NOTES

Technician's Notes

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POWERHEAD

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TEST PROCEDURES

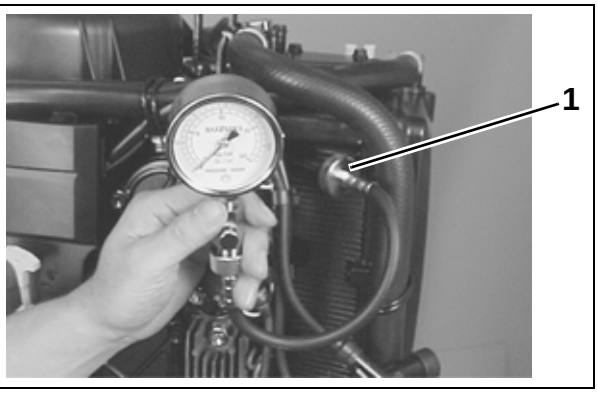
Cylinder Compression Test

Start the engine. Allow the engine to warm up, then shut off the engine.

Remove the engine side covers.

Remove all spark plugs.

Install a compression gauge and adapter into the plug hole.



1. Spark plug hole 001377

REMOTE CONTROL MODELS

Disconnect the throttle cable from the throttle lever. Hold the throttle lever in wide open position.

TILLER HANDLE MODELS

Disconnect the throttle limiter rod from the throttle drum. Hold the throttle control grip in the wide open position.

⚠ WARNING ⚠

Disconnect the safety lanyard from the emergency stop switch prior to cranking the engine. This will prevent any residual fuel from the cylinders from being ignited by a spark from the spark plug cap.

While cranking the engine, note the maximum pressure reading on the gauge for each cylinder.

IMPORTANT: The values that are shown are only guidelines, not absolute service limits.

Cylinder Compression Test	
Standard	145 to 203 psi (1000 to 1400 kPa)
Maximum difference between cylinders	14 psi (100 kPa)

Low compression pressure can indicate one or more of the following:

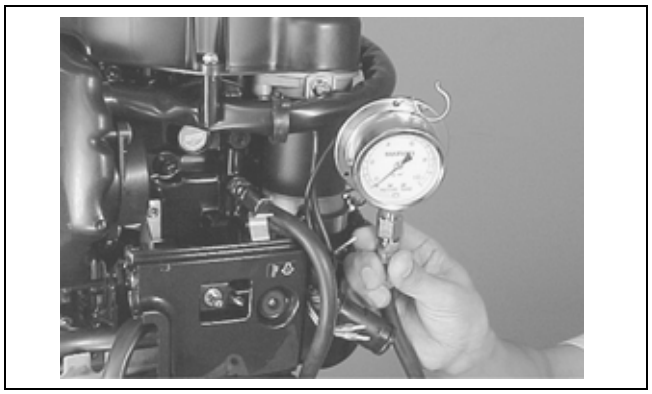
- Excessively worn cylinder wall
- Worn piston
- Worn or stuck piston rings
- Poor seating of valves
- Ruptured or damaged cylinder head gasket

Install all parts that were removed.

Engine Oil Pressure Test

Check the engine oil level.

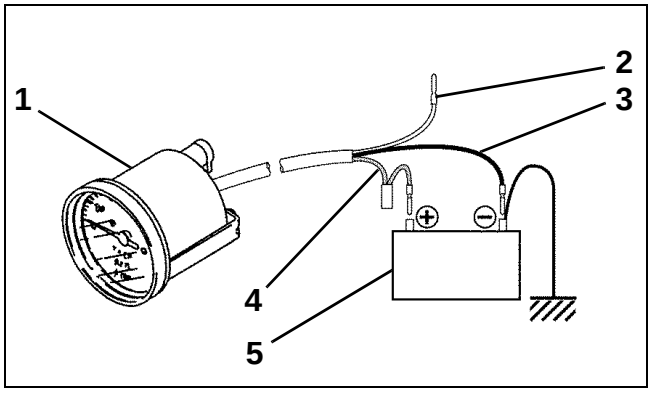
Remove the oil pressure switch. Install an oil pressure gauge and adapter into the oil pressure switch hole.



001376

Connect a tachometer to the engine in the following manner:

- Yellow lead wire to yellow/black lead wire of the power pack
- Gray lead wire to the positive (+) terminal of a 12 V battery
- Black lead wire to the negative (–) terminal of a 12 V battery
- Set the pole selection switch in the tachometer to “12”.



001331

1. *Tachometer*
2. *Yellow lead wire*
3. *Black lead wire*
4. *Gray lead wire*
5. *12 V battery*

Start the engine and warm up engine as follows:

- **Summer:** 5 minutes at 2000 RPM
- **Winter:** 10 minutes at 2000 RPM

After warm-up, shift the engine into forward gear and increase the engine speed to 3000 RPM. The oil pressure at this speed and normal operating temperature should be 58 to 72 psi (400 to 500 kPa).

If the oil pressure is lower or higher than specification, the following causes may be considered:

Low oil pressure

- Clogged oil filter
- Leakage from oil passages
- Defective oil pump
- Defective oil pressure regulator
- Damaged O-ring
- Combination of above items

High oil pressure

- Using an engine oil of too high viscosity
- Clogged oil passage
- Clogged oil pressure regulator
- Combination of above items

After testing, install the oil pressure switch.

REMOVAL AND INSTALLATION

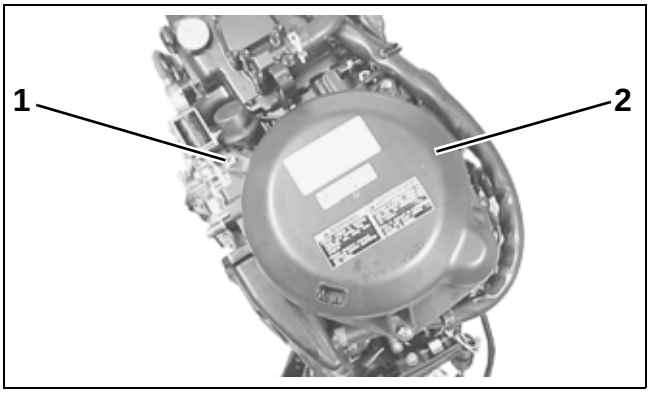
Removal

⚠ WARNING ⚠

To prevent accidental starting while servicing, twist and remove the spark plug leads and disconnect the battery cables at the battery.

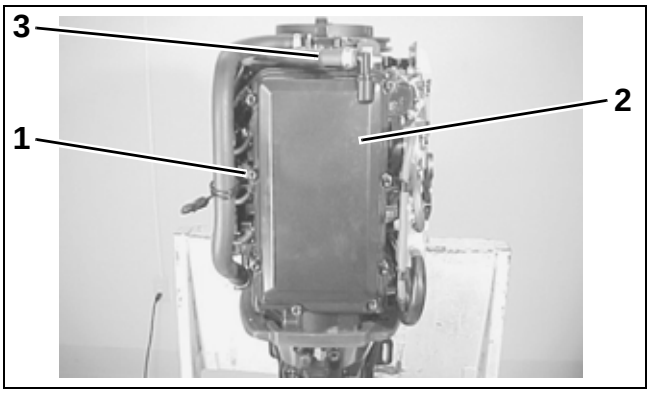
Drain the engine oil and remove the side covers. Refer to the **MAINTENANCE** section for these procedures.

