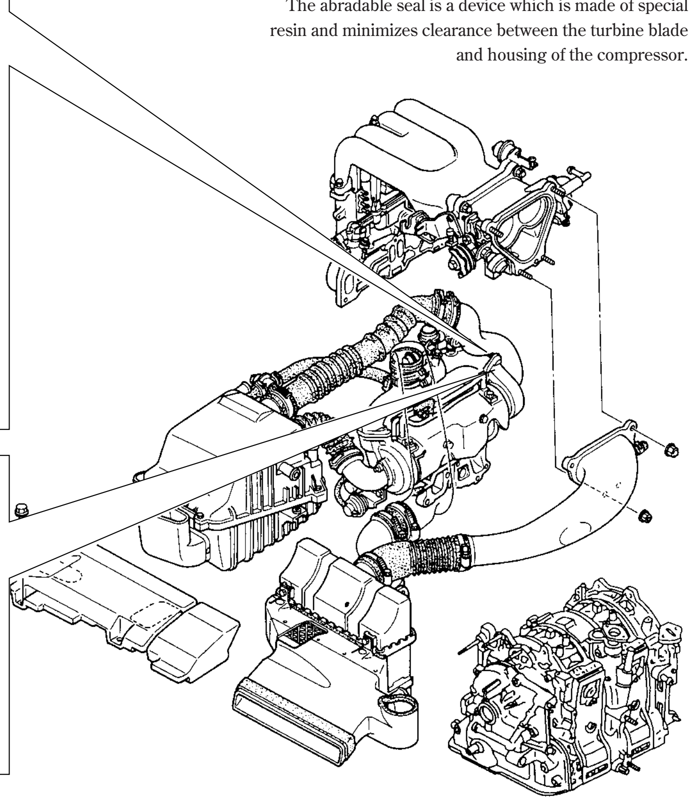
13B-REW Engine

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





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



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

features.

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

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

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

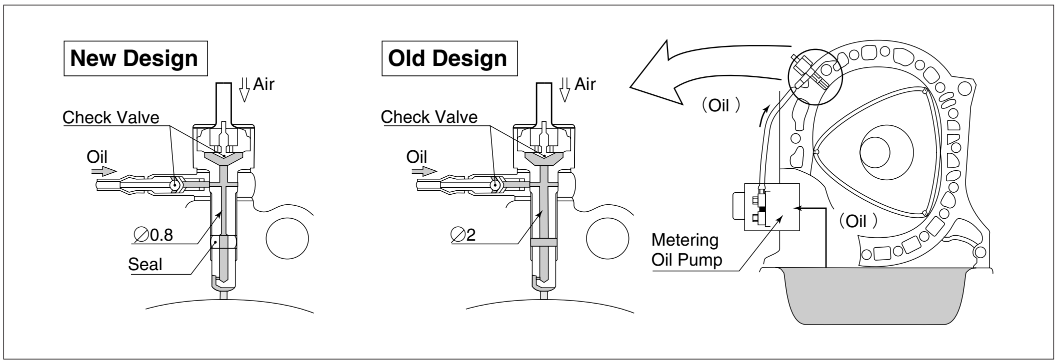
Improvements in Lubrication, Exhaust and Cooling Systems

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

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

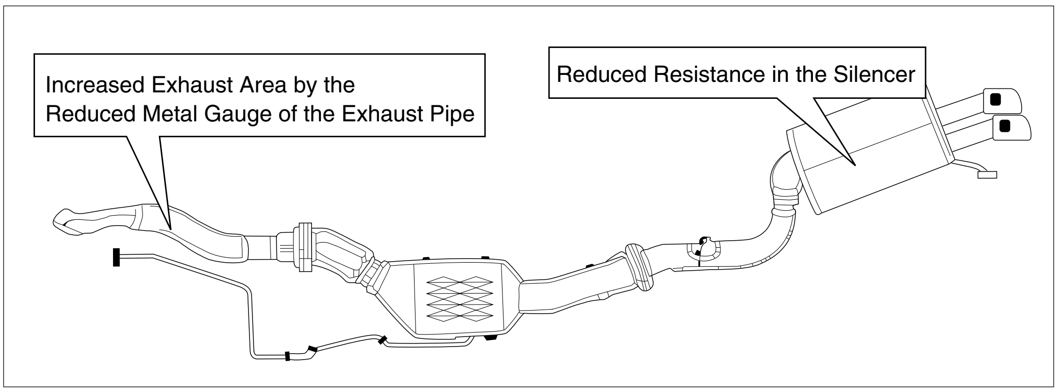
In addition, the enlarged air intakes in the car's front end also contributed to the enhanced performance of the 13B-REW. The RX-7's new front fascia design allowed an increase in cooling air intake area, by 110% for the radiator, by 80% for the intercooler, and by 80% for the oil cooler, respectively.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

Improvement in Lubrication System



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

Reduced Exhaust Resistance



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

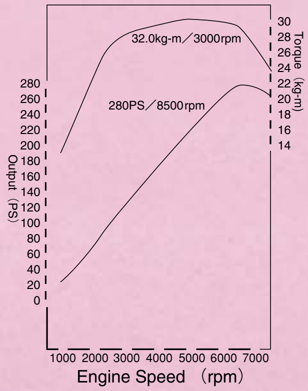
13B-REW

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

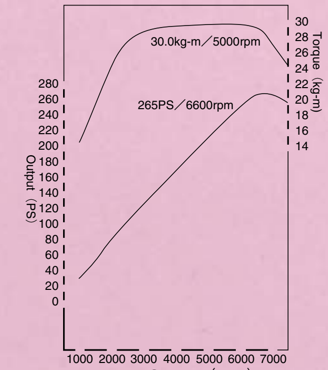
Major Specifications of the 13B-REW Engine

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

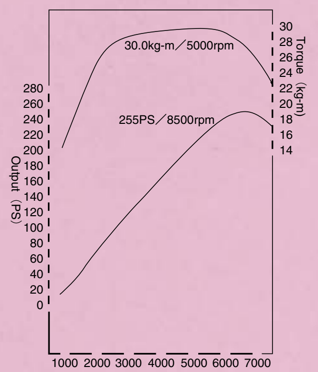
280PS Unit



265PS Unit



255PS Unit



Chronicle of Rotary Engine Development

Chapter 2

When NSU/ Wankel announced the completion of the rotaty engine, most automobile manufacturers throughout the world scrambled to propose technical cooperation plans. However, with the exception of Mazda, no company reached series-production of rotary engine car. By the mid 70s', Mazda had become the only automobile manufacturer in the world to develop and market rotary engine cars.

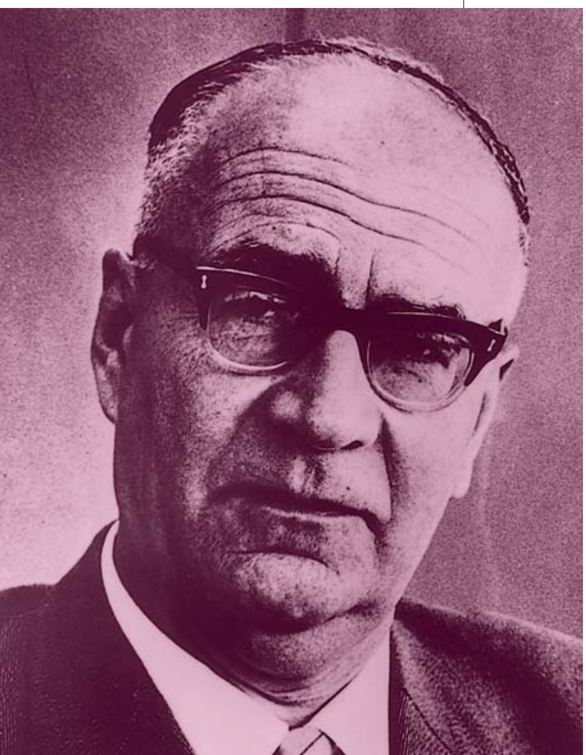
The Birth of the Rotary En

Dream of Young Wankel

The rotary engine began with an improbable dream one summer in 1919 by a 17-year-old German boy named Felix Wankel. In the dream, he went to a concert in his own hand-made car. He even remembers boasting, in the dream, to his friends; "my car has a new type of engine: a half-turbine half-reciprocated 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.

