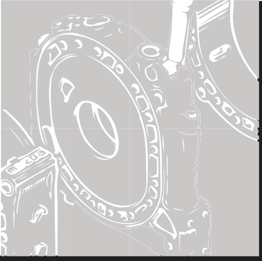
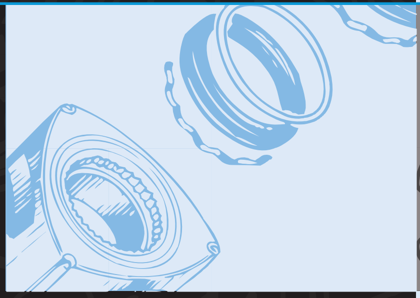
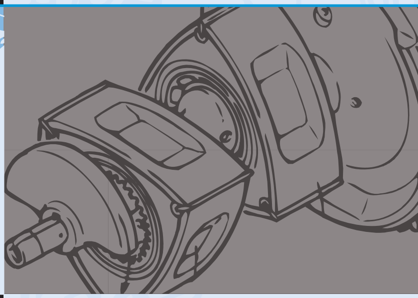


RENESIS ROTARY ENGINE FUNDAMENTALS





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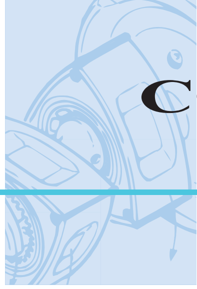

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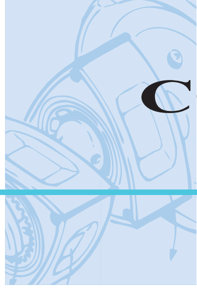
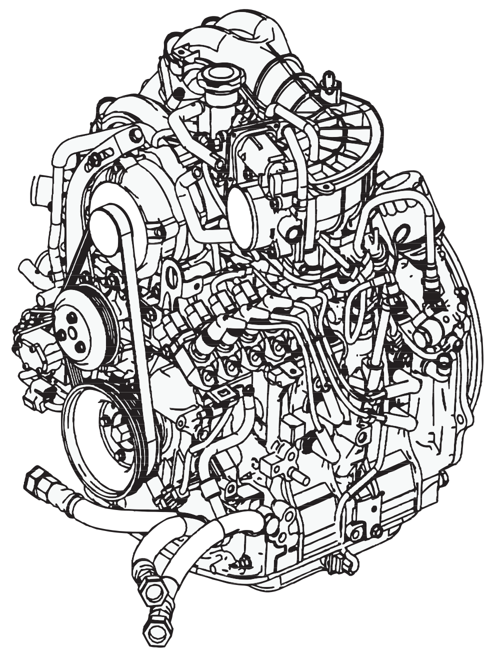


CONTENTS

1 – INTRODUCTION



COURSE OVERVIEW

Welcome to the Mazda self-study guide, *RENESIS Rotary Engine Fundamentals*. Before you begin, please read the following information.

Audience and Purpose

This guide is designed for entry-level automotive technicians. It describes major rotary engine components and introduces the basic principles of rotary engine operation, including Mazda's RENESIS rotary engine.

This guide assumes that you have little or no knowledge about rotary engine operation. The information covered in this guide is required for Mazda's Engine Course.

1 - INTRODUCTION

Course Content and Objectives

In addition to this Introduction (Section 1), this guide includes five major sections and a Glossary. The objectives for each section follow:

Section 2 - Rotary Engine Components

- Describe how a rotary engine generates power
- Identify the major parts of a rotary engine

Section 3 - Basic Operation

- Describe the benefits of rotary engines
- Define rotary engine design characteristics: process time, displacement, and compression ratio

Section 4 - Rotary Engine Controls

- Describe major rotary engine control systems, including:

  -Intake

  -Ignition

  -Cooling

  -Secondary air

  -Lubrication

Section 5 - RENESIS Rotary Engine Features and Benefits

- Describe the major differences between standard rotary engines and RENESIS rotary engines
- Describe the features and benefits of the RENESIS rotary engine in terms of:

  - Fuel economy
  - Emissions
  - Weight and mounting
  - Eccentric shaft
  - Oil consumption

Section 6 - RENESIS Rotary Engine Systems

- Describe major RENESIS rotary engine systems, including:

  - Air intake
  - Jet air-fuel mixing
  - Exhaust ports
  - Metering oil pump
  - Wet sump oil system
  - Secondary air injection system
  - Catalytic converter
  - Electronic throttle control

Section 7 - Glossary

- Define terms used throughout this guide

1 – INTRODUCTION

HOW TO USE THIS GUIDE

To get the most benefit from this guide, complete the sections in order, from 1 through 6. Allow enough time to complete each section, and don't try to finish the whole book in one sitting. **You will retain more of what you learn if you split up the reading and review exercises over several days.**

Section Objectives

Each section begins with a list of learning objectives. These objectives tell you exactly what you will learn in the section. Read these objectives before you begin a section. When you have completed the section, go back and review the objectives to make sure you have learned the material.

Text and Illustrations

Each section includes text and illustrations that explain important concepts and terms. Read the text carefully and study the illustrations. You may also want to take notes as you go along.

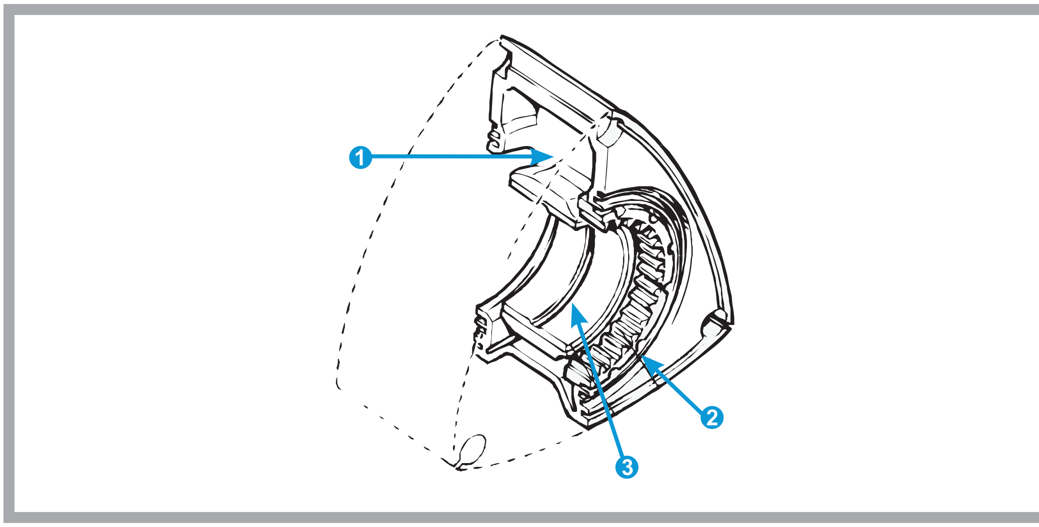
Each illustration includes numbered “callouts” that identify engine parts or processes described in the text. The numbered terms beside the illustration identify the parts that are called out, as shown in the following example from Section 2.

FIGURE 2-4.
An oil jet plug in the eccentric shaft injects oil into the rotor s hollo interior.

1 Oil

2 Internal gear

3 Rotor bearing



Review Exercises

This guide includes six sets of Review Exercises, which appear at various points throughout the guide. The exercises are designed to check your understanding of the material. Make sure you answer the questions in each Review Exercise. Then check your answers with the answer key.

If you’re not sure about one or more of your answers, go back and read the material again. Make sure you understand the previous material before moving on to new material.

1 - INTRODUCTION

2 - ROTARY ENGINE COMPONENTS

In a car or truck, the engine provides rotating power to drive the vehicle's wheels. This power is transferred to the wheels through the transmission and driving axle. In a rotary engine, this rotating power comes from the energy released when fuel burns in the engine's *working chambers*, similar to fuel burning inside the cylinders of a piston engine.

This section describes the major parts of a rotary engine, and explains how a rotary engine converts energy from burning fuel into power that drives the vehicle's wheels.

OBJECTIVES

After completing this section, you will be able to:

- Describe how a rotary engine generates power
- Identify the major parts of a rotary engine, including:
  - Rotor
  - Rotor housing
  - Front, side, and intermediate housings
  - Gas seals (apex, side, and corner seals)
  - Oil seals
  - Stationary gear
  - Eccentric shaft

HOW A ROTARY ENGINE DEVELOPS POWER

A rotary engine develops power in much the same way as a conventional piston engine. However, in a rotary engine, the *rotor* does the job of the pistons, connecting rods, and valves. The *rotor housing* and *side housings* enclose the rotor and function like the cylinders in a piston engine.

The process of burning the air-fuel mixture in the engine is called *combustion*. As the rotor turns inside the rotor housing, it forms working chambers in which the *combustion cycle* takes place.

The combustion cycle requires four steps, or strokes:

1. Intake — Admits the proper mixture of air and fuel into the working chamber.

2. Compression — Squeezes the air-fuel mixture so it will burn better and deliver more power.

3. Power (also called the expansion or combustion stroke) — Burns the air-fuel mixture.

4. Exhaust — Removes the burned gasses from the engine so the intake, compression, and combustion strokes can repeat.

Figure 2-1 shows the rotor turning inside the rotor housing during the four steps of the combustion cycle. A blue dot has been added to show the rotor’s motion.