Remove three (3) bolts and the flywheel cover.



1. Bolts (3) 001394
2. Flywheel cover

Remove eight (8) cylinder head cover bolts, then remove the cylinder head cover and the breather hose.

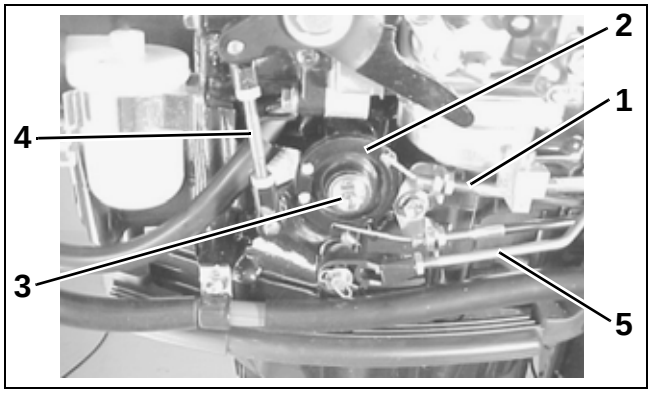


1. Bolts (8) 001395
2. Cylinder head cover
3. Breather hose

TILLER HANDLE MODELS

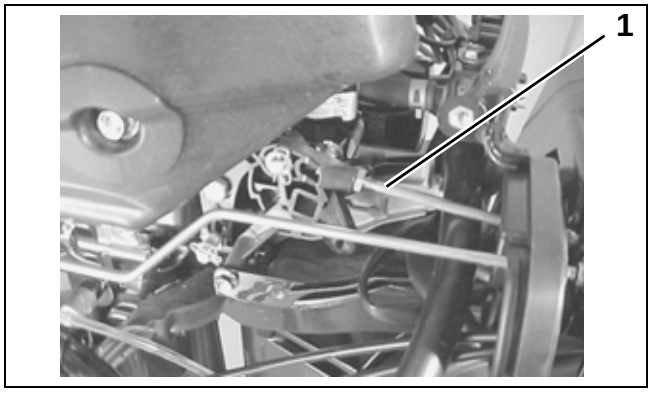
Remove the throttle cables from the throttle drum.

Remove the bolt, the throttle drum, the throttle lever rod, and the throttle limiter rod.



1. Throttle cables 001396
2. Throttle drum
3. Bolt
4. Throttle lever rod
5. Throttle limiter rod

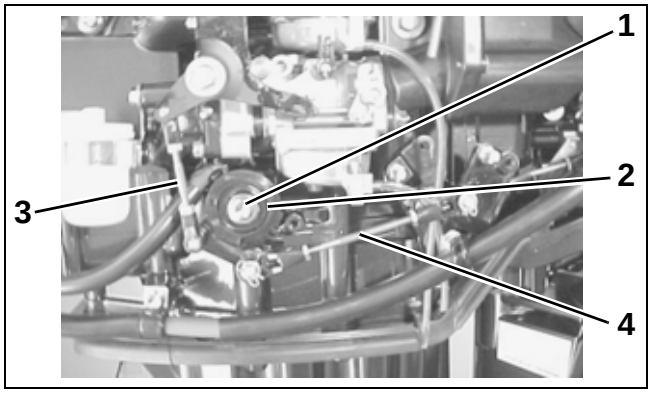
Remove the shift lever link.



1. Shift lever link 001397

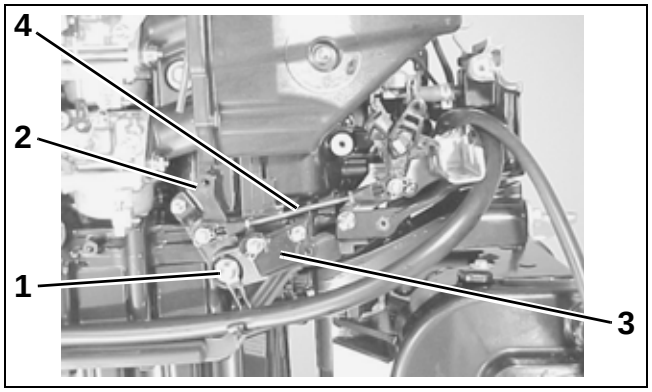
REMOTE CONTROL MODELS

Remove the bolt, the throttle drum, the throttle lever rod, and the throttle control rod.



1. *Bolt* 001398
2. *Throttle drum*
3. *Throttle lever rod*
4. *Throttle control rod*

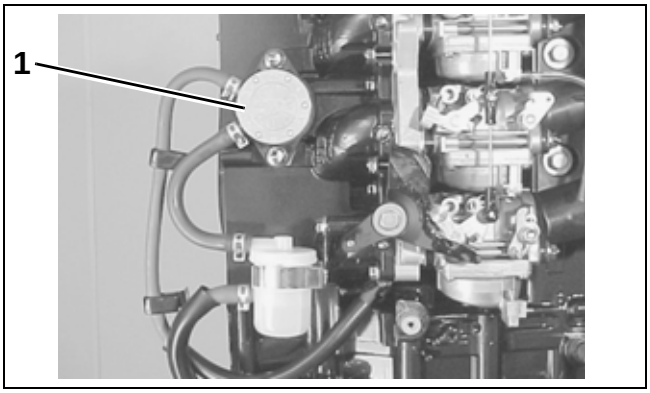
Remove the bolt, the throttle control lever, the throttle lever, and the throttle control rod.



1. *Bolt* 001399
2. *Throttle control lever*
3. *Throttle lever*
4. *Throttle control rod*

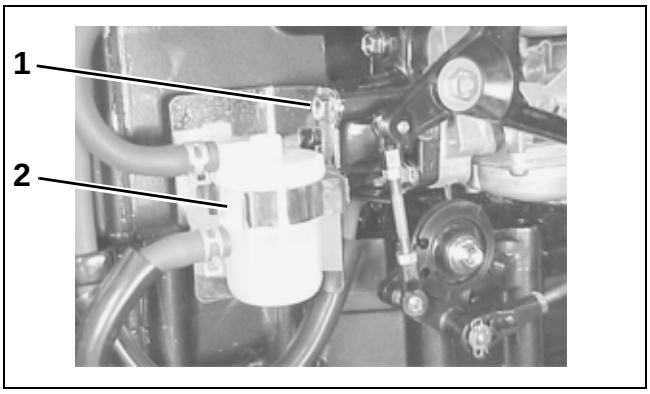
ALL MODELS

Remove the fuel pump. Refer to the **FUEL SYSTEM** section.