He had at the time 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. His dream and intuition had steered his entire life.



Felix Wankel

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

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.

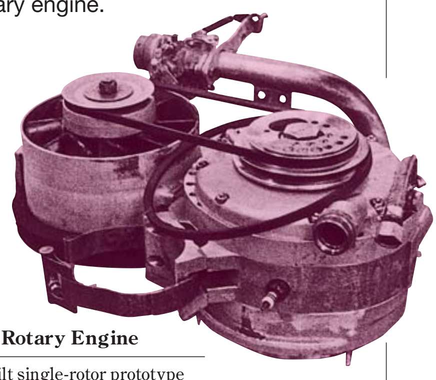
After the war, Wankel established the Technical Institute of Engineering Study (TES) and continued his work on the research and development of the rotary engine and the rotary compressor for commercial use.

One prominent motorcycle manufacturer, NSU, showed a strong interest in Wankel's research. NSU generated a great deal of enthusiasm among motor-sports fans; they were repeat winners of many World Grand Prix championships. NSU was also attracted by the ideal concept of the rotary engine. After creating partnership with Wankel, NSU promoted Wankel's research and focused on the rotary engine with trochoid housing as 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. In 1957, Wankel and NSU completed a prototype of the type DKM rotary engine, which combined a cocoon-shaped housing with a triangular rotor. The rotary engine was first invented here.

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. Forty-nine years had already passed since young Felix Wankel dreamed of the rotary engine.



KKM 400 Rotary Engine

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

gine

Chronicle of Rotary Engine Development Chapter 2

In search of 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 in 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.

Mazda, while testing the NSU-built rotary engine, made its own prototype rotary engine in November, 1961. The engine was independently designed in-house. 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 material-research—began exhaustive efforts in research and development. Its main objective was the practical use of the rotary engine: namely, mass production and market sales. The most critical engineering issue, the chatter mark problem, had to be solved.

The chatter marks were made inside the trochoid housing at the wall, where the apex seals on the three vertexes of the triangular rotor glided while juddering.

The apex seal itself caused abrasive vibration and the inside wall of the trochoid housing was marked as traces of abnormal wear. The RE Research Division called them Devil's Nail Marks and found that they were made when the apex seal vibrated at the inherent natural frequency.

To eliminate this phenomenon, a cross-hollow seal was developed, which helped a prototype engine to complete 300 hours of high-speed continuous operation.

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

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

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

Mr. Tsuneji Matsuda

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

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.

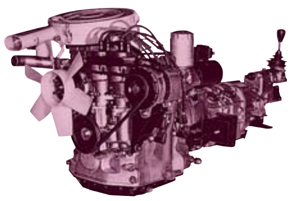
Chatter Marks

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

RE Research Department

In 1963, Mazda organized a new department which specialized in research and development of the rotary engine. The Department Manager, Kenichi Yamamoto (center) and a total of 47 engineers undertook exhaustive work for the commercialization of the rotary engined car.

From Cosmo Sport to RX-7

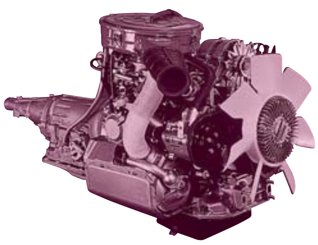


First Two-Rotor Engine

In 1967 Mazda announced the world's first commercialized two-rotor unit, the type 10A. It developed 110PS.

Cosmo Sport (S110)

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



Low-Emission 13B

Type 13B is a two-rotor engine with a 672cc unit chamber volume. First introduced in 1973 with full low-emission packages.

The Luce AP

The second generation Luce made its debut in 1973 and, in next year the first low emission version with a 13B engine was introduced.

From Dual-Rotor to Multi-Rotor

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, causing vibrations and a lacking of torque. This was due to the fundamental characteristics of single-rotor engines, which had large torque fluctuations.

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-cycle reciprocating engine. The rotary engine could also further enhance the smoothness of revolution.

The first two-rotor test engine, type L8A (399cc unit chamber volume), was Mazda's original design, and mounted on a prototype sports car (type L402A, early prototype of the Cosmo Sport) exclusively designed for the rotary engine. Test drives began soon afterward. In December 1964, another two-rotor test engine, type 3820 (491cc unit chamber volume) was designed. It soon evolved to the mass-production trial-type L10A. 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, Mazda R16A; test drives began soon afterward. Those driving tests were performed on a high speed test circuit at Miyoshi Proving Ground that was 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 unit chamber volume) equipped with newly developed apex seals made with pyro-graphite, a high-strength carbon material, and specially processed aluminum sintering. This type of apex seal resulted from Mazda's independent development work and was proven durable through 1,000 hours of continuous testing. Even after a 100,000 km test drive, it showed only slight wear and an absence of chatter marks.

For the intake system, the side-port configuration, coupled with a two-stage four-barrel carburetor, was adopted 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 recorded more than 3 million km of test drives in six years. Its futuristic styling and superb driving performance delighted car buffs throughout the world.

Development of Low-Emission Rotary Engines

After starting mass-production of its two-rotor rotary engine, type 10A, in 1967, Mazda did not limit its application to just the Cosmo Sport (which represented, after all, a relatively small market): it expanded its installation into other sedan and coupe models for larger volume production, acquiring a larger number of customers along the way.

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

In 1970 it started export to the United States, whose government was actively preparing the introduction of Muskie Act, the most stringent automobile emissions standards the country had yet devised.

Chronicle of Rotary Engine Development Chapter 2

In 1966, Mazda started development for the reduction of exhaust emissions 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). For clearing the automobile emission standards under the Muskie Act, Mazda promoted the development of an ideal catalyst system, but as a more realistic solution, developed a thermal reactor system that could be soon applied. The thermal reactor was a device that burned HC in the exhaust gas for reducing HC emissions. This thermal reactor system came equipped in the first U.S.-bound export car with a rotary engine, 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 expressed that early compliance of 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. In November 1972, in Japan, Mazda launched the first low-emission series-production car in the domestic market, which came equipped with a Rotary Engine Anti-Pollution System (REAPS).

The Phoenix Project

In 1970s, the world went through a stormy period in international political relations. Many developing nations, however, were gaining stature and power by using their oil resources as a political weapon. The "Oil Crisis" was the result of this political wrangling.

Most Middle-Eastern oil-producing countries during that time restricted their exports of oil; oil prices on the world market soared because of the supply shortage. Automotive manufacturers, responding to those situations, started to develop mass-produced cars with dramatically improved fuel efficiency. Mazda realized that a drastic reduction in fuel consumption was a decisive factor for the survival of the rotary engine and initiated the "Phoenix Project" that targeted a 20 percent rise in fuel economy for the first year of research and development, followed by a 40 percent rise as an ultimate goal.

After challenging the engineering development to improve the fundamentals of the engines, and, among other measures, to improve their thermal reactor systems and carburetors, the company concluded that fuel economy could be raised by 20 percent as targeted. Further development, including enhancing reaction efficiencies 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.

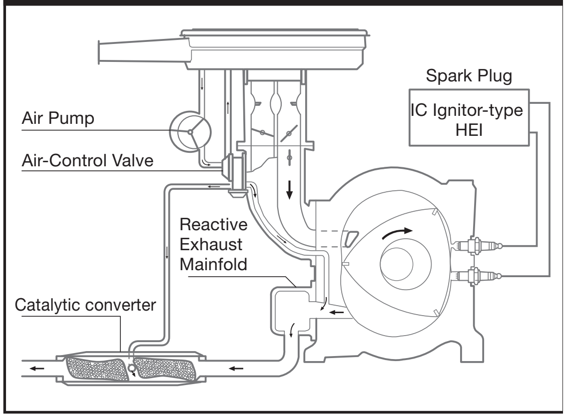
Six-Port Induction

After completing two key projects—the development of a low emission system and fuel economy improvement—Mazda adopted the six-port induction system and the two-stage monolithic catalyst system for its type 12A engine (573cc unit chamber volume).

The six-port induction system had three intake ports for one rotor chamber. Through controlling the three intake port openings in three stages, fuel economy could be improved without sacrificing performance at high speeds.