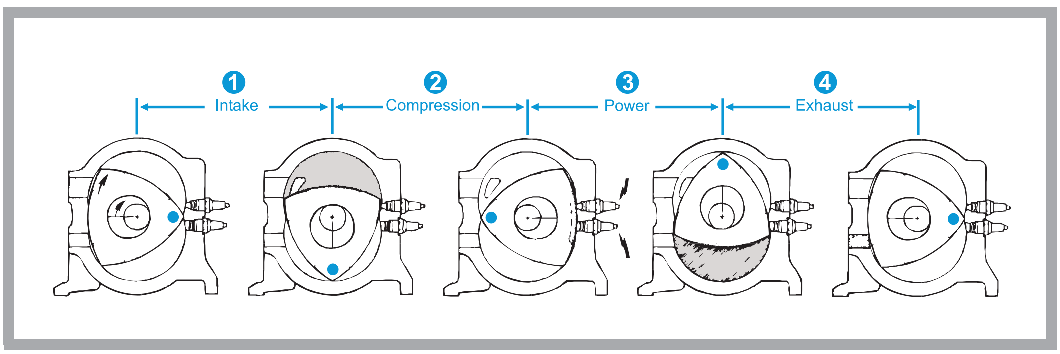


FIGURE 2-1.
These are the four steps of the combustion c cle.

1 Intake

2 Compression

3 Po er (Combustion)

4 E haust

Intake Stroke

When the working chamber is at (1), its volume is at minimum, corresponding to top dead center in a piston engine. The *intake stroke* begins here.

As the rotor continues to turn, the rotor uncovers the *intake ports* on the side housings, and the ports draw in the air-fuel mixture. At the same time, the intake working chamber grows larger, reaching maximum capacity at (2).

At this point, the rotor position corresponds to bottom dead center in a piston engine. In a rotary engine, this position is called *intake bottom dead center*.

Compression Stroke

At the end of the intake stroke, the rotor covers the intake ports. The working chamber's capacity gradually becomes smaller, and the air-fuel mixture is compressed. This is the *compression stroke*.

As the rotor turns, the working chamber continues to become smaller. When compression is almost complete, sparks from the spark plugs ignite the air-fuel mixture. At position (3), the working chamber is at its minimum capacity. This is called compression top dead center.

Power Stroke

When the air-fuel mixture ignites in the rotor's *combustion recess*, pressure and volume increase, and expansion continues. This is called the *power stroke*.

During this time, the combustion energy of the air-fuel mixture presses against the rotor's surface, forcing the rotor to turn on the *eccentric shaft*, which converts the combustion energy into rotational energy. This energy passes from the eccentric shaft through the clutch to the transmission and drive train, eventually powering the wheels. At this point, the working chamber's capacity again grows to its maximum. This is called power (combustion) bottom dead center.

Exhaust Stroke

When the power stroke is completed, the rotor expels burned gases from the *exhaust ports* in the rotor housing, and the capacity of the working chamber decreases. This is the *exhaust stroke*. When this stroke ends, the rotor returns to (1), where the cycle starts again.

The cycle shown in Figure 2-1 focuses on only one of the working chambers. The other two chambers operate in exactly the same way. Because there are three working chambers, one rotation of the rotor produces three power strokes. In addition, the rotor's internal gear ratio yields three rotations of the eccentric shaft for each complete rotation of the rotor.

In other words, there is one power stroke for each rotation of the eccentric shaft. And remember, the same cycle is being repeated in both rotors.

2 - ROTARY ENGINE COMPONENTS

ROTARY ENGINE COMPONENTS

Most rotary engines have two *rotors*. A two-rotor engine consists of the major parts shown in Figure 2-2.

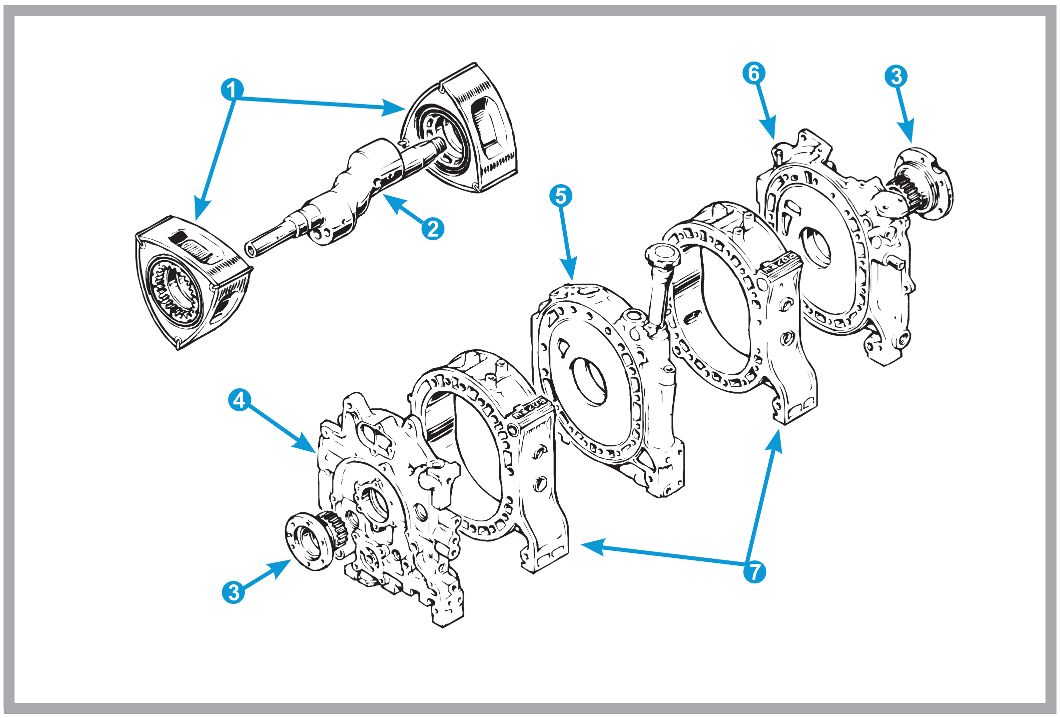


FIGURE 2-2.
A rotar engine consists of these major parts.

1. Front and rear rotors
2. Eccentric shaft
3. Stationar gear
4. Front side housing
5. Intermediate housing
6. Rear side housing
7. Front and rear rotor housings

The two rotors (front and rear) are connected by an *eccentric shaft,* similar to a crankshaft in a piston engine. The eccentric shaft spins the rotors inside the rotor housing, which is enclosed between an intermediate housing and a side housing.

These housings are sandwiched tightly together to form a sealed chamber, similar to a cylinder in a piston engine.

Rotor

The rotor has three sides, like a triangle, and it is made of special cast iron. As the rotor turns inside the rotor housing, it functions like the pistons, connecting rods, and valves in a piston engine. Figure 2-3 shows the major parts of the rotor.

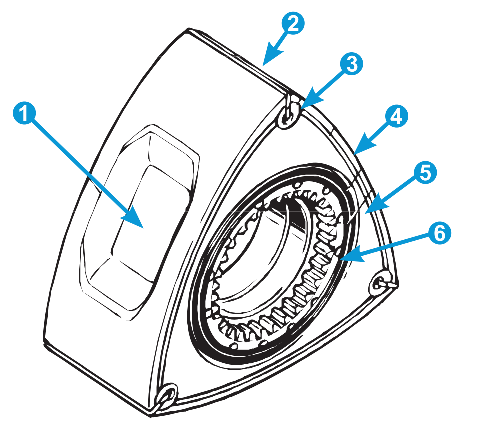


FIGURE 2-3.
The rotor does the jobs of the pistons, connecting rods, and valves in a piston engine.

1. Combustion recess
2. Ape   seal
3. Corner seal
4. Side seal
5. Outer oil seal
6. Inner oil seal

The rotor converts the pressure of combustion gases into energy to drive the rotating eccentric shaft. The turning rotor causes the engine's intake and exhaust ports to open and close, allowing the proper air-fuel mixture into the engine and exhausting burned gasses after combustion.

Each of the rotor's three sides contains a combustion recess, sometimes called a bathtub. *Spark plugs* ignite the compressed air-fuel mixture in these recesses, generating power, which passes through the rotor bearing to the eccentric shaft, sometimes called the output shaft.

One side of the rotor contains an *internal gear*, as shown in Figure 2-4. This internal gear meshes with the *stationary gear* on the rotor housing and guides the rotor in its motion inside the housing. A *rotor bearing* at the rotor's center supports the eccentric shaft, which holds the rotor in place.

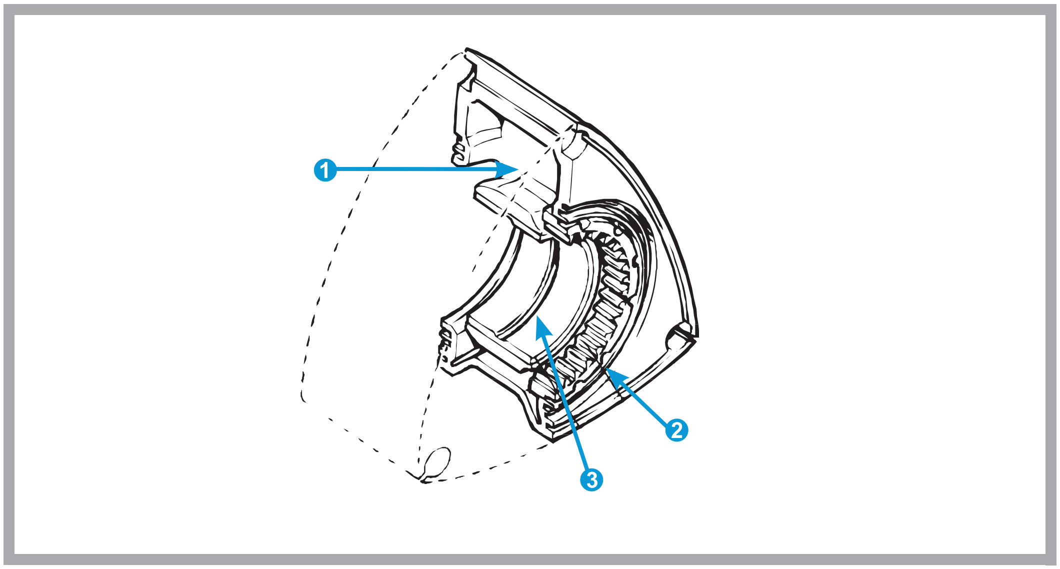


FIGURE 2-4.
An oil jet plug in the eccentric shaft injects oil into the rotor s hollo interior.