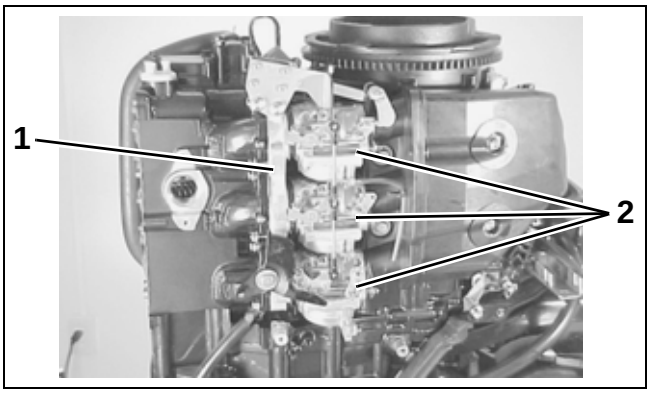
1. *Fuel pump* 001400

Remove the bolt, the fuel filter bracket, and the fuel filter.



1. *Fuel filter bracket bolt* 001612
2. *Fuel filter*

Remove the inlet case and carburetor assembly. Refer to the **FUEL SYSTEM** section.



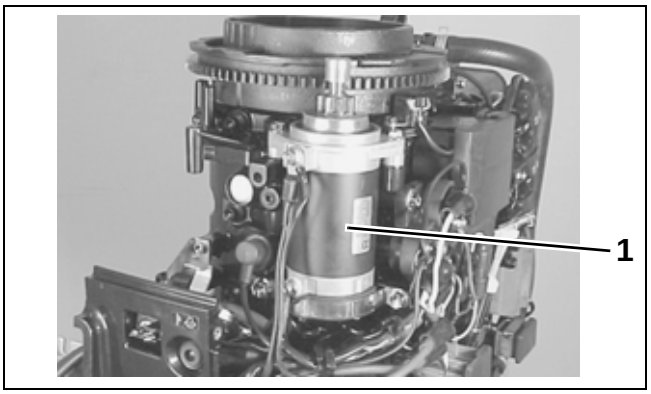
1. *Inlet case* 001402
2. *Carburetors (3)*

REMOTE CONTROL MODELS

Disconnect the choke solenoid lead wire.

ALL MODELS

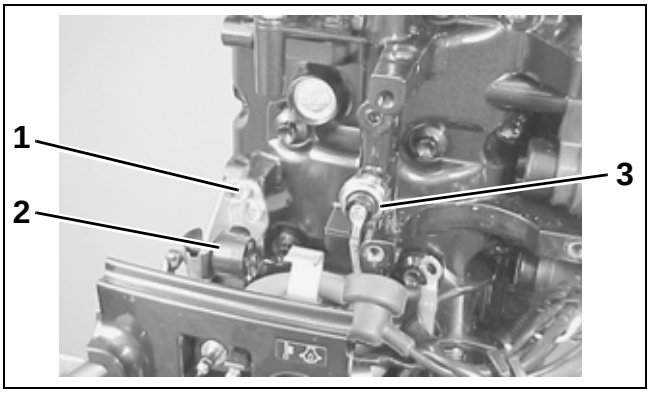
Remove the starter motor. Refer to the **ELECTRICAL** section.



1. Starter motor 001403

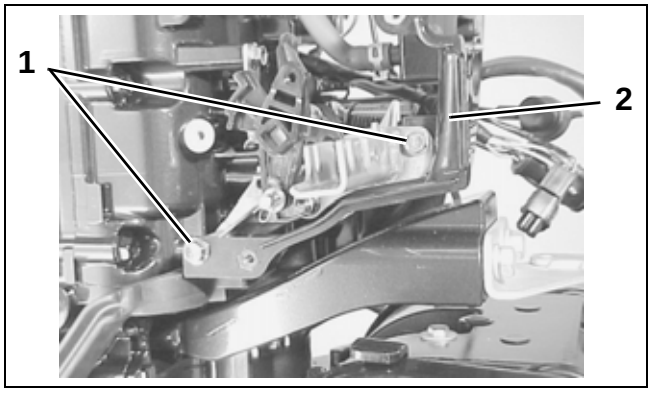
Remove two (2) bolts, the neutral switch, and the switch bracket. Disconnect the neutral switch lead wire.

Loosen the screw and disconnect the oil pressure switch lead wire.



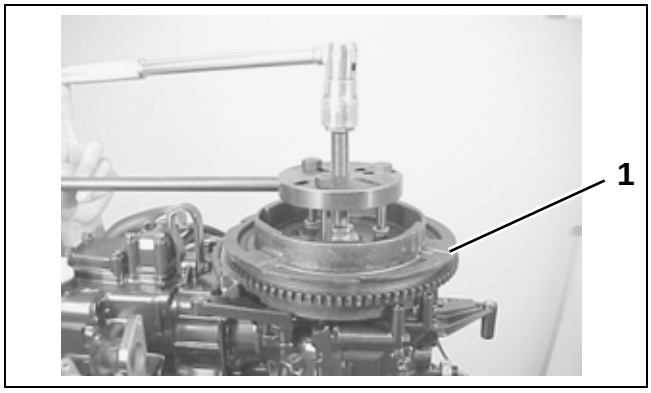
1. Bolts (2) 001404
2. Neutral switch
3. Oil pressure switch

Remove the two (2) bolts that secure the front panel.

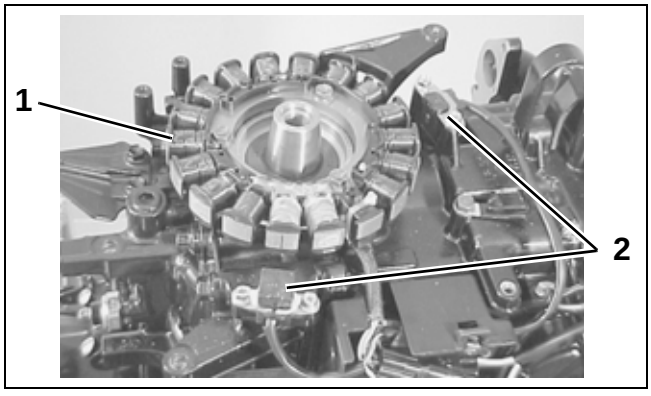


1. Bolts (2) 001405
2. Front panel

Remove the flywheel, the charge coil, and the crankshaft position sensors (CPS). Refer to the **ENGINE CONTROL** section.