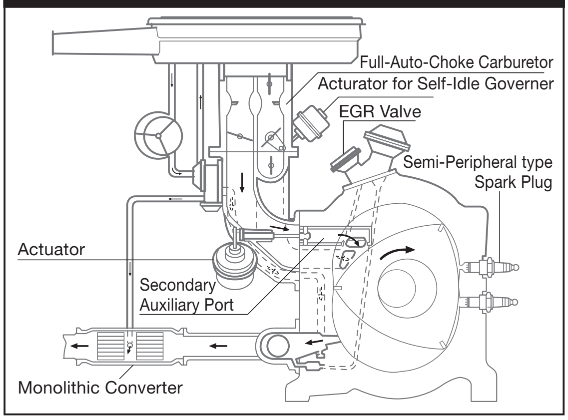
This system, coupled with the two-stage monolithic catalyst system, would further advance the rotary engine.

Lean-Burn Rotary Engine



By introducing a catalytic converter as a device to purify exhaust emissions, one could achieve leaner mixture settings.

Six Port Induction System



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

Turbo, Multi-Rotor and A Rotary Engines

Turbo and Dynamic Supercharger

The Cosmo RE Turbo, which went on sale in 1982, was the world's first rotary engine car with a turbocharger. The rotary engine's exhaust system inherently had more exhaust energy to drive the turbocharger turbine compared with the reciprocating engine; the rotary engine was better suited to the turbocharger. Moreover, the Cosmo RE Turbo was the world's first series-production rotary engine car equipped with an electronically controlled fuel injection system.

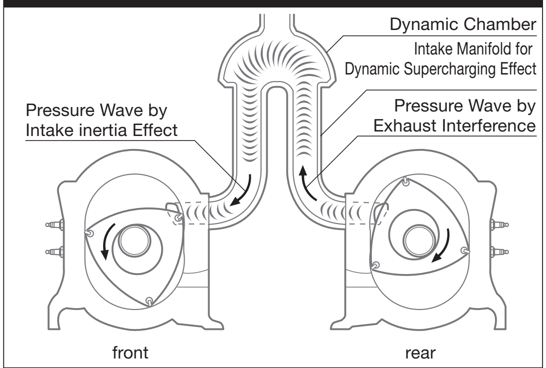
The Cosmo RE Turbo was the fastest commercial car in Japan at that time. It clearly demonstrated the attractiveness of the rotary engine. Thereafter, the "Impact-Turbo", developed exclusively for the rotary engine, made its debut. It was responsible for even further improvements in response and output.

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.

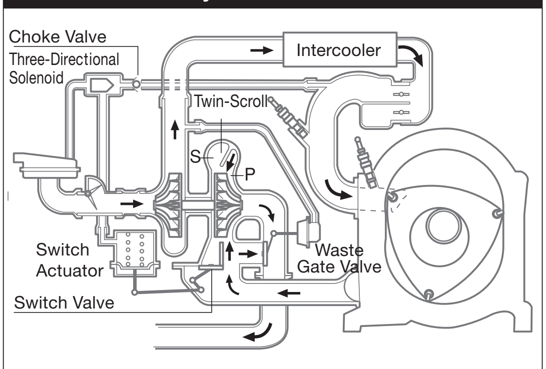
With the six-port induction system and the dual injector system, which had two fuel injectors in the chamber for each rotor, the 13B rotary engine came equipped with this dynamic supercharging system and achieved significant output increases regardless of the speed range. The dynamic supercharging system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

This system used neither turbo nor supercharger, but filling efficiency could be drastically increased over the conventional design, by utilizing pressure waves generated inside the intake tracts by the sudden opening and closing of the ports.

Dynamic Supercharging System



Twin-Scroll Turbo System

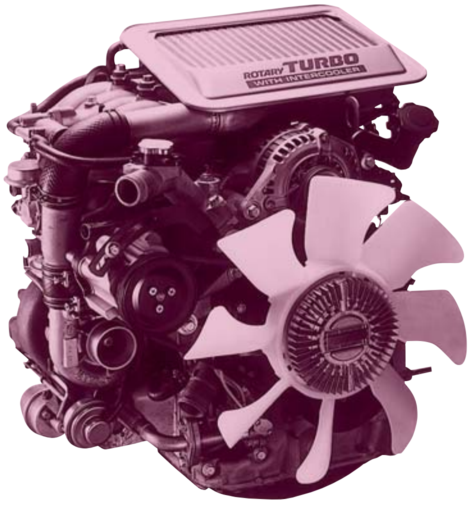


This system helps reduce the turbo-lag, a traditional drawback of the turbo-engine. The duct leading the exhaust gas to the turbine was split into two passages, one of which was closed by a valve to accelerate exhaust gas flow at low speeds.

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 which would 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 sufficiently 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 improvements in the engine internals, it provided more outstanding low-speed torque, improved responsiveness, and upgraded driving performance.



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.

Dual Fuel Injector

Since 1983, the electronically controlled fuel injection system for Mazda rotary engines has adopted two injectors in each rotor chamber. Generally speaking, a large nozzle is most suitable for high-performance output because it can provide increased amounts of fuel. For more stable combustion at low speeds, however, a small size nozzle is more suitable because it can atomize the fuel better.

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

Type 20B-REW Rotary Engine

In 1990, the Eunos Cosmo, with its three-rotor rotary engine 20B-REW, went on sale after steady continuation of research and development for a quarter-century that passed since the beginning of the rotary engine project. While the two-rotor rotary engine produced a smooth operation equivalent to the six-cylinder reciprocating engine, the three-rotor rotary engine exceeded that of the V8 engine; it even approached the level of the V12 engine.

However, a difficult engineering barrier existed for manufacturing the multi-rotor rotary engines en masse. When the rotary engine was planned with an inline 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, from the 1960s, Mazda had focused on the coupled eccentric shaft layout because the fixed gear split layout was considered too complicated for mass production. It then 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 rotary 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.

Sequential Twin-Turbo

The Sequential Twin-Turbo first adopted in type 20B-REW and type 13B-REW rotary engines in 1990 was developed based on the unique engineering concept of utilizing two turbochargers in sequence. At low speeds, only the first turbocharger works, but in the high speed range, the second turbocharger kicks in. Using both turbochargers enabled sufficient supercharging capacity and yielded high output. Running two turbochargers simultaneously also had the added benefit of reducing the exhaust resistance, which in turn contributed to even higher performance.

As the base engine to install the turbocharger, the rotary engine had several inherent superior characteristics, including a stronger exhaust pulse caused by the sudden opening of the exhaust port, and a short and smooth manifold. To fully utilize such features, the uniquely shaped Dynamic Pressure Manifold was adopted to guide the exhaust gas into the turbocharger in a minimum distance.

The World's Only Rotary Engine Plant

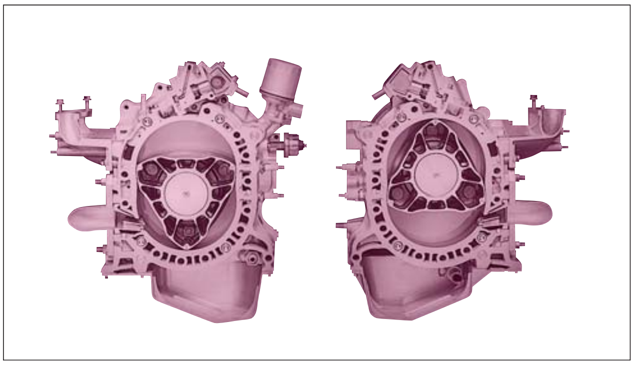
How was Mazda able to pioneer the development of practical two-rotor rotary engines, and to continue to improve them for 32 years? The answer lies in the company's superior expertise in production and manufacturing engineering. For mass-production of the rotary engines, brand-new production engineering and production facilities were required. Mazda built a manufacturing plant of 34,000 square meters, with a production capacity of 15,000 units per month, exclusively for the rotary engine. This was the only production plant for rotary engines in the world. It combined incomparable craftsmanship evolved through decades-long rotary engine production, with Mazda's state-of-the-art production engineering.