1 Oil

2 Internal gear

3 Rotor bearing

The interior of the rotor is hollow for easier cooling and reduced weight. An *oil jet plug* in the eccentric shaft lubricates the interior of the rotor.

As the rotor rotates inside its housing, it creates three working chambers in the space between the inner walls of the rotor housing and the three points of the rotor.

The rotor, like a piston in a piston engine, has *gas seals* that keep the working chambers airtight. The rotor also has *oil seals* that prevent lubricant from entering the working chambers.

Gas Seals

The gas seals in a rotary engine serve the same purpose as the piston rings in a piston engine. These seals maintain the airtightness of the three working chambers created by the rotor as it turns inside the rotor housing. The working chambers must be airtight so the combustion cycle can take place efficiently, without loss of power. Figure 2-5 shows the position of the gas seals fitted into the rotor.

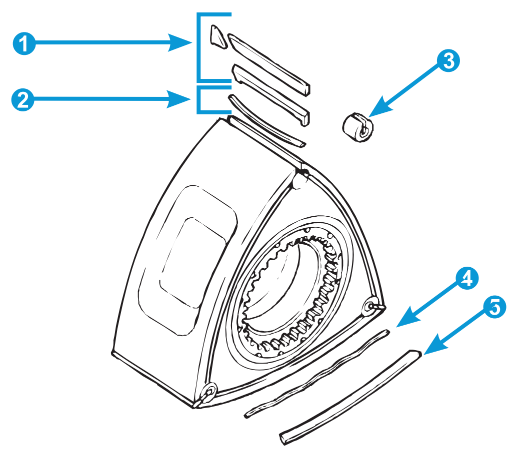


FIGURE 2-5.
Gas seals maintain the airtightness of the orking chambers.

1. Ape seal
2. Ape seal spring
3. Corner seal and spring
4. Side seal spring
5. Side seal

There are three sets of gas seals: *apex seals*, *side seals*, and *corner seals*. The seals fit into grooves in the rotor, and each seal is attached with a spring.

The cast iron apex seal maintains the airtightness between the rotor housing's inner surface and the rotor. Depending on engine type, the apex seal may consist of two or three pieces, held in place by a two-piece spring. The apex seal is held in place by a combination of the apex seal springs and the centrifugal force of the rotor's rotation.

The side seal performs the same sealing function between the intermediate housing and the side housing of the rotor. The corner seal closes up any remaining space between the ends of the apex seal and the ends of the side seal.

During engine operation, gas pressure generated by the turning rotor presses against the lower portion of the apex seals, further improving the airtightness of the working chambers, as shown in Figure 2-6.

FIGURE 2-6.
Gas pressure further improves the sealing abilit of the ape seals.

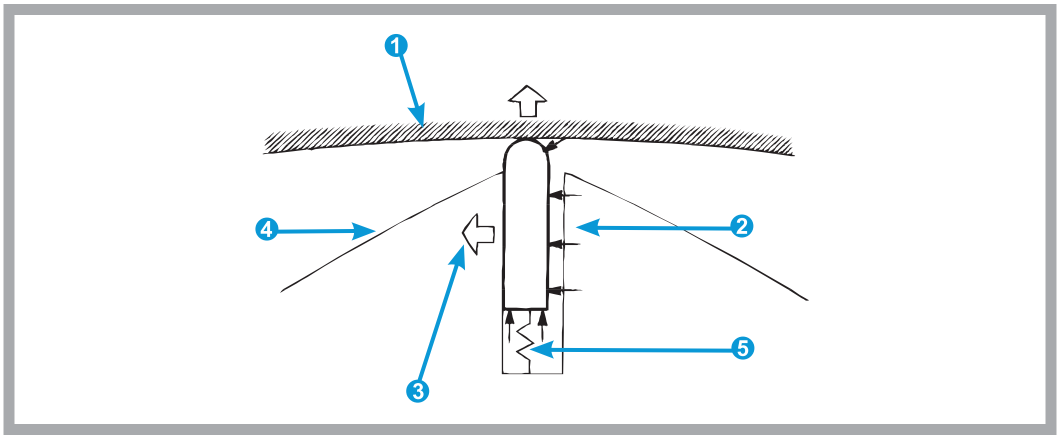
❶ Rotor housing

❷ Gas pressure

❸ Pushing pressure

❹ Rotor

❺ Spring pressure



Oil Seals

Engine oil lubricates the rotor bearing and cools the rotor. The oil seals in the rotor prevent engine oil from passing through the clearance between the rotor wall and the side housing. The oil seals also keep oil from leaking into the working chambers. Figure 2-7 shows the rotor's inner and outer oil seals.

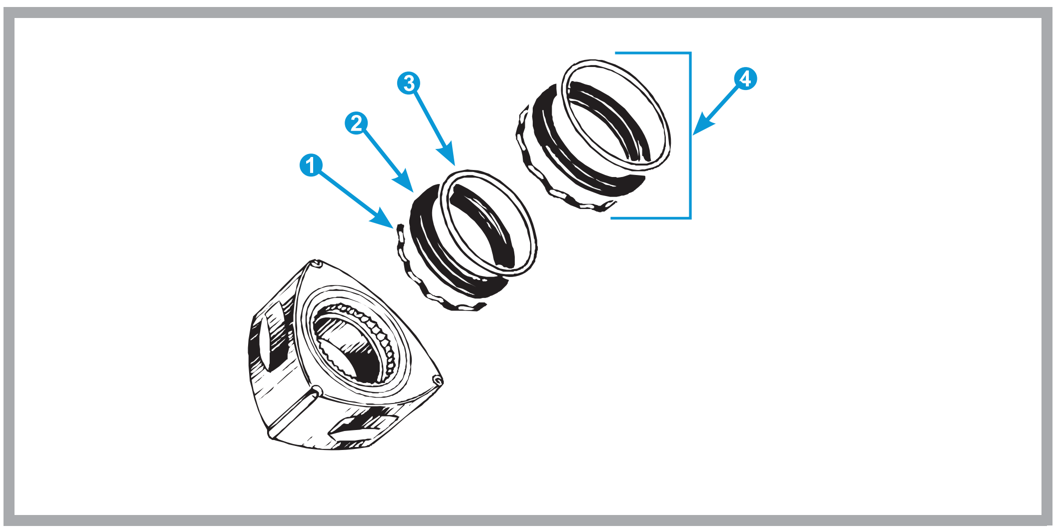
FIGURE 2-7.
Oil seals prevent oil from leaking into the orking chambers.

❶ Spring

❷ Inner oil seal

❸ O-ring

❹ Outer oil seal, ith O-ring and spring



The oil seals fit into grooves in the sides of each rotor. Both the inner and outer oil seal have a spring and an O-ring to improve sealing ability.

As the rotor spins, the oil seals form two overlapping ranges inside the rotor housing: a *scrape-away range* and a *cross-over range*.

As Figure 2-8 shows, when the oil seals slide against the surface of the side housing, they remove carbon within the scrape-away range. In the cross-over range, an oil film forms on the contact surfaces, indirectly lubricating the side seal and corner seal.

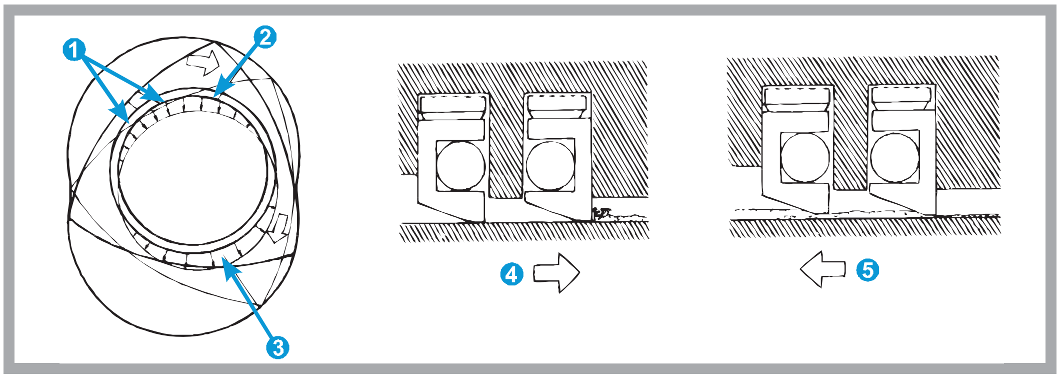


FIGURE 2-8.
The oil seals remove carbon buildup.

1. Oil seals
2. Scrape-a a range
3. Cross-over range
4. During scrape a a
5. During cross over

Rotor Housing

The rotor housing is made from aluminum alloy cast around a chrome-plated steel insert. The inner surface of the rotor housing is sometimes called the “trochoid” surface because of the curved shape it has.

The apex seals in the rotor slide against the inner surface of the rotor housing as the rotor turns. The rotor's rotation creates three working chambers (shaded in gray), as shown in Figure 2-9.