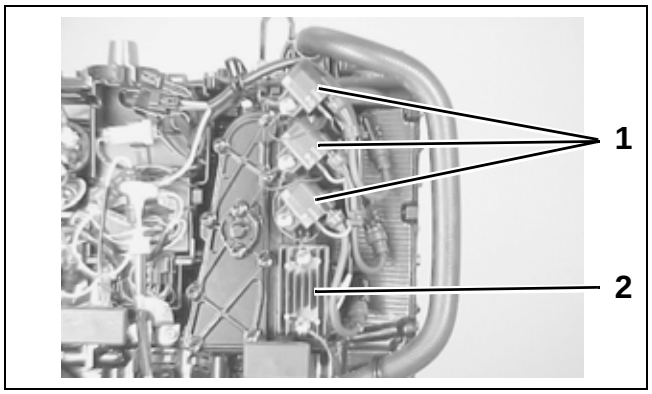
1. Flywheel 001406



1. Battery charge coil 001407
2. Crankshaft position sensors (2)

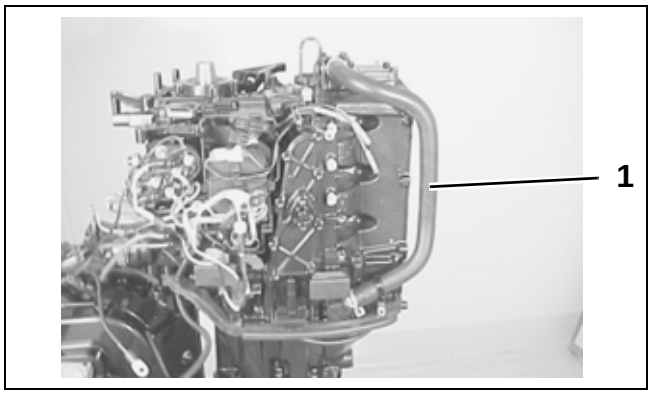
Remove three (3) ignition coils. Disconnect the primary lead wire.

Remove two (2) bolts and the rectifier and regulator.



1. Ignition coils (3) 001408
2. Rectifier and regulator

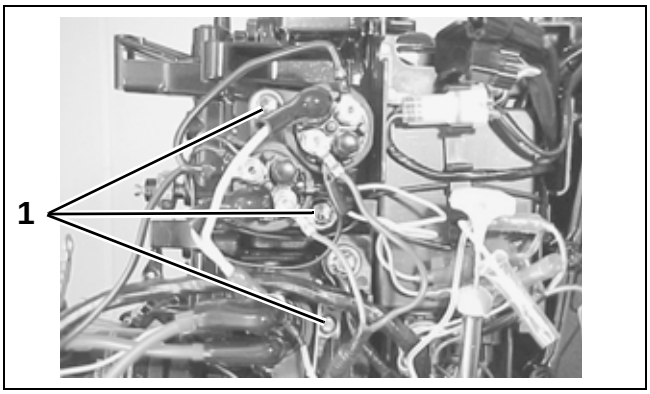
Disconnect the water hose from the thermostat cover and the engine holder.



1. Water hose 001409

Remove three (3) bolts, then the starter motor relay and bracket.

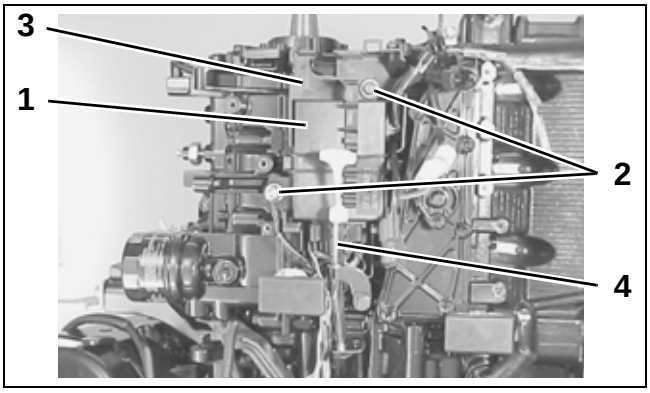
For models with a power trim and tilt (PTT) unit, remove the bolts, then the PTT motor relay and bracket.



1. Bolts (3) 001410

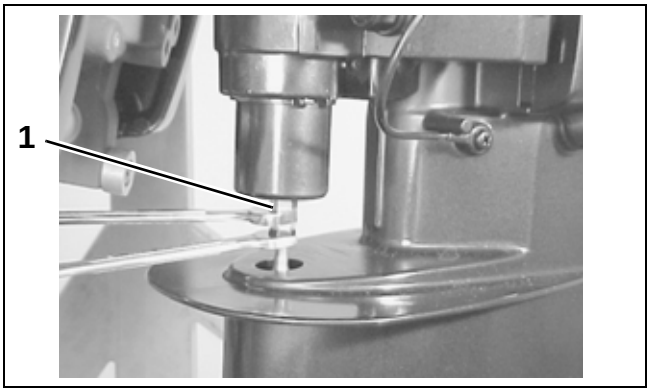
Disconnect all engine wiring harness connectors from the power pack, then remove the power pack.

Remove two (2) bolts and the electric parts holder. Remove the bolt and the oil level dipstick guide.



1. Power pack 001411
2. Bolts (2)
3. Electric parts holder
4. Oil level dipstick guide

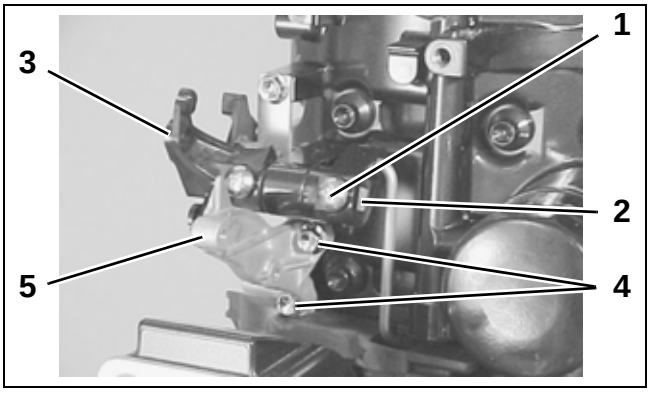
Disconnect the clutch rod from the shift rod by loosening the locknut and the turnbuckle.



1. Locknut 001412

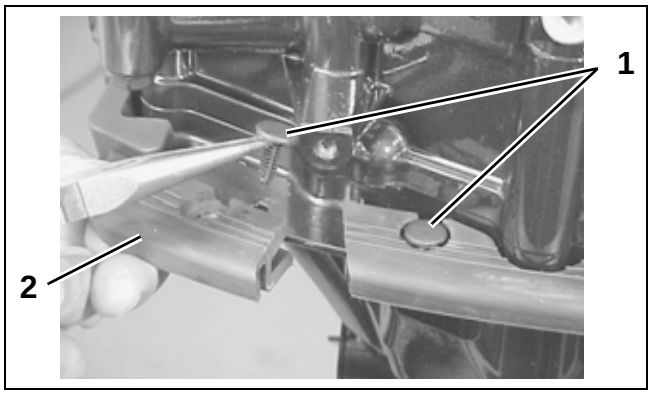
Remove the screw, the shift lever and shaft, and the shift shaft arm.

Remove two (2) bolts and the front panel bracket.