Advanced Rotary Engine

Mazda announced a hydrogen-fueled concept rotary engine in 1991 at the Tokyo Motor Show. Hydrogen used as fuel produces no carbon dioxide, which has been linked with the global warming problem. Mazda continued this line of research and, focusing on applications of hydrogen fuel to the engine under a fundamental research project for future rotary engines, actually built some experimental models powered by a hydrogen rotary engine.

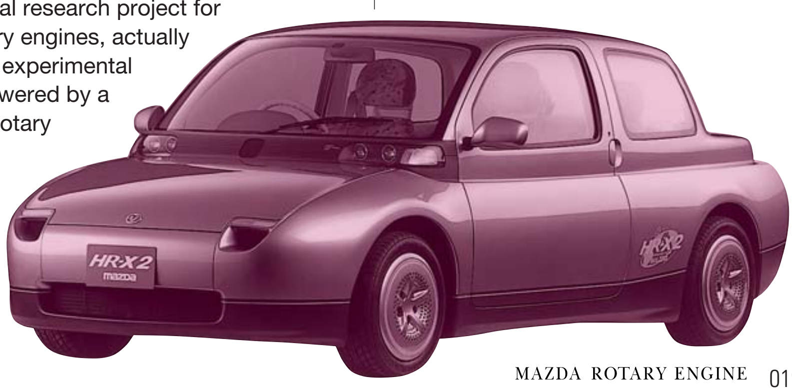
Production Line

At Mazda's rotary engine plant in Hiroshima, many innovative process and manufacturing methods were introduced which includes the plating of the trochoid surface and precision casting of the rotors.



Hydrogen Rotary Engine

The rotary engine has advanteges in using hydrogen fuel since temperatures around the intake port are relatively low and it can induct air and hydrogen separately.



HR-X2

A concept car featuring a Hydrogen rotary engine which was first inveiled at the 1993 Tokyo Motor Show. This car used metal-hydride to carry hydrogen fuel safely.

Mazda's Series-Production Rotary Engine Cars & Trucks

Cosmo Sport / Mazda 110S (1967~1972)

World's first two-rotor rotary engine car was launched in May 1967. The low, streamlined silhouette and futuristic body styling took advantage of the compact rotary engine. It also defined the start of the rotary engine era, and thrilled customers everywhere. In July of 1968, the improved version of the Cosmo Sport went on sale, featuring a souped-up 128PS L10B rotary engine and a 150mm extended wheelbase. A maximum speed of 200km/h and acceleration of 0 to 400mm in 15.8sec. excited sports car fans all over the globe. A total of 1,176 units were produced in 5 years.

Major specifications:

Length x Width x Height: 4140 x 1595 x 1165mm; Wheelbase: 2200mm; Track (front/rear): 1250/1240mm; Vehicle Weight: 940kg; Seating Capacity: 2; Engine Type: 10A; Displacement: 491cc x 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)

Developed based on the prototype Mazda RX-85, which was 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 on a fastback, two-door coupe style body. Designed as a high performance touring car, but had sufficient space to be used as a family car. In 1969, the sedan version–a high-performance family car, the Familia Rotary SS–was added to the lineup. A total of 95,891 units were produced in 5 years.

Major Specifications of the Familia Rotsry Coupe:

Length x Width x Height: 3830 x 1480 x 1345mm; Wheelbase: 2260mm; Track (front/rear): 1200/1190mm; Vehicle Weight: 805kg; Seating Capacity: 5; Engine Type: 10A; Displacement: 491cc x 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)

A highly refined personal coupe, developed based on the prototype Mazda RX-87, was announced in 1968 at the 15th Tokyo Motor Show. It had a front-engine, front-wheel-drive configuration, and went on sale in October 1969. Its egantly designed Italian-style body exhibited streamlined curves and shapely sualptured facades without the then-popular front deflector windows. The type 13A rotary engine, generating 126PS at 6000 rpm, boasted an outstanding performance; it was extra quiet, and fit right into the trend of high-speed driving that was becoming popular at the time.

Major Specifications:

Length x Width x Height: 4585 x1635 x 1385mm; Wheelbase: 2580mm; Track (front/rear): 1330/1325mm; Vehicle Weight: 1185kg; Seating Capacity: 5; Engine Type: 13A; Displacement: 655cc x 2; Maximum Output: 126PS/6000rpm; Maximum Torque: 17.5kg-m/3500rpm (JIS gross) ; Maximum Speed: 190km/h; Transmission: 4-speed Manual.

Capella Rotary / Mazda RX-2 (1970~1978)

Launched as a high-performance model in the series of the mid-sized Capella. Went on sale in May 1970. A newly designed rotary engine, the 12A, was installed under the hood. The G series—the world's first rotary engine cars with authentic automatic transmission, was added in 1971. The high-performance model 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 that time.

Major Specifications of the Capella Rotary Coupe:

Length x Width x Height: 4150 x 1580 x 1395mm; Wheelbase: 2470mm; Track (front/rear): 1285/1280mm; Vehicle Weight: 950kg; Seating Capacity: 5; Engine Type: 12A; Displacement: 573cc x 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 x Width x Height: 4065 x 1595 x 1350mm; Wheelbase: 2310mm; Track (front/rear): 1300/1290mm; Vehicle Weight: 875kg; Seating Capacity: 5; Engine Type: 10A; Displacement: 491cc x 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. It came in three body styles: hardtop, sedan, and custom. These models led the way for rotary engine cars being positioned in the top sport & luxury markets. In 1973, the Luce Wagon and the Grand Turismo, which had 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:

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

The specifications are all for the original models.

Rotary Pickup (1973~1977)

Marketed exclusively in the North American area, where pick-up trucks were very popular. 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 mirror, 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 in Japan since this was a product exclusively marketed in North American countries.

Parkway Rotary 26 (1974~1976)

World's first rotary engine bus, launched in July 1974. The 13B rotary engine was installed and yielded 135PS maximum power and 120km/h cruising speed. Pleasant riding comfort, with low noise and little vibration, was pursued, making full use of the rotary engine's benefits such as smooth operation. Two models were on sale; 26-passenger Deluxe version with optional air-conditioning operated by the sub-engine, and the 13-passenger Super-Deluxe version, with full luxury equipment. This was a unique model that had shown that the rotary engine was not solely for passenger cars.

Major Specifications:
Length x Width x Height: 6195 x 1980 x 2290mm; Wheelbase: 3285mm; Track (front/rear): 1525/1470mm; Vehicle Weight: 2885kg; Seating Capacity: 26; Engine Type: 13B; Displacement: 654cc x 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. Some of the body parts and mechanical components were supplied by GM-Holden in Australia; but 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 in three years.

Major Specifications:
Length x Width x Height: 4850 x 1885 x 1465mm; Wheelbase: 2830mm; Track (front/rear): 1530/1530mm; Vehicle Weight: 1575kg; Seating Capacity: 5; Engine Type: 13B; Displacement: 654cc x 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)

Highly refined specialty car, launched in October 1975. Mazda's full confidence shone through with this model. It was named after the Cosmo Sport, Mazda's first commercialized rotary engine car. Both the 12A,and 13B rotary engines with low-emissions package were prepared for the Cosmo AP, 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 x Width x Height: 4545 x 1685 x 1325mm; Wheelbase: 2510mm; Track (front/rear): 1380/1370mm; Vehicle Weight: 1220kg; Seating Capacity: 5; Engine Type: 13B; Displacement: 654cc x 2; Maximum Output: 135PS/6000rpm; Maximum Torque: 19.0kg-m/4000rpm (JIS gross) ; Transmission: 5-speed Manual / 3-speed Automatic.

Luce Legato / Mazda 929L (1977~1980)

Launched in October 1977 as the top-of-the-line Luce series. The concept for development was high quality, grace, and distinctiveness. The two rotary engines—type 13B with 135PS and 12A with 125PS—were optional. Two bodylines, the 4-door Pillared Hardtop and the 4-door Sedan, were offered. To meet subdivided market requirements, 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, 13B engine-powered Limited.

Major Specifications of the Luce Legato 4-door Hardtop:
Length x Width x Height: 4625 x 1690 x 1385mm; Wheelbase: 2610mm; Track (front/rear): 1430/1400mm; Vehicle Weight: 1225kg; Seating Capacity: 5; Engine Type: 13B; Displacement: 654cc x 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. 10 years of experience with rotary engine development was reflected in this model. The concept of development was the pursuit of driving pleasure. The front mid-ship layout of improved 12A engine and the then-uique retractable headlights helped realized 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 installed in 1981, and the 12A turbo rotary engine, which developed 165PS added in 1983.