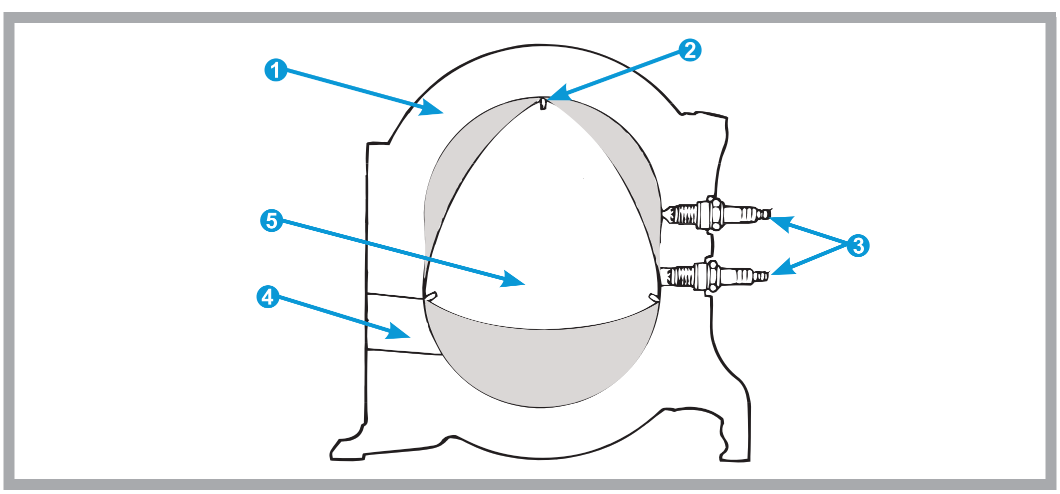


FIGURE 2-9.
The turning rotor creates three orking chambers.

1. Rotor housing
2. Ape seal
3. Spark plugs
4. E haust port
5. Rotor

The *trochoid surface* of the rotor housing also contains the exhaust port, the oil nozzle installation hole, and the *spark plug installation holes*, as shown in Figure 2-10.

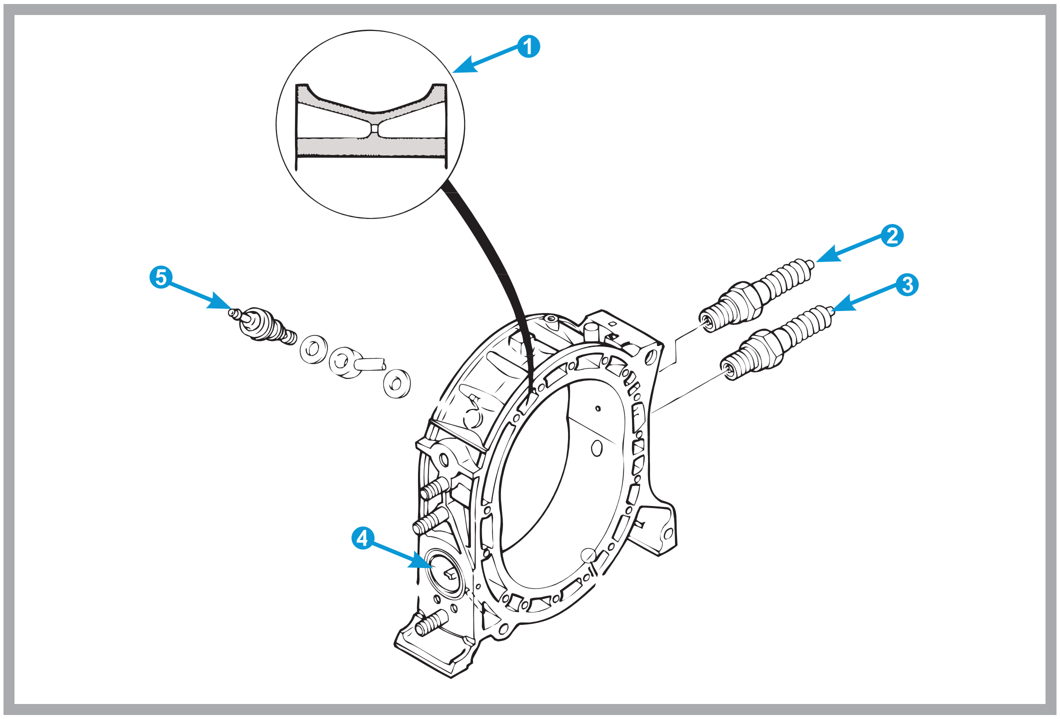


FIGURE 2-10.
The rotor housing is the installation point for man components.

1. Coolant passage
2. Trailing spark plug
3. Leading spark plug
4. E haust port
5. Housing oil no le

The rotor housing also has *coolant passages* around the outside of the trochoid surface to provide engine cooling.

Side Housings

The side housings form walls at the front and rear of the rotor housing. These walls define the airtight working chambers. The side housings also provide the contact surfaces for the side seals and the intake ports for the working chambers. The front and rear side housing may have one or more intake ports, depending on engine type. The intermediate housing usually has one intake port.

The side housings function like the cylinder and cylinder head in a piston engine. Figure 2-11 shows the front, intermediate, and rear side housings with typical intake port location.

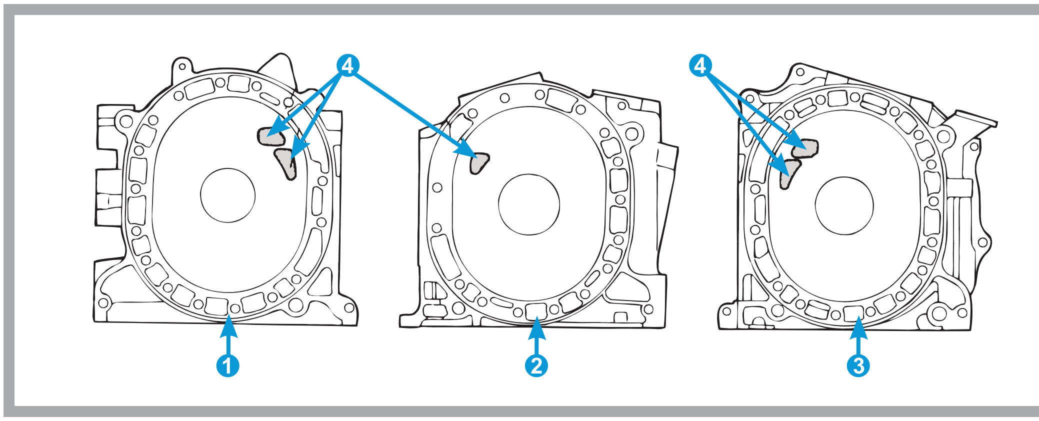


FIGURE 2-11.
The side housings form the side surfaces of the orking chambers.

1. Front side housing
2. Intermediate housing
3. Rear side housing
4. Intake ports

Sealing rubber gaskets installed around the coolant passages of the side housings prevent coolant or gases from leaking, much like the head gasket works in a piston engine. Figure 2-12 shows the rubber sealing gasket's position in the side housing.

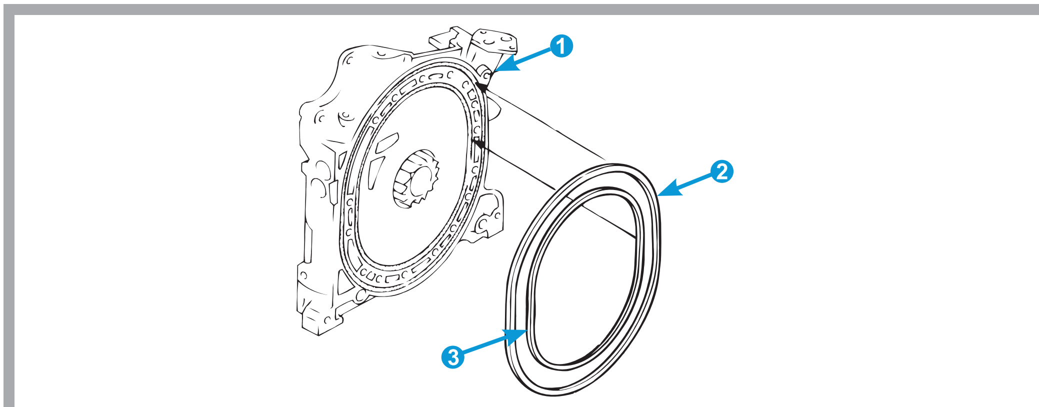


FIGURE 2-12.
Sealing rubber parts keep gas or coolant from leaking from the rotor housing.

1. Side housing
2. Outer sealing rubber
3. Inner sealing rubber

Side housings are usually made of cast iron, but may also be made of aluminum alloy. The interiors of the side housings are hollow, providing a coolant passage. The housings have a ribbed structure to increase rigidity and improve cooling.

The intermediate housing has a lubricating oil passage at its center so that the oil used to cool the rotor's interior can be returned to the oil pan. There may also be a passage for EGR (exhaust gas return) gases and secondary air that is used to burn the exhaust gas for cleaner emissions.

Stationary Gear

Two stationary gears, front and rear, are secured to the front and rear side housings. The stationary gears, along with the main bearings inside the gears, support the eccentric shaft as it turns. Figure 2-13 shows the stationary gear and main bearing.

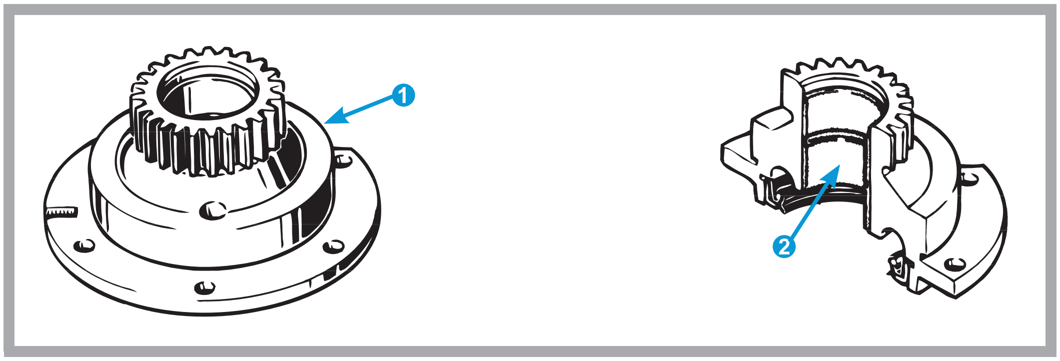


FIGURE 2-13.
The stationar gear supports the eccentric shaft.