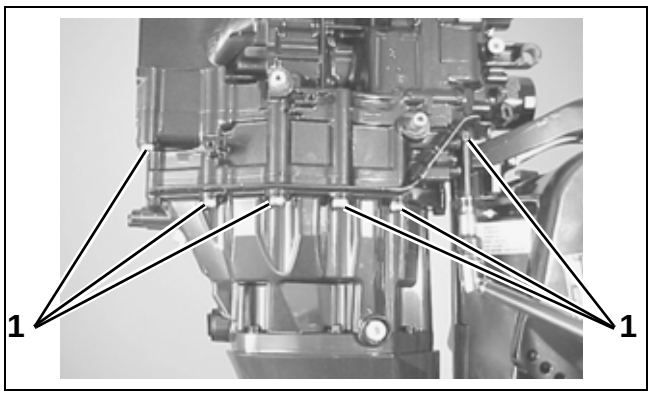
1. Screw 001413
2. Shift shaft arm
3. Shift lever and shaft
4. Bolts (2)
5. Front panel bracket

Remove two (2) pins and the side cover seal.

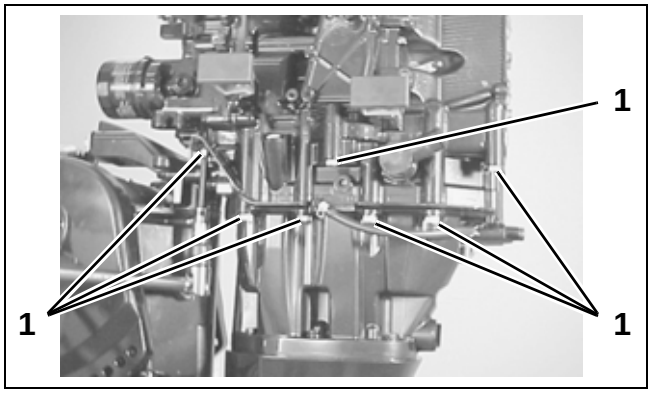


1. Pins (2) 001414
2. Side cover seal

Remove 13 bolts. Lift the powerhead from the engine holder.



1. Bolts (6) – starboard side 001415

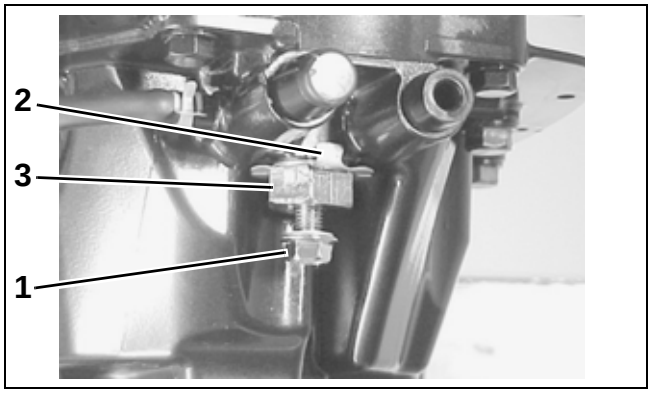


1. Bolts (7) – port side 001416

Installation

Before installing the powerhead, remove the oil pump stop from the oil pan:

- Remove the bolt.
- Use a screwdriver to drive the locking edges of the stop washer upward.
- Remove the oil pump stop, the stop washer, and the gasket from the oil pan.



1. *Bolt* 001417
2. *Stop washer*
3. *Oil pump stop*

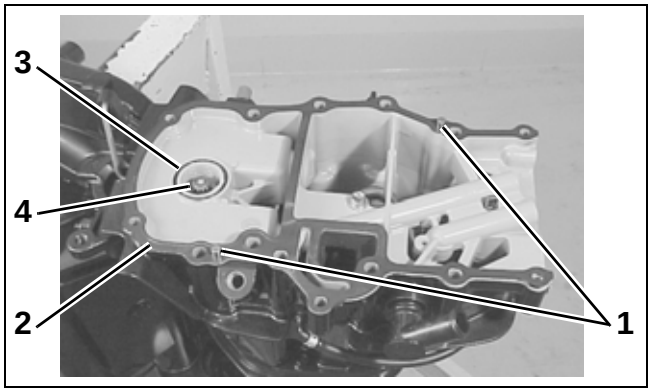
Install two (2) dowel pins and a **new** gasket on the engine holder mating surface.

Install a **new** O-ring around the driveshaft bore.

Apply *Moly Lube* to the driveshaft splines.

Lower the powerhead onto the engine holder.

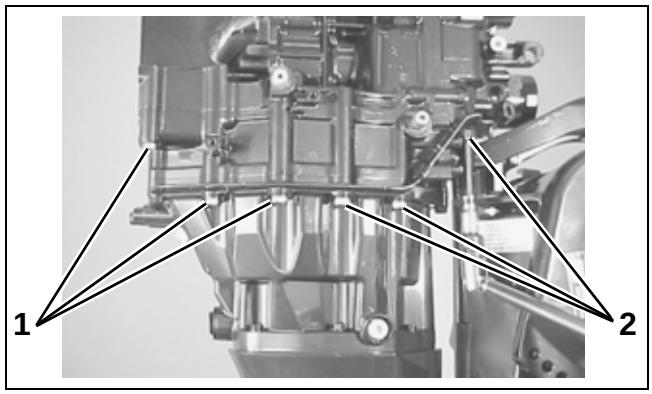
IMPORTANT: Rotate the crankshaft to aid in aligning the driveshaft and crankshaft splines.



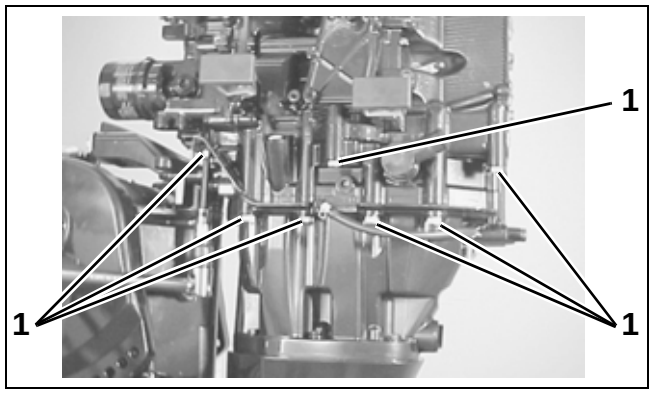
1. *Dowel pins (2)* 001418
2. *Gasket*
3. *O-ring*
4. *Driveshaft*

Apply *Gasket Sealing Compound* to the threads of the powerhead mounting bolts. Install and tighten the bolts to the following specified torques.