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

The specifications are all for the original models.

Mazda's Series-Production Rotary Engine Cars & Trucks

Cosmo (1981~1990)

The third-generation Cosmo, launched in October 1980, was developed as a high-end personal car to meet the requirements of the day. Three body variations were designed: 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 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 x Width x Height: 4670 x 1690 x 1340mm; Wheelbase: 2615mm; Track (front/rear): 1430/1425mm; Vehicle Weight: 1170kg; Seating Capacity: 5; Engine Type: 12A; Displacement: 573cc x 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 4-door sedan and hardtop, powered by a 2.0-liter reciprocating or a 12A rotary engine. Like with the Cosmo, the rotary engine model employed Mazda's first 4-wheel independent suspension system. Later, the Luce underwent a big 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 x Width x Height: 4640 x 1690 x 1360mm; Wheelbase: 2615mm; Track (front/rear): 1430/1420mm; Vehicle Weight: 1165kg; Seating Capacity: 5; Engine Type: 12A; Displacement: 573cc x 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 inter-cooler developed a maximum power of 185PS. Mazda's unique multi-link rear suspension with toe-control capability was also came as standard. The interior was designed with the 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 x Width x Height: 4310 x 1690 x 1270mm; Wheelbase: 2430mm; Track (front/rear): 1450/1440mm; Vehicle Weight: 1240kg; Seating Capacity: 4; Engine Type: 13B turbo; Displacement: 654cc x 2; Maximum Output: 185ps/6500rpm; Maximum Torque: 25.0kg-m/3500rpm (JIS net) ; Transmission: 5-speed Manual / 4-speed Automatic.

Luce Rotary (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 the newly developed automatic transmission, it realized a smoother and quicker acceleration. The highly rigid monocoque body featured strut for the front and the 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 x Width x Height: 4690 x 1695 x 1395mm; Wheelbase: 2710mm; Track (front/rear): 1440/1450mm; Vehicle Weight: 1500kg; Seating Capacity: 5; Engine Type: 13B turbo; Displacement: 654cc x 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, Type 20B-REW, with Sequential Twin Turbo system, developed a 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. The interior materials—leather and wood—were examined from the stage of raw materials. The engine, suspension automatic transmission, and air-conditioning system were all electronically controlled.

Major Specifications:

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

Mazda RX-7 (1991~)

The third-generation RX-7, launched in December 1991, featured a powerful and responsive 13B-REW rotary engine with Sequential Twin-Turbo with a naturally harmonized beautiful body silhouette. The all-wheel double-wishbone suspensions, with newly developed dynamic geometry control mechanism, came standard on all models. Completed as a true sports car; it pursued ultimate driving pleasure. It was face-lifted in 1996 and in 1998, and the maximum output of the 13B REW was boosted up to 280PS for enhanced sports-car sansations.

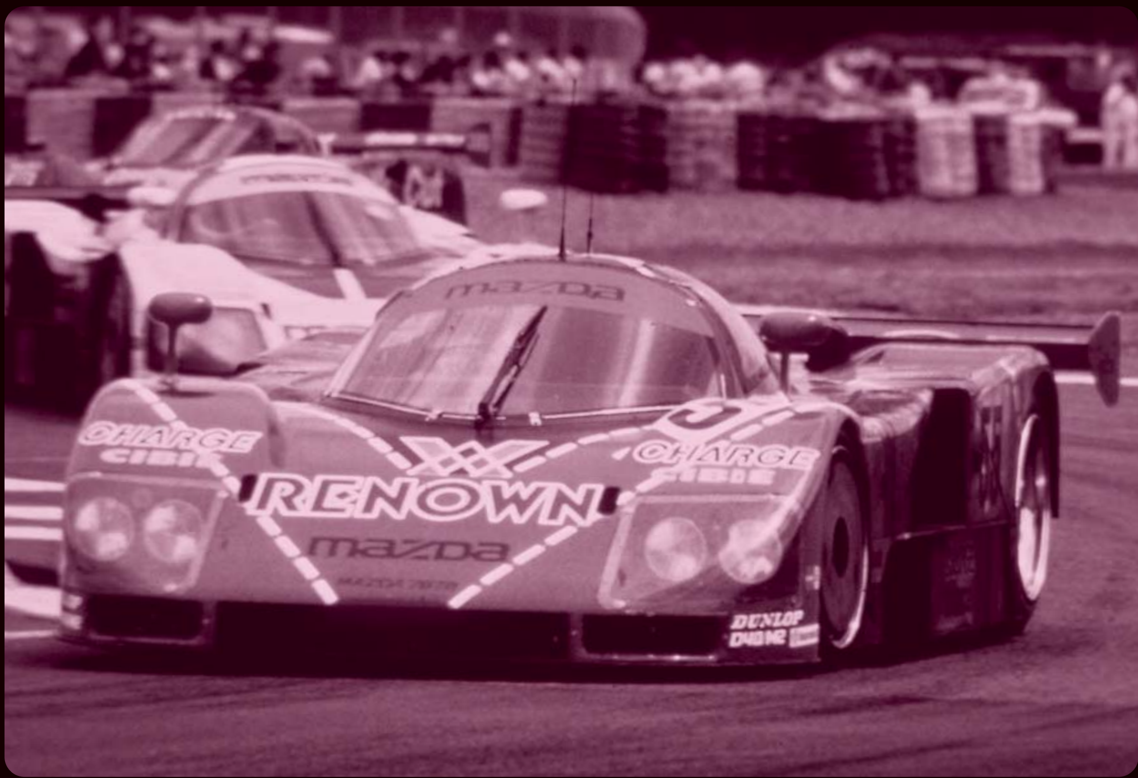
Major Specifications:

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

The specifications are all for the original models.

RE Challenges the World

Chapter 3



To demonstrate the high performance and reliability of the rotary engine, Mazda participated in international endurance races with the Cosmo Sport, Mazda's first series-production rotary engine car, in 1968. Since then, Mazda continued motor sports activities and, in 1991, Mazda 787B powered by a four-rotor rotary engine achieved overall victory in the Le Mans 24 Hours endurance race. It was an historic win for the rotary engine and the only win ever for a Japanese car.

mazda

Mazda RE Dominates Le Mans 24 Hours Race

The first overall victory by Japanese makes at the Le Mans, it was achieved by the rotary engine powered Mazda 787B.

The first Le Mans Challenge

At Mazda, participation in motor-sports activities is mainly to showcase the reliability, durability, and high performance of the rotary engine. So, winning the world's most traditional endurance race–the Le Mans 24—was the most inspiring objective.

The rotary engine car competed in Le Mans for the first time in 1970. Mazda supplied the 10A rotary engine to a private team organized by Belgian drivers, and they mounted it in their racing car costructed in the U.K., the Chevron B16, and entered the race. Regrettably, the car was forced to retire because the water cooling hose broke down after four hours of operation. In 1973, a Japanese team—the Sigma Automotive team—mounted the rotary engine in their car and competed in the race for the first time. A 12A rotary engine was supplied to their car, a modified Sigma MC73 Mazda. The car, however, had to retire after 11 hours due to trouble with the electrical system. The following year (1974), 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 French private team entered the race with a Mazda S124A (Savanna RX-3), but retired before completing the race. In 1979, the motor sports department of the Mazda Auto Tokyo challenged the IMSA class race with a Silhouette Formula based on the Savanna RX-7, the so-called Mazda RX-7 / 252i, but regrettably retired in the trial phase of the race. In 1980, an American private team entered the race with a RX-7, and wound up in 21st place overall. It was the first rotary engine car which finished this historic endurance race.

In 1981, Mazda Auto Tokyo entered the race again with two Mazda RX-7／253s (modIfled 252i of 1979), but could not finish due to the differential and transmission problems. The following year (1982), two improved RX-7／254s entered in the IMSA-GTX category ; one of them finished the race in 14th place overall (6th in its category).