1 Stationar gear

2 Main bearing

The stationary gears mesh with the rotor's internal gear, guiding the rotor through its rotation inside the rotor housing. The stationary gear is made of special alloy steel for durability. It is unified with the main bearing and then pressed and bolted into the front and rear side housing.

Eccentric Shaft

The eccentric shaft is the output shaft of the rotary engine, similar to the crankshaft in a piston engine. The eccentric shaft, shown in Figure 2-14, is made of highly durable, forged carbon steel.

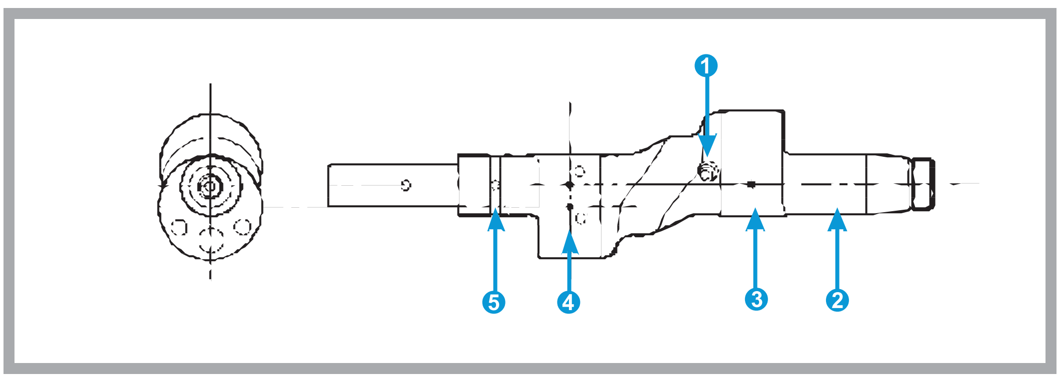


FIGURE 2-14.
The eccentric shaft is the engine s output shaft.

1 Oil discharge port

2 Rear main journal

3 Rear rotor journal

4 Front rotor journal

5 Front main journal

The *rotor journal* (corresponding to a crankshaft pin) supports the rotor. At both ends of the shaft are front and rear *main rotor journals* that support the main bearings.

The center of the eccentric shaft is hollow and contains an oil passage to lubricate the rotor bearing and cool the rotor. The oil passage runs from the front end of the eccentric shaft to the rear main journal. Oil jets spray oil directly into the rotor's hollow inner chamber. Figure 2-15 shows the oil passage and oil jet nozzle.

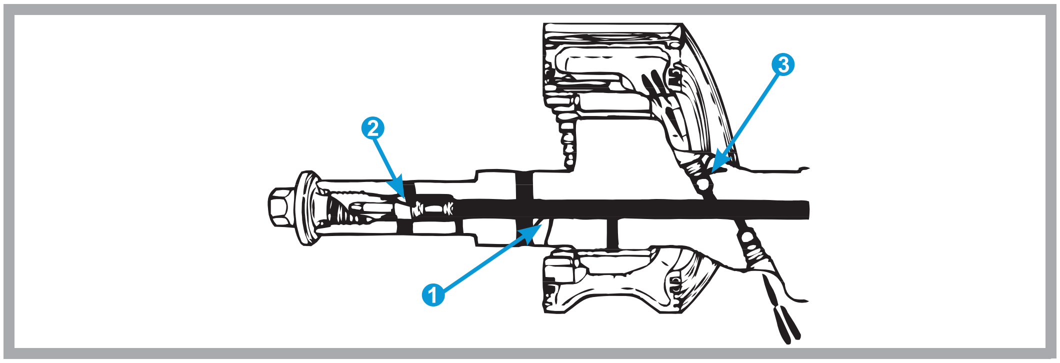


FIGURE 2-15.
An oil passage runs the length of the eccentric shaft.

1. Oil passage
2. Eccentric shaft b pass valve
3. Oil jet plug

The front end of the eccentric shaft has components such as a *balance weight*, a gear for an auxiliary drive, an oil pump, and a V-belt pulley (used to power the oil pump, generator, and A/C). These components vary, depending on engine type.

At the rear of the eccentric shaft is a *flywheel*, a heavy round plate that turns with the shaft. The weight of the flywheel keeps the eccentric shaft turning smoothly even though power is supplied only during the engine's power (combustion) stroke. Figure 2-16 shows the position of the flywheel and *balance weight* on the eccentric shaft.

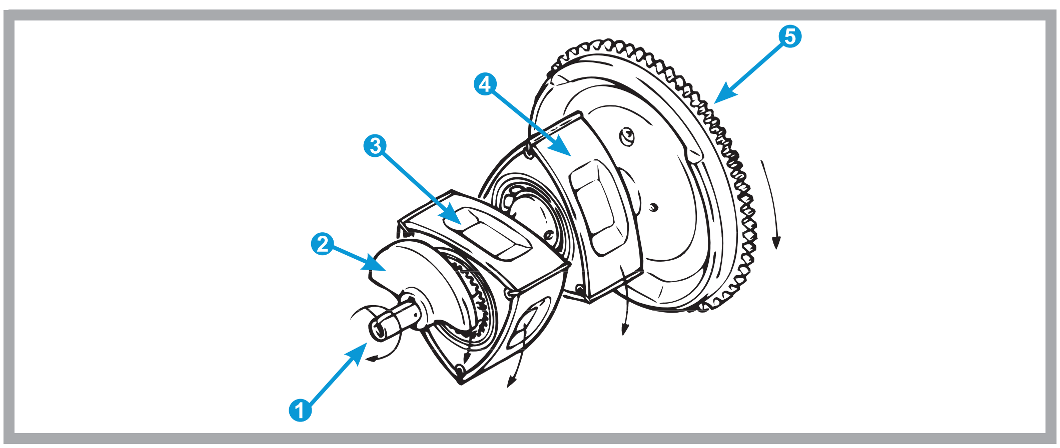


FIGURE 2-16.
The fl heel keeps the eccentric shaft turning smoothl .

1. Eccentric shaft
2. Balance eight
3. Front rotor
4. Rear rotor
5. Fl heel

The flywheel stores energy generated by the engine for a smooth transfer of power. The balance weight helps counterbalance the weight of the flywheel for smoother operation.

REVIEW EXERCISE 1

Fill in the words that correctly complete these sentences. Check your answers with the answer key on page 22.

1. In a rotary engine, the __________ performs the functions of the pistons, connecting rods, and valves in a piston engine.

2. The front and rear rotors are connected by a/an ________________ ____________.

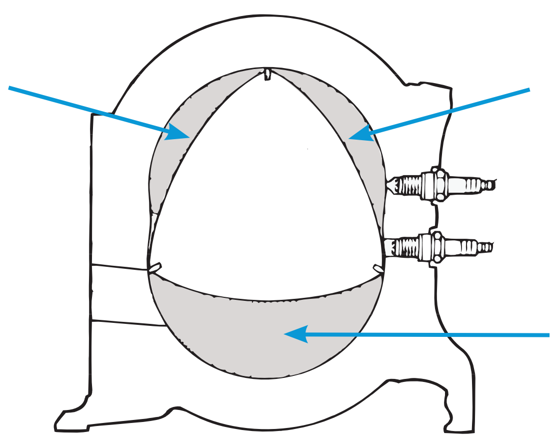
3. The rotor's internal gear meshes with the ______________ ________, guiding the rotor through its rotation inside the rotor housing.

4. To maintain the airtightness of the engine's working chambers, three sets of ________ _________ are installed in the rotor.

5. The eccentric shaft contains a/an ________ _______ _______, used to lubricate the interior of the rotor.

Refer to the following illustration to answer question 6.

6. The spaces marked by arrows around this rotor are called ________________ ________________.



While rotary engines develop power much like piston engines, they use different components to produce energy from burning fuel. This section describes the rotary engine’s main advantages, explains more about their operation, and discusses some of the rotary engine’s basic design characteristics.

OBJECTIVES

After completing this section, you will be able to:

- Describe the benefits of rotary engines
- Define rotary engine design characteristics: process time, displacement, and compression ratio

BENEFITS OF ROTARY ENGINES

Compact and High Output

Compared to piston engines, rotary engines are usually smaller, and produce more power for their size. A two-rotor rotary engine is only about two-thirds the size of a six-cylinder piston engine. Figure 3-1 shows the relative sizes of a six-cylinder piston engine, a four-cylinder piston engine, and a two-rotor rotary engine.

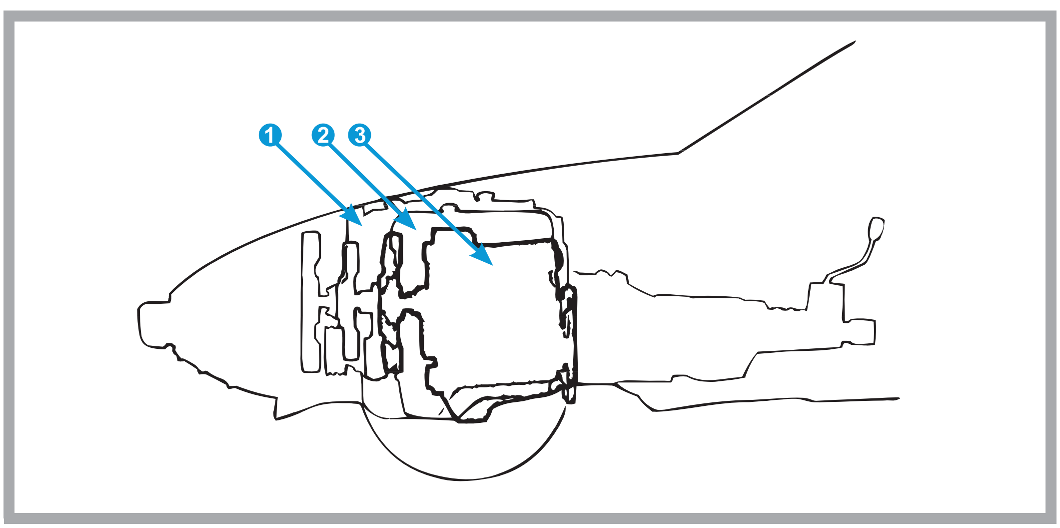


FIGURE 3-1.
The rotar engine is compact compared to a piston engine, but produces high po er output for its si e.