Powerhead Mounting Bolt Torques	
8 mm bolt	17 ft. lbs. (23 N·m)
10 mm bolt	37 ft. lbs. (50 N·m)

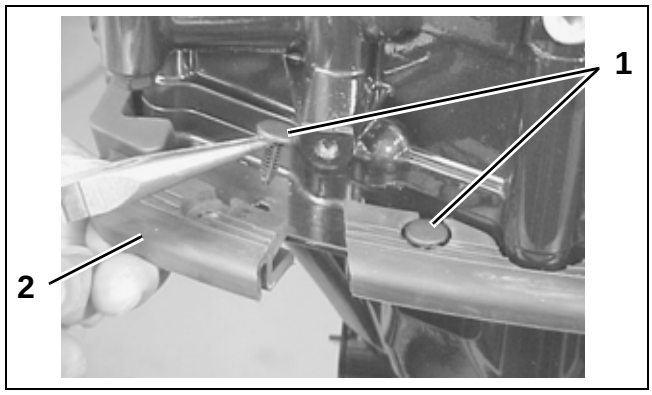


1. *Bolts (6) – starboard side* 001415



1. *Bolts (7) – port side* 001416

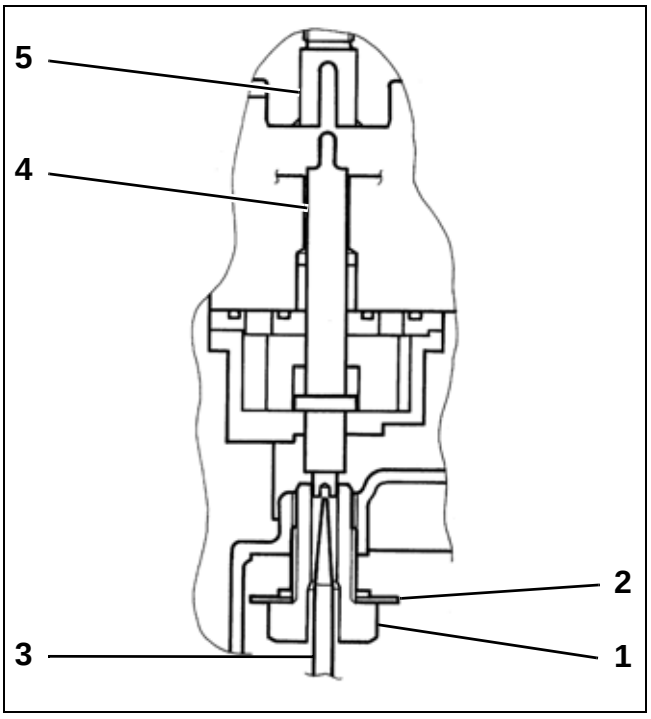
Install the side cover seal and two (2) pins.



1. *Pins (2)* 001414
2. *Side cover seal*

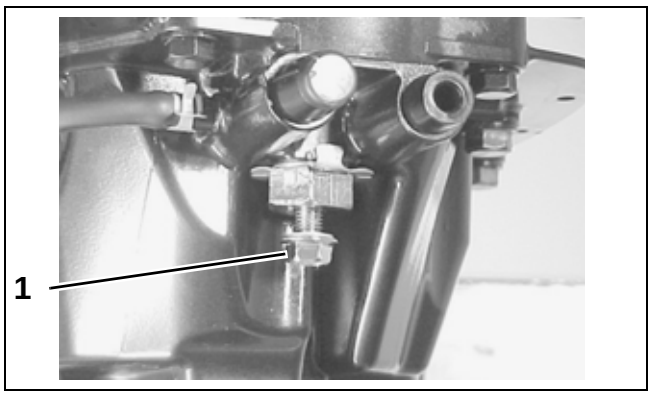
To engage the oil pump shaft, install the oil pump stop in the oil pan:

- Install the stop washer and a **new** stop gasket on the oil pump stop.
- Screw the oil pump stop onto the oil pan (2-3 turns). DO NOT fully tighten the stop.
- To engage the oil pump shaft with the groove in the camshaft, insert and turn a screwdriver as shown.
- While holding the oil pump shaft in place with the screwdriver, tighten the oil pump stop to a torque of 37 ft. lbs. (50 N·m).
- Bend two of the stop washer tabs in opposite directions (one up and one down).



1. *Oil pump stop* 001419
2. *Stop washer*
3. *Screwdriver*
4. *Oil pump shaft*
5. *Camshaft*

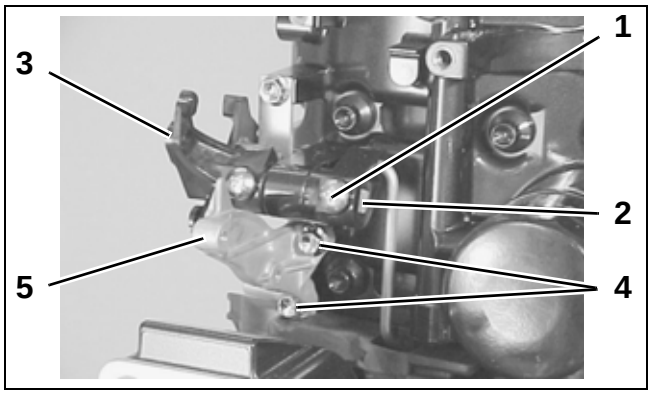
- Install a **new** gasket on the bolt. Install and tighten the bolt to a torque of 17 ft. lbs. (23 N·m).



1. *Bolt* 001417

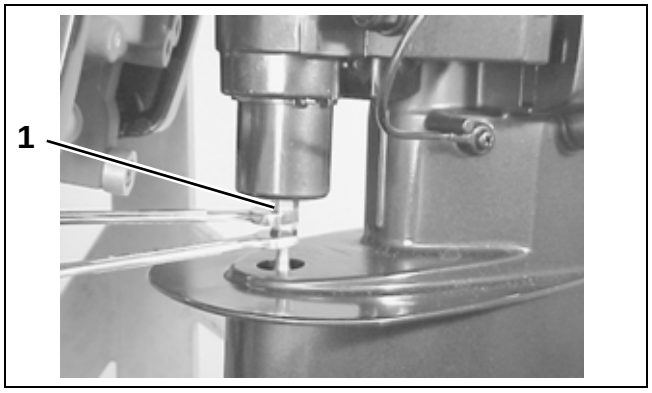
Install the front panel bracket and two (2) bolts.

Install the shift shaft arm, the shift lever and shaft, and the screw.



1. *Screw* 001413
2. *Shift shaft arm*
3. *Shift lever and shaft*
4. *Bolts (2)*
5. *Front panel bracket*

Connect the clutch rod to the shift rod. Tighten the locknut and the turnbuckle.

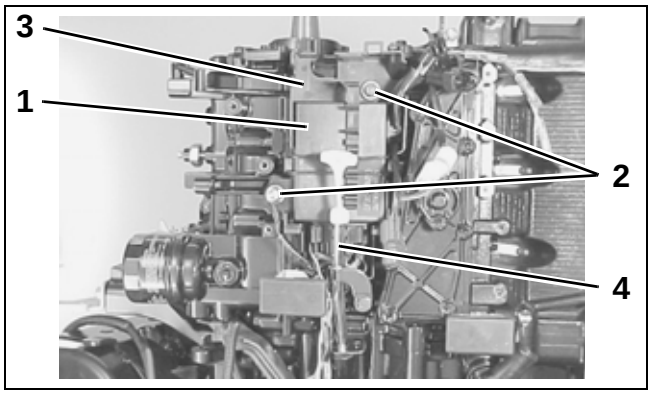


1. Locknut 001412

Install the oil level dipstick guide and the bolt.