Le Mans Pit in 1991

The winner of the 1991 Le Mans 24 Hours the Mazda 787B, car number 55, was driven by V. Weidler(Germany), J. Herbert(UK) and B.Gachot(France)

Repeated Trials

From 1983, Mazda Auto Tokyo targeted the newly defined Group C Junior category (which changed their name to Group C2 in 1984) and developed a mid-ship sports prototype car, the so-called Mazda 717C; two of those entered the race. Their strategy worked: they came in first and second in the C Junior category and won several awards (12th and 18th overall). In June of that year, Mazda Auto Tokyo reorganized its motor sports department into what they called the Mazda Speed, where the sports prototype car for Le Mans could be designed and built on a full scale, and where the Mazda Racing Team activities were to be developed.

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

One of the Lauras took first place in the C2 category (10th place overall), and the other came in 3rd 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 C2 category was dominated by them for two consecutive years. Such results were

Mazda 787B
The victory of Mazda 787B was extremely valuable because it defeated the heavily favored Peugeot 905, Jaguar XJR12, Mercedes-Benz C11 and other tough contenders.

enough to prove the high reliability and performance of the rotary engines yet again.

In 1985, two Mazda 737Cs, modified from the 727C, entered the race, but ended up in disappointing 3rd place (19th place overall) and 6th place (24th place overall) finishes in C2 category due to transmission and other troubles. In 1986, two newly developed Mazda 757s with type 13G three-rotor rotary 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 won the GTP category (7th place overall).

Multi-Rotor Rotary Engine

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 place 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 runners.

In 1989, two 767Bs and one 767 entered the race. Two of them unfortunately crashed in the trial run, jeopardizing their entry into the final race, but the cars were restored by extraordinary teamwork efforts; all three cars finished the final. The results were 7th place (won the IMSA-GTP category), 9th place, and 12th place overall, but still several steps short of the hoped-for first place overall win.

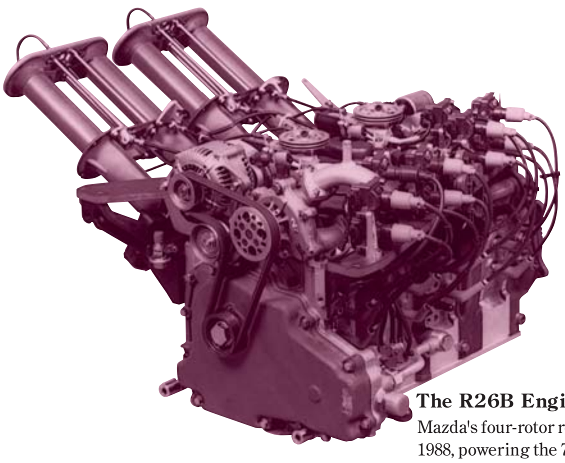
In 1990, two new cars, Mazda 787s with their newly developed R26B four-rotor rotary engines, and one 767B entered the race. The Mazda 787s were fitted with full-carbon twin-tube chassis for the enhanced "fighting ability" of the car, and were regarded as most promising for victory. However, the two 787s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

Long Awaited Victory

The Mazda team challenged the 1991 Le Mans 24 hours race with two further strengthened 787Bs and one 787. The R26B four-rotor unit had greatly improved both power and fuel efficiency on the basis of the high reliability and durability of the rotary engine. The organizer of this historic event had decided to hold the race next year only with machines powered by a 3.5-liter reciprocating engine. So this was the last chance for the four-rotor engine powered 787B and 787.

The three Mazdas competed successfully from the beginning. At the 12th hour, the787B 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 got top place.

At just 4 o'clock in the afternoon of June 23, 1991, the 787B passed the goal line, achieving Mazda's long awaited target; two hundred fifty thousand spectators cheered the car.



The R26B Engine of the 787B
Mazda's four-rotor rotary engine first appeared at the Le Mans in 1988, powering the 767 and yielding 550PS. But the maximum output had been boosted to 700PS in the type R26B unit of the 1991 787Bs.

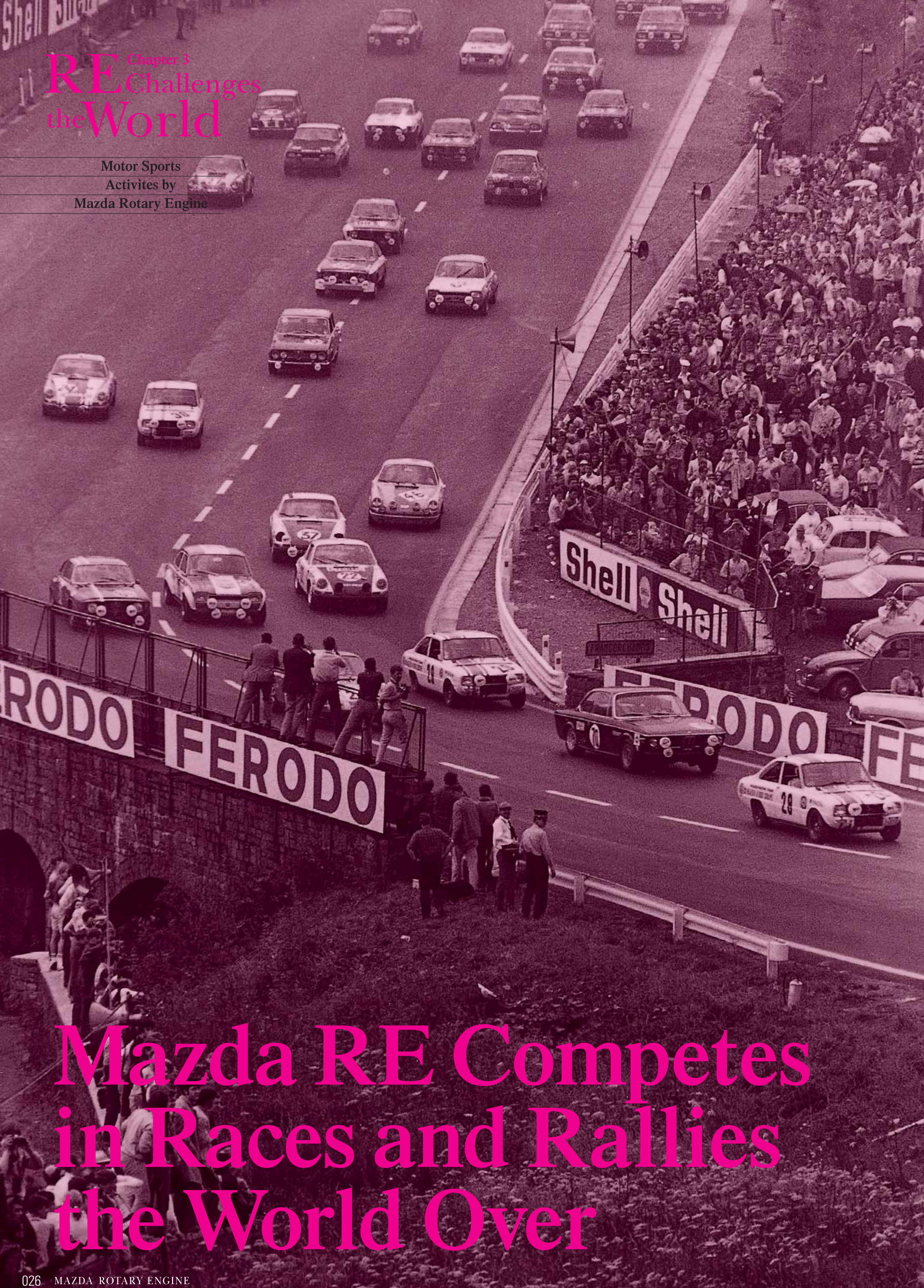
Chevron B16 in 1970
The first rotary engine car that competed at the Le Mans, the Chevron B16 was powered by a 10A unit.

Mazda 717C in 1983
Mazda Speed's first entry, this car, driven by three Japanese, won the C Junior class and finished 12th place overall.

Mazda 767B in 1989
Racing prototype powered by a four-rotor rotary engine, the 767B came in 1st, 2nd, and 3rd places in the IMSA-GTP class.

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

Motor Sports
Activites by
Mazda Rotary Engine



Mazda RE Competes in Races and Rallies the World Over

Legendary First Race

After announcing the world's first mass-produced rotary engine car, Cosmo Sport, Mazda immediately planned to participate in motor-sports activities; they believed that motor sports enthusiasts were highly attracted to the high performance, reliability, and durability of rotary engines.