1 Si -c linder piston engine

2 Four-c linder piston engine

3 T o-rotor rotar engine

Ans ers to
Revie E ercise 1

1. rotor
2. eccentric shaft
3. stationar gear
4. gas seals
5. oil jet plug
6. orking chambers

Low Vibration and Noise Levels

In any engine, the forces generated by moving parts must be balanced so the engine can run smoothly at high rpm (revolutions per minute). In a piston engine, the alternating up-and-down motion of the pistons, valves, and connecting rods is difficult to balance.

In a rotary engine however, the rotor, eccentric shaft, flywheel, and other parts always rotate in the same direction (Figure 3-2), making perfect dynamic balance possible. This balance creates less noise and vibration. Also, in a rotary engine there is no opportunity for metal surfaces to strike each other, as they can during the up-and-down motion of the valves and pistons in a piston engine.

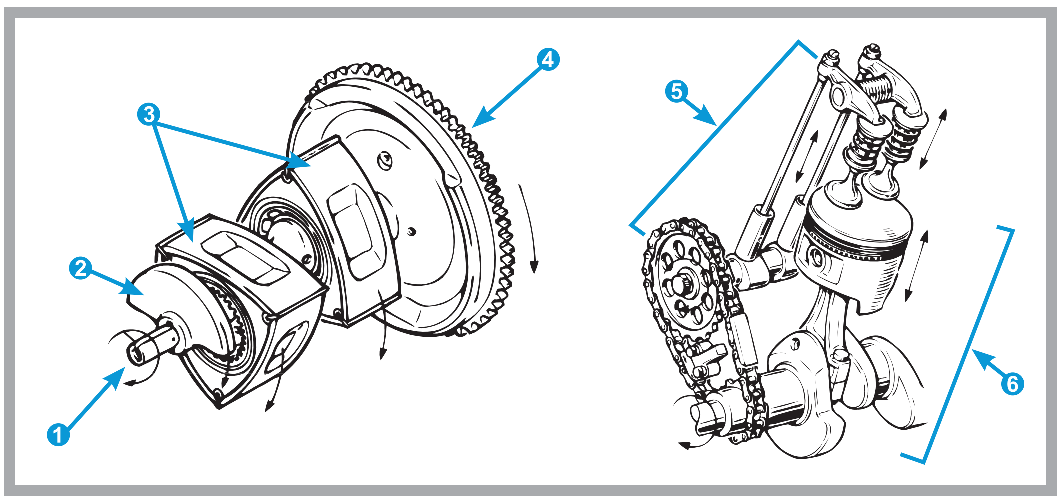


FIGURE 3-2.
All rotar engine parts rotate in the same direction, unlike piston engines.

1. Eccentric shaft
2. Balance eight
3. Rotors
4. Fl heel
5. Valve mechanism
6. Crank mechanism

Flat Torque Characteristics

A piston engine produces power only during the power stroke of the four-stroke cycle. The other three strokes — intake, compression, and exhaust — generate no power. In the interval between the end of one power stroke and the beginning of the next, the rotation of the crankshaft is momentarily interrupted, causing a change in force. This is called *torque fluctuation*. If torque fluctuation is great enough, it can cause engine vibration.

Because a rotary engine has three power strokes for each rotation of the rotor, the interval between power strokes is shorter. This reduces torque fluctuation and engine vibration.

Fewer Component Parts

The rotor in a rotary engine performs all the functions of the pistons, connecting rods, and valves in a piston engine. A rotary engine has no valves or valve-related components, so it has many fewer parts than a piston engine. In fact, a typical two-rotor rotary engine contains fewer than half the parts of a six-cylinder piston engine.

DESIGN CHARACTERISTICS

Process Time

Process time is the time it takes an engine to complete one of the four strokes of the combustion cycle: intake, compression, power, or exhaust. Process time is measured by the number of degrees that the crankshaft or eccentric shaft rotates during the stroke.

In a piston engine, the crankshaft must rotate twice to produce one power stroke. Remember, the intake, compression, and exhaust strokes do not produce any power; in fact, they use energy.

In a rotary engine, the four strokes are repeated in each of the three working chambers, so there are actually three power strokes during each complete rotation of the rotor. This means the eccentric shaft rotates three times for each complete rotation of the rotor.

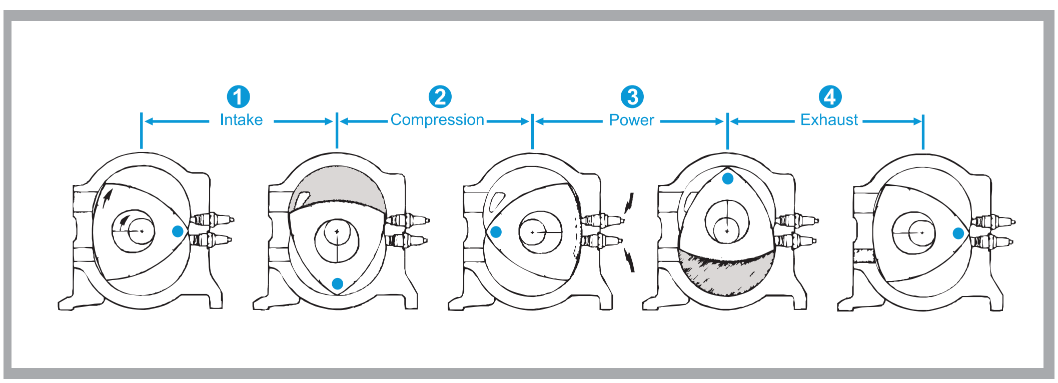


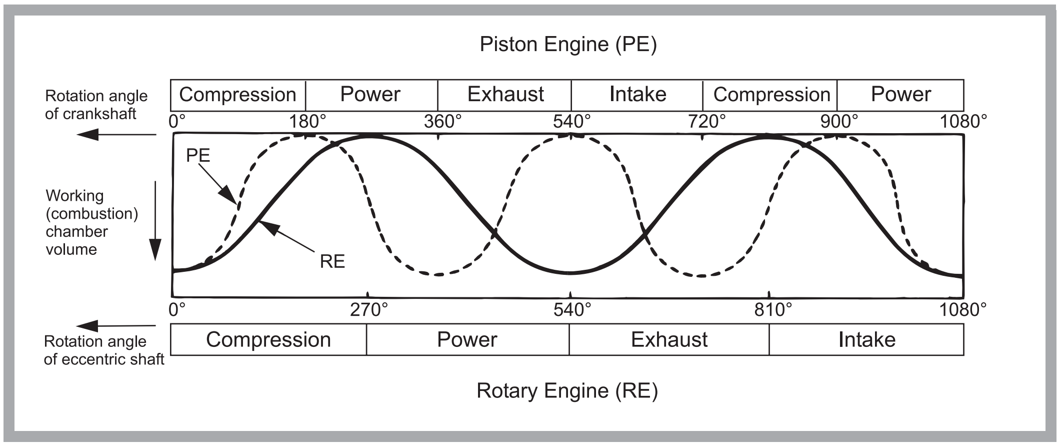
FIGURE 3-3.
A rotar engine produces three po er strokes for each full rotation of the rotor.

1 Intake
2 Compression
3 Po er (combustion)
4 E haust

In a rotary engine, the eccentric shaft rotates three times for each full rotation of the rotor (3 x 360° = 1080°). Because four strokes occur during the rotor's rotation, the process time for each stroke is 270° (1080° ÷ 4 = 270°).

In a piston engine, the crankshaft turns one half of a rotation during each stroke, so the process time of a piston engine is 180°. The rotary engine's longer 270° process time allows more time for gas exchange (intake and exhaust), producing more torque at high RPM, while reducing overall torque fluctuation, as Figure 3-4 shows.

FIGURE 3-4.
The rotar engine s 270 process time produces more po er at high RPM and reduces torque fluctuation.



Displacement

In a piston engine, the *displacement* of a cylinder is the volume of the cylinder between its top dead center (TDC) and bottom dead center (BDC) positions. Engine displacement is the total displacement of all the cylinders in the engine. Displacement is usually measured in cubic centimeters (cc) or liters (L).

Generally speaking, engine displacement is a rough indicator of power output. For example, a 2000 cc (2.0 L) engine is usually more powerful than a 1500 cc (1.5 L) engine.

Rotary engines measure displacement differently. In a rotary engine, each rotor has three working chambers. To calculate displacement, you must first know the volume of a single working chamber.

To calculate single chamber volume, measure the maximum volume (intake BDC) of one working chamber and then subtract the chamber's minimum volume (power TDC), as shown in Figure 3-5. This gives you the volume of a single working chamber.