Install the electric parts holder and two (2) bolts.

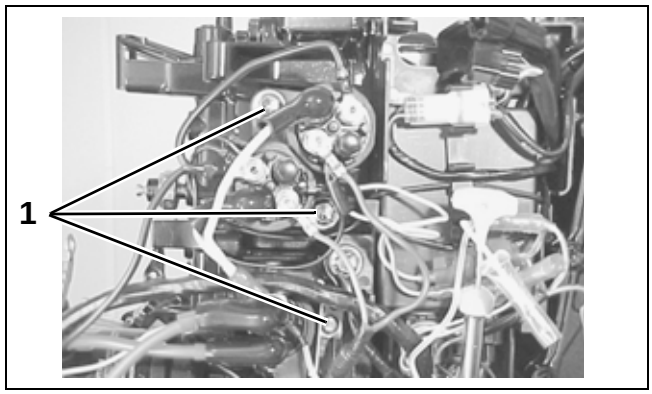
Install the power pack, then connect all engine wiring harness connectors to the power pack.



1. Power pack 001411
2. Bolts (2)
3. Electric parts holder
4. Oil level dipstick guide

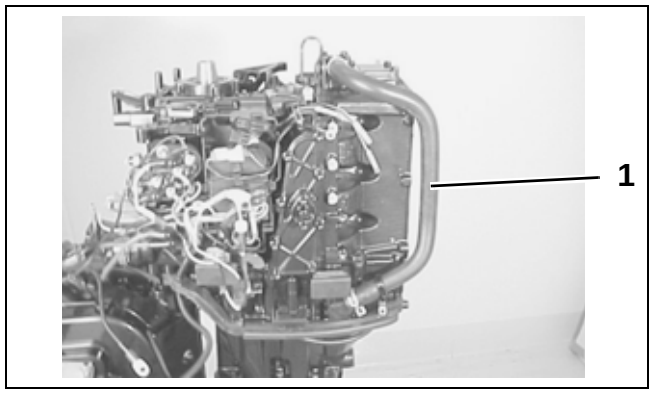
Install the starter motor relay and bracket. Secure the bracket with three (3) bolts.

For models with a power trim and tilt (PTT) unit, install the PTT motor relay and bracket. Secure the bracket with the bolts.



1. Bolts (3) 001410

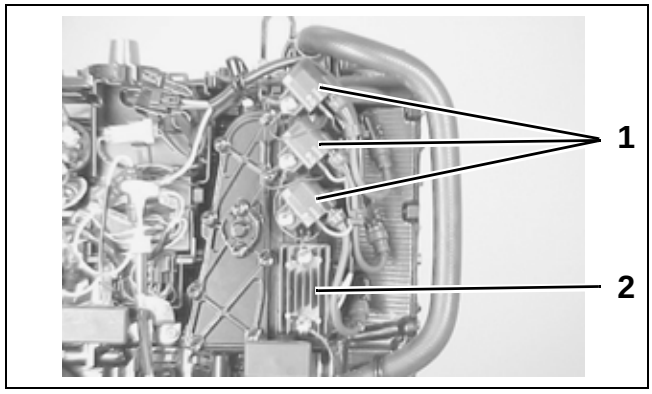
Connect the water hose to the thermostat cover and the engine holder.



1. Water hose 001409

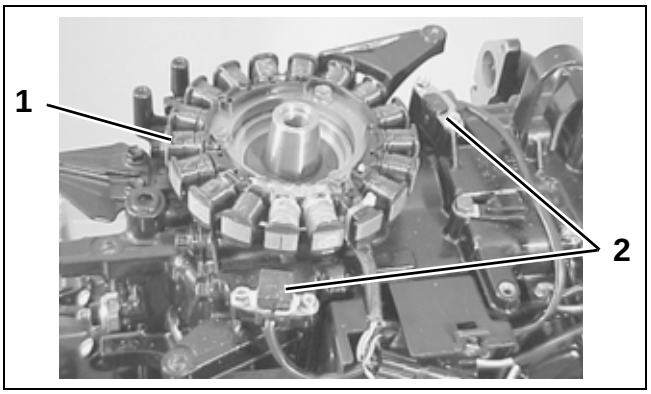
Install the rectifier and regulator and two (2) bolts.

Install three (3) ignition coils. Connect the primary lead wire.

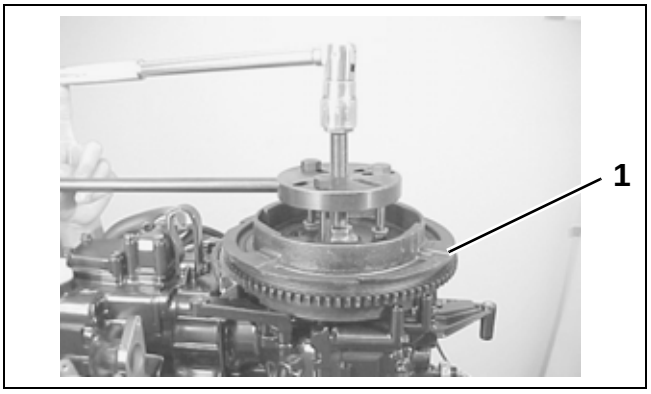


1. Ignition coils (3) 001408
2. Rectifier and regulator

Install the battery charge coil, the crankshaft position sensors, and the flywheel. Refer to the **ENGINE CONTROL** section.

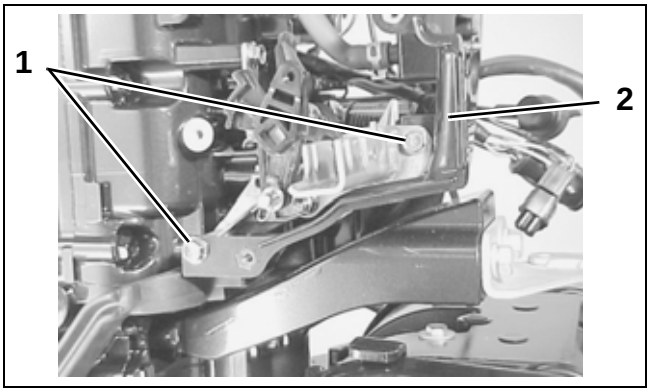


1. *Battery charge coil* 001407
2. *Crankshaft position sensors*



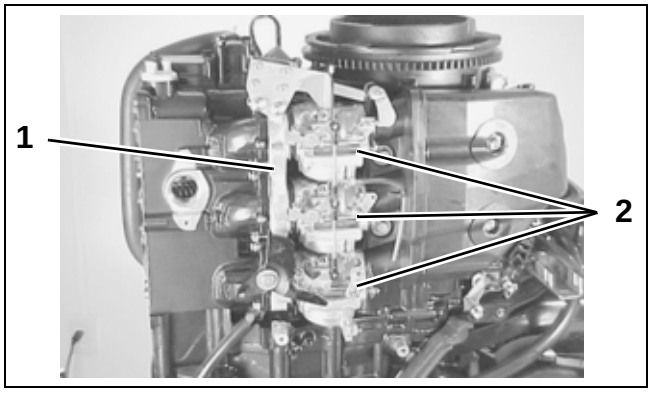
1. *Flywheel* 001406

Install the two (2) bolts that secure the front panel.