But, in the initial stage of development, intensive efforts were 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 sports.

But until Mazda's entry, a rotary-engine car had never competed in auto races. An international race 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 Nurburgring Circuit in West Germany, the 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. The 10A rotary engines there 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.

R100: Small Giant

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

In April 1969, the Familia Rotary Coupe took first place overall in the Singapore Grand Prix. It then moved on to Europe. In July of that year, competing with a Porsche 911 fleet, the team 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, 1970, the team took 8th place overall at the RAC Tourist Trophy Race in England, followed by a 4th place showing overall in July at West Germany Touring Car Grand Prix. Later that year, four Familia Rotary Coupes registered to compete in the Spa-Francorchamps 24-hour race; Mazda aimed to dominate the race. In the race, the Mazda team boldly confronted the BMW team, and finished in a dead heat. Although the Japanese driver pair (Yoshimi Katayama and Toshinori Takechi) held the lead at the 12th hour, the team encountered some ill-fated 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.

RX-3 Defeats GT-R

While the Familia Rotary Coupe was racing all over the world, the first race in Japan for the car took place in November 1969. The debut race was the All Japan Suzuka Automobile Grand Cup Race, where the Mazda team took first place overall. The 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 unseat 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 winning positions. After some fierce racing battles, the Savanna finally defeated the Skyline GT-R and became the grand champion of racing.

Thereafter, the Savanna retained its champion position, leaving a legacy of undefeatable race records. Mazda supported its owners by offering sports kits in the market to meet the requirements of motor-sports fans and continued their motor-sports activities. The Savanna chalked up its 100th victory in domestic race events when it won the JAF

Mazda RX-3 (Savanna)

The RX-3 defeated the Nissan Skyline GT-R and accumulated 100 wins by 1976 in the domestic touring car championship.

RX-7 in 1979 Daytona 24-hr

In its first race in the U.S. the 1979 Daytona 24 Hours, the RX-7 won the GTU class and demonstrated high potential.

8-Year Consecutive Wins

The RX-7 won the IMSA series of the U.S. for eight consecutive years, from 1980 to 1987, a great record in IMSA history.

Cosmo Sport

In 1968, the year following its debut, the Cosmo Sport entered the Marathon de la Route, an 84-hour endurance race held at Nurburgring in West Germany, and finished 4th overall.

Mazda RX-7: Unbeatable Champion in the World Sports-Car Races

RX-7 in 1992 Bathurst

The new RX-7, launched in 1991, won the famous Bathurst 12-hour race in Australia, for three straight years from 1992 to 1994

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.

RX-7: The Great Winner

The Mazda RX-7 (Savanna RX-7 in the domestic market) made its debut in May 1978. It was a high-performance sports car that received a laudatory welcome by racing enthusiasts all over the world. Rotary engines, with their proven high durability and reliability, were easy to tune and maintain, two attributes that made them extremely attractive for motor sports enthusiasts.

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. They have never lost a race in the GTU class. For eight consecutive years (from 1980 to1987), 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. Until 1990, a total of 100 victories were accumulated, an IMSA series record.

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—a dream of the Familia Rotary Coupe that could not become a reality 11 years earlier—was finally achieved by the RX-7.

WRC Challanges

Mazda also challenged 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, the entry in the New Zealand Rally ended up 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.

Challange Will Continued

In October 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.

Especially in Australia, from 1992 through 1994, it consecutively won the overall championship in the most popular touring car race, the Bathurst 12-hour Endurance Race.

In Japan, many private teams using the RX-7 actively competed in the All Japan GT Championship Race and in the Super Endurance Series.

The Mazda RX-7, with its compact and high performance rotary engine, will continue to be well received by motor sports fans and racing teams throughout the world, and will play very active roles in the circuits.

RX-7 in 1985 Acropolis

In 1984, Mazda entered to the WRC a special Group-B RX-7 with larger 13B rotary engine. It finished 3rd overall in the 1985 Acropolis Rally.

1990 IMSA GTO Class

In 1990 at the San Antonio GP,a RX-7 driven by Pete Halsmer took first place in the GTO class, achieving the 100th win of the RX-7 in the IMSA series.

100th Win at IMSA

Since its first race at the Daytona 24-hour in 1979, the RX-7 accumulated victories in the IMSA series and achieved its record 100th win in 1990.

APPENDIX

Structure and Working Principles of 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 using would be superceded by an elegant prime mover bearing a closer resemblance to the "wheel", one of mankind's greatest inventions.

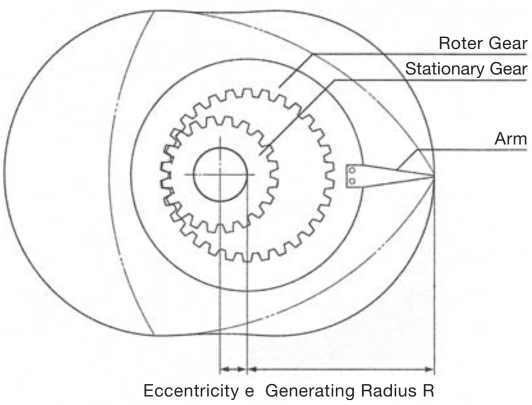
It was late in the sixteenth century that the phrase,"continuous rotating internal combustion engine" first appeared in print. James Watt (1736~1819), the inventor of the connecting rod and crank mechanism, also took up research on a rotary-type internal combustion engine. For the last 150 years especially, 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 working knowledge on the rotary valves used for the aircraft engines, the airtight sealing mechanism for the superchargers and the incorporation of these mechanisms into his design contributed to practical realization of Wankel-type rotary engine.

Structure and Operation of the Rotary Engine :

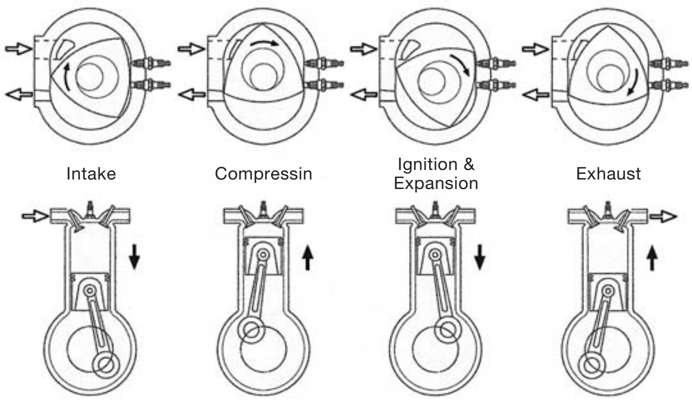
The rotary engine is composed of a cocoon-shaped housing and a triangular-shaped rotor inside of it. The space between the rotor and the housing wall provided the chamber for internal combustion and the force of the expansion pressure served to turn the rotor. In order to make the rotary engine work as an internal combustion engine, the four processes of intake of the mixture, compression, combustion and exhaust had to be performed in succession in the working chamber. Let us 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 one turn, thus the four processes of the internal combustion engine could be achieved. With the Wankel-type rotary engine, the rotor's apexes follow the oval contour of the inner periphery of the engine casing while



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.



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 moves. Four processes of intake, compression, combustion and exhaust are executed succesively in a different place of the trochoid housing. This is significantly different from the reciprocating engine, where the four process are carried out within a cylinder.

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 :

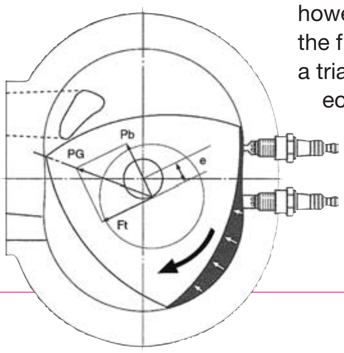
In order to get the turning force, both the reciprocating engine and the rotary engine rely on the expansion pressure created by the combustion of the fuel-air mixture. The difference between the mechanisms of the two engines is in the way that the expansion pressure is used. In the reciprocating engine, 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 expansion pressure is applied to the flank of the rotor. One of the three sides of a triangle is forced oward 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.