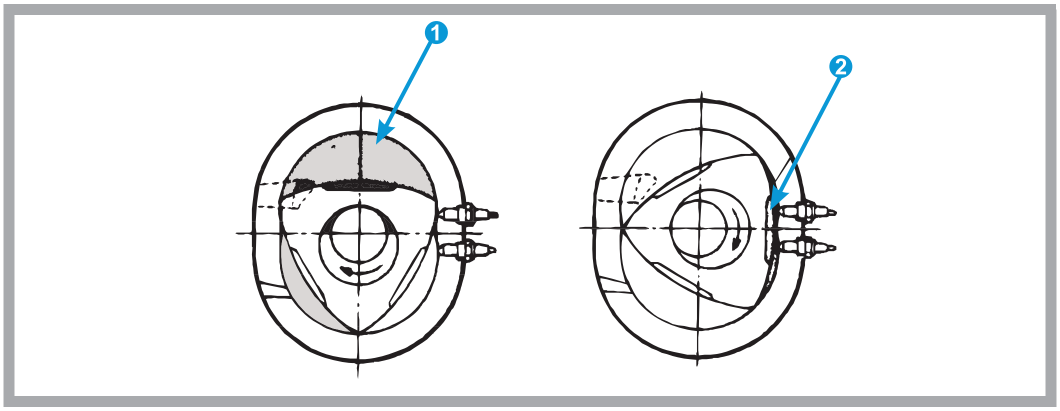


FIGURE 3-5.
To calculate engine displacement, first determine the volume of a single orking chamber.

1. Ma imum volume (Vma / intake BDC)
2. Minimum volume (Vmin / po er TDC)

The working chamber's maximum volume is called *Vmax*. Its minimum volume is called *Vmin*. To calculate the single chamber volume, subtract Vmin from Vmax. To calculate total engine displacement, multiply the single chamber volume by the number of rotors in the engine (usually two).

Single chamber volume = Vmax – Vmin

Total engine displacement = Single chamber volume x number or rotors

For example, Mazda's 13B rotary engine has a single chamber volume (Vmax) of 654 cc. Multiply the single chamber volume times the number of rotors and you get a total displacement of 1308 cc (1.3 L). This makes the 13B a 1300 cc, or 1.3 L engine, as shown below.

654 cc x 2 = 1308 cc (1.3 L)

Compression Ratio

Once you know the engine's displacement, you can calculate its *compression ratio*. Compression ratio measures how much the air-fuel mixture is squeezed during the compression stroke.

Usually, a higher compression ratio means greater power output. For example, a compression ratio of 10 to 1 will probably produce more power than a ratio of 9 to 1. However, higher-compression engines may require premium fuel. Most engines have compression ratios of 9.5 to 1 or less so they can run on regular unleaded fuel.

In a rotary engine, the compression ratio is the ratio of Vmax to Vmin. To calculate compression ratio, divide the single chamber Vmax by its Vmin.

For example, if an engine's single chamber Vmax is 575 cc and the Vmin is 62 cc, the compression ratio would be 9.27 to 1, as the following example shows.

$$575 \text{ cc} \div 62 \text{ cc} = 9.27:1$$

REVIEW EXERCISE 2

Fill in the words that correctly complete these sentences. Check your answers with the answer key on page 28.

1. One reason rotary engines produce more power for their size is that the eccentric shaft rotates __________ times for each complete rotation of the rotor.

2. If the time from the end of one power stroke to the beginning of the next is too long, the rotation applied to the shaft will be interrupted, causing ________________ __________________.

3. The time it takes an engine to complete one of the four strokes of the combustion cycle is called the engine's ______________ __________ cycle.

4. In a rotary engine, the single chamber volume times the number of rotors is called the engine's ___________________.

5. The ____________________ ____________ of an engine measures how much the air-fuel mixture is squeezed before being ignited.

4 - ROTARY ENGINE CONTROLS

Sections 2 and 3 introduced the basic components of a rotary engine and described how they produce power from burning fuel. A rotary engine also uses several other systems to control engine performance and ensure peak efficiency. This section describes the major control systems of a rotary engine.

OBJECTIVES

After completing this section, you will be able to describe major rotary engine control systems, including:

- Ignition
- Intake
- Fuel Injection
- Cooling
- Secondary air
- Lubrication

ROTARY ENGINE CONTROL SYSTEMS

Ignition System

Each side of a three-sided rotor has a combustion recess (sometimes called a *bathtub*) where the spark plugs ignite the air-fuel mixture during the engine's power stroke. This combustion recess is longer and narrower than the combustion chamber in the cylinder of a piston engine.

Because this recess is so long, a rotary engine uses two spark plugs for each rotor to make sure the air-fuel mixture ignites efficiently and burns completely. This dual-plug system provides excellent combustion under a wide range of driving conditions.

4 - ROTARY ENGINE CONTROLS

Ans ers to Revie E ercise 2

1. three
2. torque fluctuation
3. process time
4. displacement
5. compression ratio

In a rotary engine, the working chambers constantly move in the direction of rotor rotation. The side of the combustion recess that reaches the plugs first is called the *leading side*. The side that reaches the plugs last is called the *trailing side*.

Because of their position in the rotor housing, the spark plugs are also called leading and trailing. In a dual-plug system, the trailing spark plug fires first, followed closely by the leading plug.

To avoid contact with the rotor and its apex seal, the tips of the spark plugs are recessed into the rotor housing, as Figure 4-1 shows.

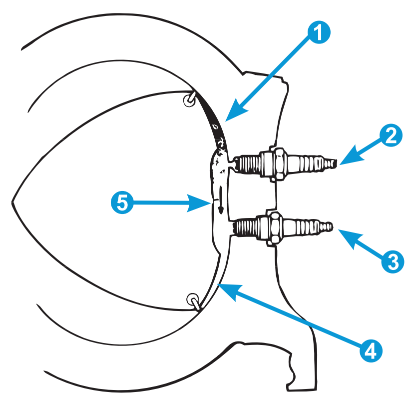


FIGURE 4-1.
A rotar engine uses t o spark plugs per rotor to improve combustion.

1. Trailing side
2. Trailing spark plug
3. Leading spark plug
4. Leading side
5. Gas flo

When the rotor reaches compression top dead center, the pressure at the trailing side of the recess is higher than the leading side. This forces the compressed air-fuel mixture into the leading side of the recess, and the trailing plug fires. This process enhances combustion efficiency.

When the rotor's apex seal passes by the trailing spark plug hole immediately after ignition, the combustion pressure on the leading side of the recess is much greater than the trailing side. This pressure difference could force exhaust gas to leak past the trailing spark plug hole and flow in the direction of lower pressure, as Figure 4-2 shows. The leaking exhaust gas is called *blowby.*

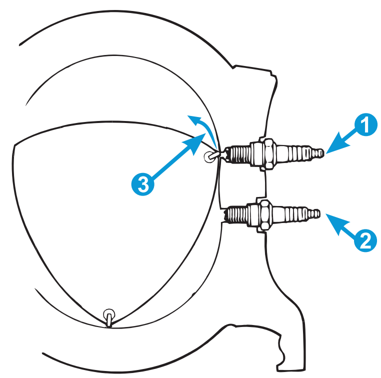


FIGURE 4-2.
The installation hole for the trailing side spark plug is smaller to reduce blo b .

1. Trailing spark plug
2. Leading spark plug
3. Combustion gas (blo b)

To prevent blowby, the trailing spark plug's hole is smaller than the hole for the leading plug. This smaller hole creates a tighter seal, but it can cause plug fouling at lower RPM. However, with modern spark plug technology, the trailing plug cleans itself when the engine runs at higher speeds.

Blowby normally does not occur past the leading spark plug because pressure is balanced in the current and the succeeding working chambers. Figure 4-3 shows the balanced pressure on either side of the leading plug. Since there is little risk of gas leaking past the leading plug, the hole for the leading plug can be larger, resulting in less plug fouling. This design improves engine performance at starting and at low speeds.

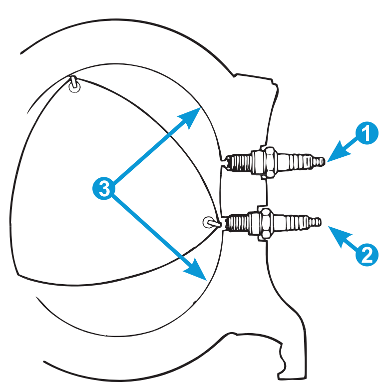


FIGURE 4-3.
Balanced pressure in the chambers on either side of the leading plug means its installation hole can be larger.

1. Trailing spark plug
2. Leading spark plug
3. Balanced pressure

Spark timing is critical to engine performance, so each spark plug (leading and trailing) has its own ignition coil to ensure proper timing. The *PCM* (*Power Train Control Module*) controls each ignition coil separately.

Spark plugs may be either side-electrode type, or ring-electrode type. Trailing and leading spark plugs may be marked *T* or *L* (you can think of T as standing for “top” and L for “lower”). Spark plugs may also be color-coded to mark their proper installation position in the rotor housing.

Intake (Induction) System

Modern piston engines use *fuel injectors* and valves to control the supply of air-fuel mixture to the cylinders. In a rotary engine, fuel injectors supply fuel through a *six-port induction system* to provide the proper air-fuel mixture to the working chambers at any given speed. See “Fuel Injection System” on page 33 for more information about fuel injectors.

Figure 4-4 shows the position of major engine components related to the intake system. In the Figure, “P” indicates primary intake ports, and “S” indicates secondary intake ports.