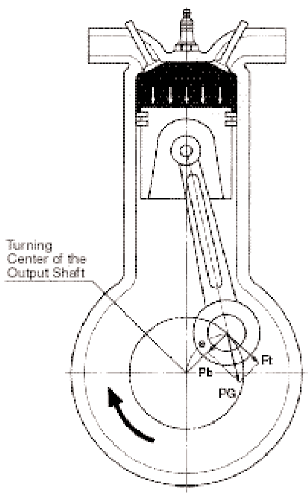
The inside space of the housing, called (or the trochoid chamber) is always divided into three working chambers. Due to the turning of the rotor, those three working chambers are always in motion and successively execute the four processes of intake, compression, ignition (combustion) and exhaust inside 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.

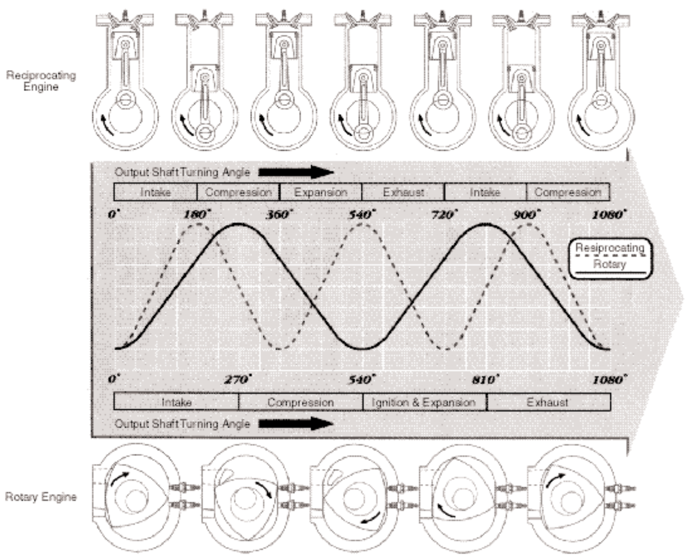
The displacement volume of the rotary engine is generally expressed by the unit chamber volume and by the number of rotors. For example, with the model 13B two-rotor rotary engine, the displacement volume is shown as "654cc x 2".

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 below, 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 two engines. One difference is the turning angle per 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

Principle of Generating Torque
With the reciprocating engine, the expansion pressure of the combustion gas is changed to the turning motion through the connecting rod and 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.







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, on the other hand, 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.

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 :

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 spotlight once again.

Flat Torque Characteristics

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

Less Vibration and Low Noise

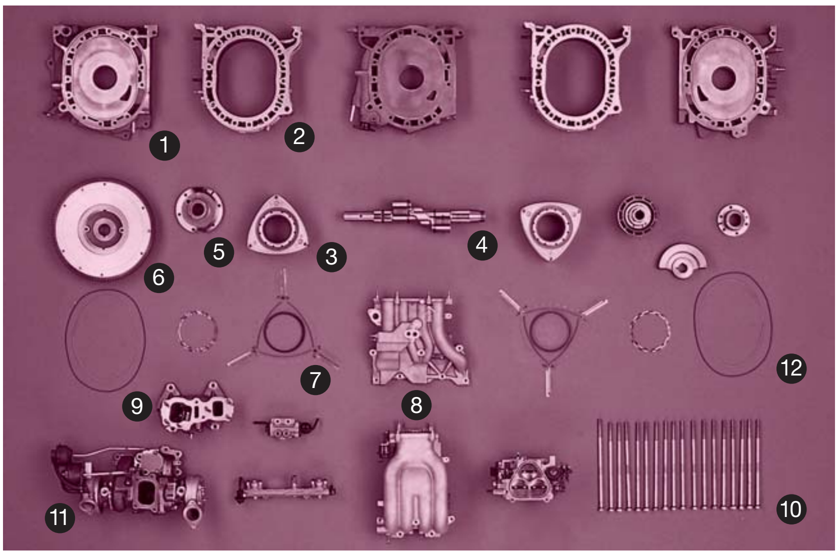
With the reciprocating engine, piston motion itself could be a source of vibration, while the valve acting system generates unwanted mechanical noises. The smooth turning motions of the rotary engine generate considerably less vibration and the absence of a valve acting mechanism contributes to a smooth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

Simple Structure

As the rotary engine converts the expansion pressure of the burnt 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 include the timing belt, the camshaft, the rocker arm, the valve, the valve spring, etc. required in the reciprocating engine are not required and can therefore be built with far fewer parts.

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 duarable under high load operations. This was demonstrated by the overall win at the Le Mans in 1991.



Major Components of the Rotary Engine

The rotary engine need not a valve acting mechanism to open and close the intake and exhaust port and, compared with the reciprocating engine, is composed of much fewer parts. The photo on the left shows the RX-7's type 13B-REW twin-rotor unit disassembled for reference. The names of major components are: 1 side housing, 2 rotor housing, 3 rotor, 4 eccentric shaft, 5 stationary gear, 6 fly wheel, 7 apex, side and oil seals, 8 intake manifold, 9 exhaust manifold, 0 rotor housing assembly volts, A turbocharger, B sealing rubbers

Mazda Rotary Engine: Chronological Table

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.
1959	Wankel completed the type KKM250 rotary engine.
1960	Wankel/NSU tested their rotary engine in public.
1961.7	Mazda made a technical contract with NSU and Wankel.
1961.11	Mazda completed its own first prototype rotary engine.
1963.4	Mazda organized Rotary Engine Research Department.
1964.9	A prototype sports car powered by a rotary engine is unveiled at the Tokyo Motor Show.
1967.5	Mazda announced the completion of the rotary engine. The Cosmo Sport was introduced into the domestic market.
1968.7	The Familia Rotary Coupe was intoroduced.
1969.9	Mazda exported rotary engine cars for the first time (to Australia and Thailand).
1969.10	The Luce Rotary Coupe (front-wheel-drive) was introduced. Mazda's rotary engine car cleared the emission test by US Federal Government.
1970.4	Mazda was awarded by Japanese Mechanical Engineering Society for the commercialization of the rotary engine.
1970.5	Export of rotary engine cars to Europe (Switzerland) started. The Capela Rotary (powered by 12A unit) was introduced.
1970.6	Export of rotary engine cars to the United States started.
1970.12	Accumulative production of rotary engine cars reached 100,000 units.
1971.9	The Savanna Rotary was introduced.
1971.10	Accumulative production of rotary engine cars reached 200,000 units.
1972.1	The Capela Rotary Coupe completed 100,000km endurance run, through eleven European countries and with its engine fully sealed.
1972.10	The first series production car with full emission control package, the Luce Rotary was introduced.
1973.2	Mazda's rotary engine car cleared the US 1975 emission standards, and this fact was confirmed by EPA test.
1973.6	Accumulative production of rotary engine cars reached 500,000 units.
1973.12	The Luce AP Grand Tourismo powered by 13B engine was introduced.
1974.7	The Parkway Rotary 26 was introduced.
1975.3	The Roadpacer was introduced.
1975.10	The Cosmo AP was introduced featuring a low emission rotary engine with 40% improved fuel-efficiency.
1978.3	The Savanna RX-7 was introduced.
1978.11	Accumulative production of rotary engine cars reached 1,000,000 units.
1981.10	The New Cosmo and Luce Rotary were introduced.
1983.9	The RX-7 was face-lifted and the world-first turbo rotary engine model was added.
1985.10	The RX-7 was entirely redesigned.
1986.4	Accumulative production of rotary engine cars reached 1,500,000 units.
1986.9	The Luce was entirely redesigned.
1990.4	The Eunos Cosmo debuted featuring the world's first three-rotor rotary engine (20B-REW).
1991.6	The Mazda 787B achieved overall win at the 59th Le Mans 24 Hours race.
1991.10	The RX-7 was completely redesigned (with a 255PS 13B-REW unit).
1995.10	The RX-01 concept car (powered by a type MSP-RE experimental engine) was unveiled at the Tokyo Motor Show.
1996.1	The RX-7 was face-lifted (engine output increased up to 265PS).
1998.12	The RX-7 was face-lifted (engine output increased up to 280PS).
1999.10	The RX-EVOLV concept car with the RENESIS experimental engine was unveiled at the Tokyo Motor Show.

Mazda Motor Corporation.
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