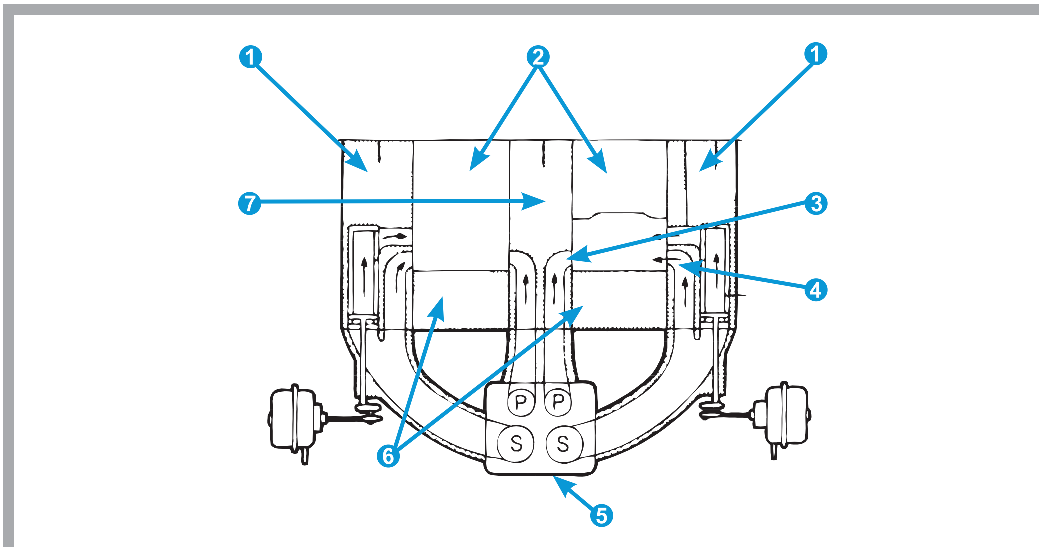


FIGURE 4-4. Primar , secondar , and au iliar ports provide intake air to the engine.

1 Side housing

2 Rotors

3 Primar port

4 Secondar port

5 Intake manifold

6 Rotor housings

7 Intermediate housing

Under low-speed, low-load conditions, the intermediate housing's primary port takes in the air-fuel mixture. During medium-speed, medium-load conditions, the secondary port on the side housing also provides air-fuel mixture. Figure 4-5 shows the location of the intake ports in the side and intermediate housings.

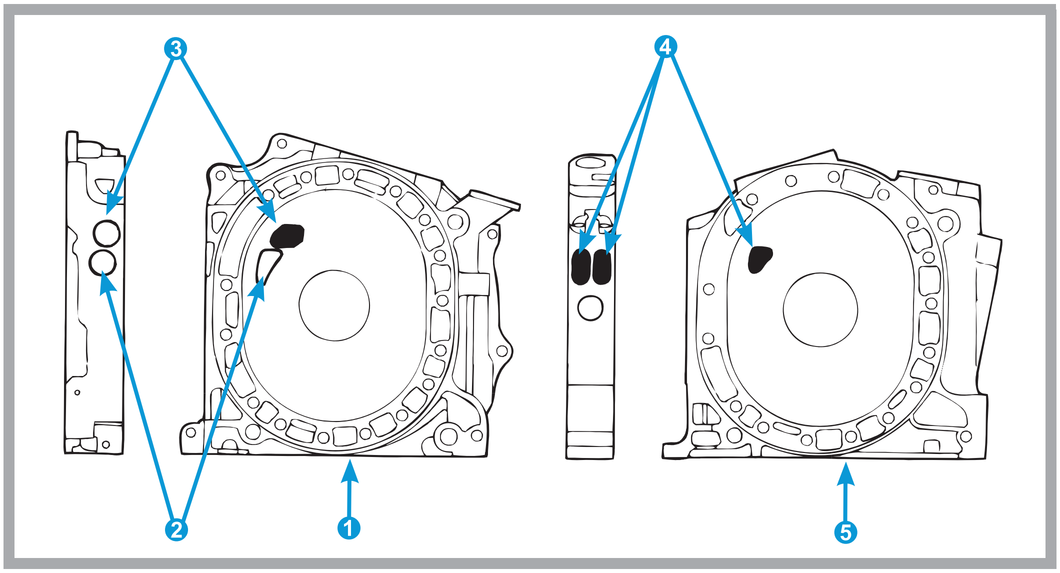


FIGURE 4-5.
Intake ports are located in the intermediate and side housings.

1 Side housing
2 Secondar port
3 Au iliar port
4 Primar ports
5 Intermediate housing

During high-speed, high-load conditions, auxiliary ports in the side housing provide additional air-fuel intake. Valves controlled by *actuators* regulate the opening and closing of the auxiliary ports. Figure 4-6 shows the location of the auxiliary ports, valves, and actuators.

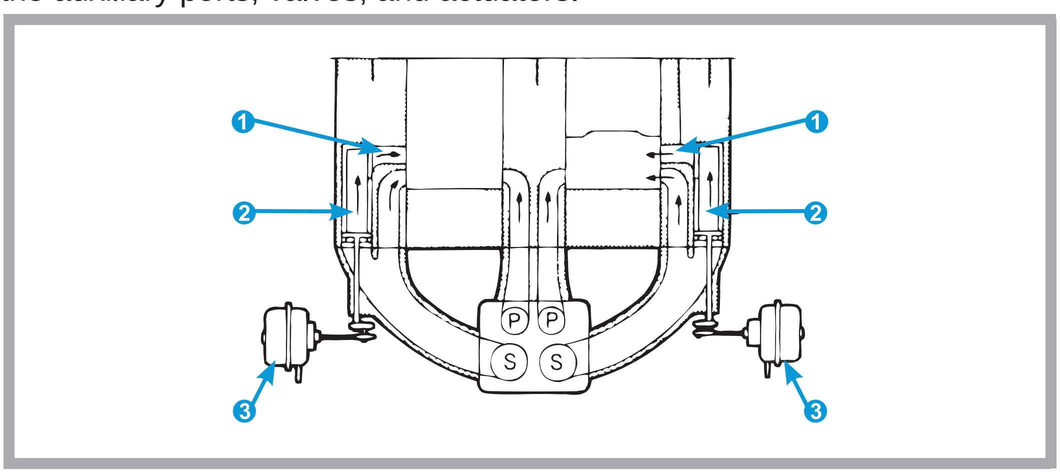


FIGURE 4-6.
Au iliar intake ports activate under high-speed, high-load conditions.

1 Au iliar ports
2 Au iliar port valves
3 Actuators

Most normally aspirated (non-turbo charged) rotary engines use a six-port system, while all rotary turbo engines use a four-port induction system.

Variable Dynamic Effect Intake (VDI) System

To further improve engine performance, some rotary engines use an induction method known as a *Variable Dynamic Effect Intake (VDI) system*. The VDI system includes the VDI valve, a solenoid valve, and an actuator.

The VDI valve is built into the extension manifold. Figure 4-7 shows how the VDI system operates.

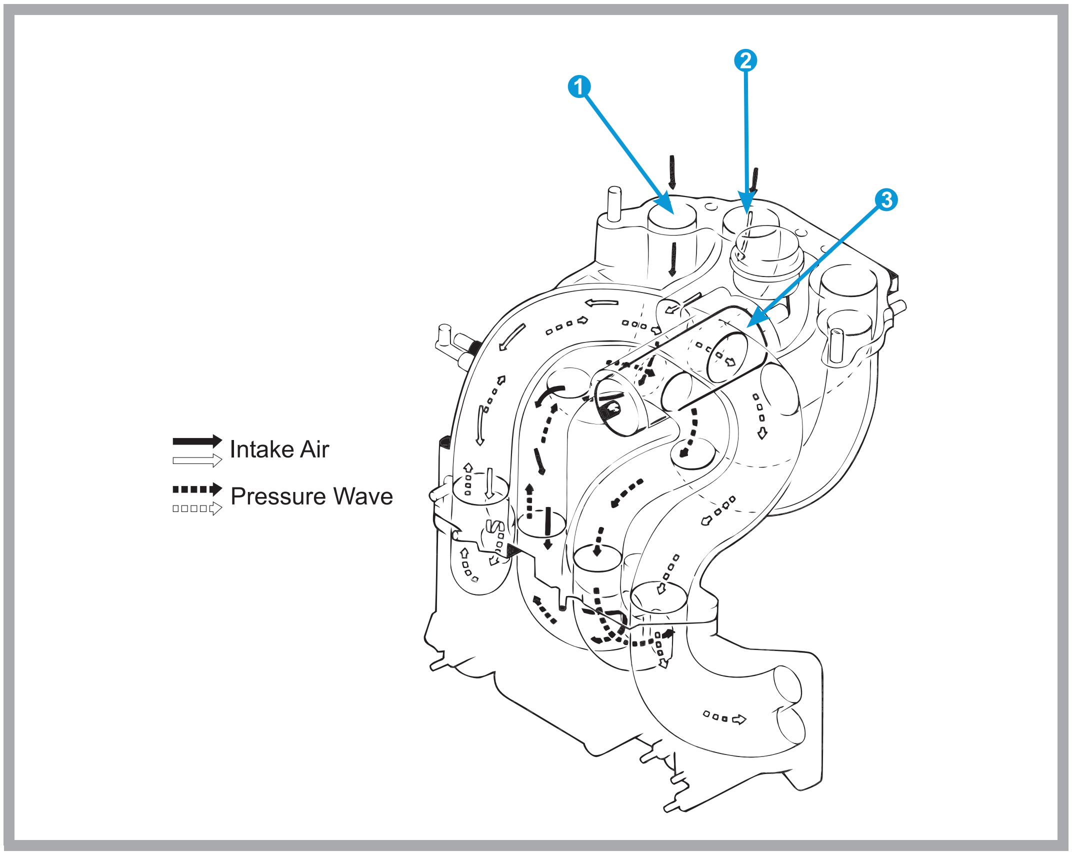


FIGURE 4-7.
At the lo -speed range, the secondar and au iliar ports close, and high-velocit intake air flo s onl from the primar port. This improves fuel atomi ation and combustion efficienc , increasing torque.

1 Intake air

2 Pressure ave

3 VDI valve

When the engine operates, intake air initially flows to a port that is closed by the rotor. This creates a pressure wave that sends the air to the open intake port, compressing it along the way.