1. *Bolts (2)* 001405
2. *Front panel*

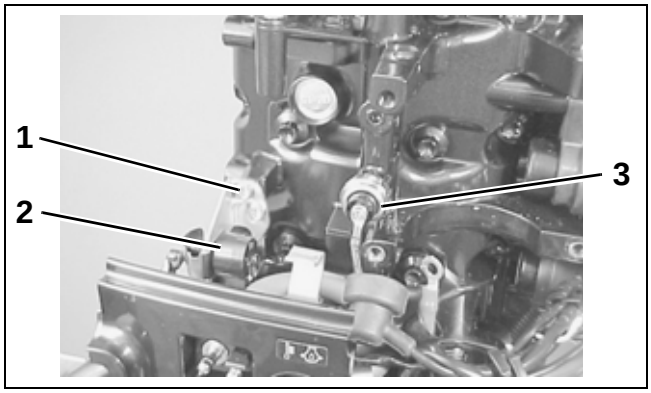
Install the inlet case and carburetor assembly. Refer to the **FUEL SYSTEM** section.



1. *Inlet case* 001402
2. *Carburetor assemblies (3)*

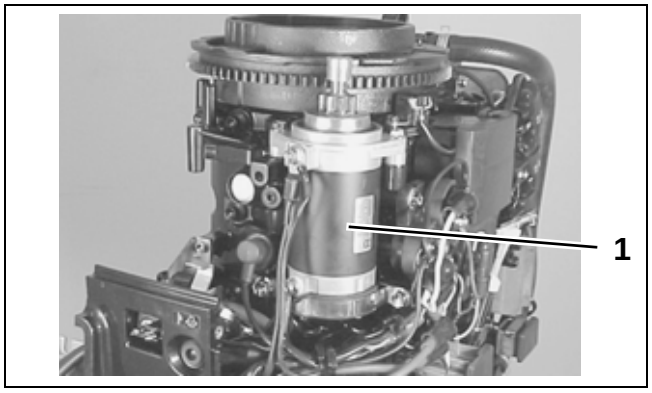
Install the switch bracket, the neutral switch, and the two (2) bolts. Connect the neutral switch lead wire.

Connect the oil pressure switch lead wire. Tighten the screw securely.



1. *Bolt* 001404
2. *Neutral switch*
3. *Oil pressure switch*

Install the starter motor. Refer to the **ELECTRICAL** section.



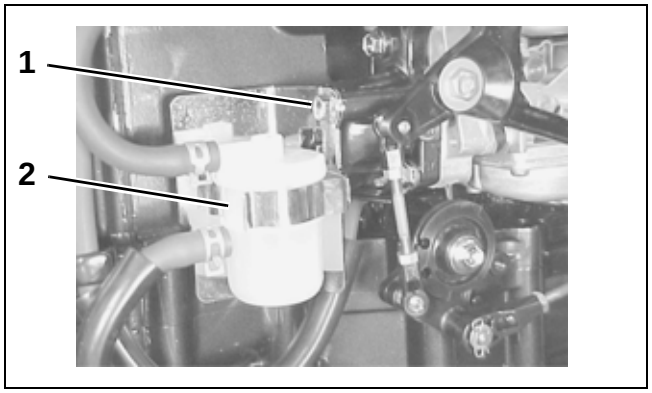
1. Starter motor 001403

REMOTE CONTROL MODELS

Connect the choke solenoid lead wire.

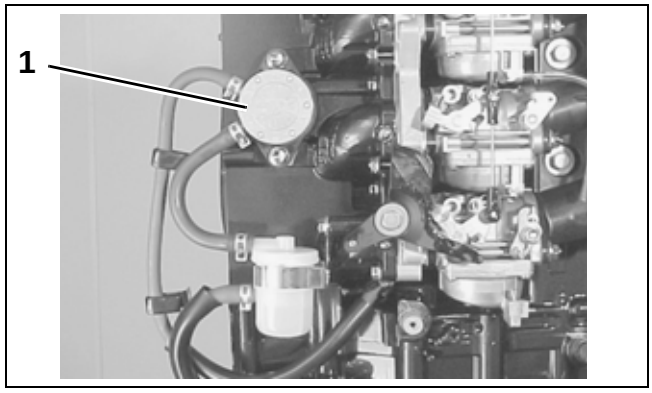
ALL MODELS

Install the fuel filter, the fuel filter bracket, and the bolt.



1. Fuel filter bracket bolt 001612
2. Fuel filter

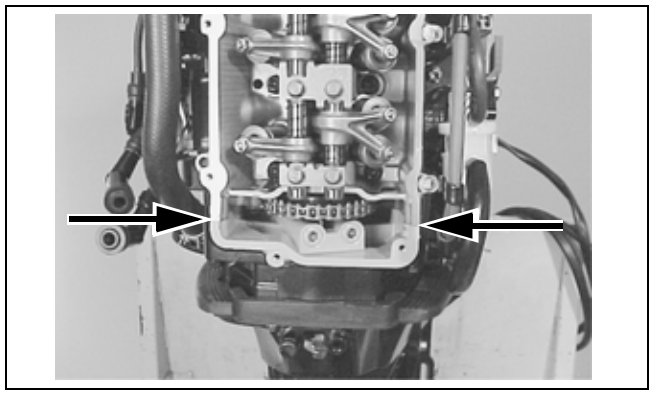
Install the fuel pump. Refer to the **FUEL SYSTEM** section.



1. Fuel pump 001400

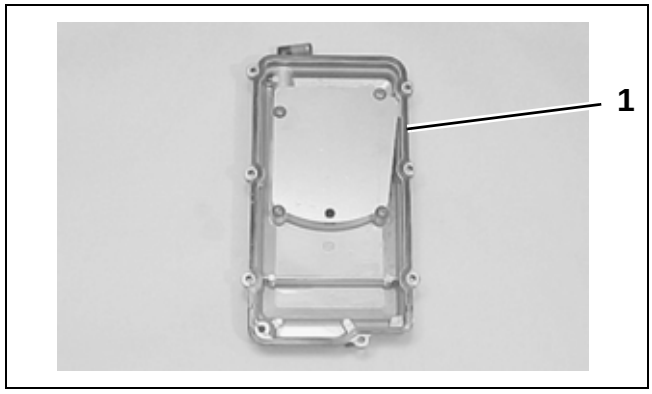
IMPORTANT: Before installing the cylinder head cover, check the valve clearance.

Apply *Three Bond No. 1207B* to the indicated areas on the cylinder head mating surface.



001329

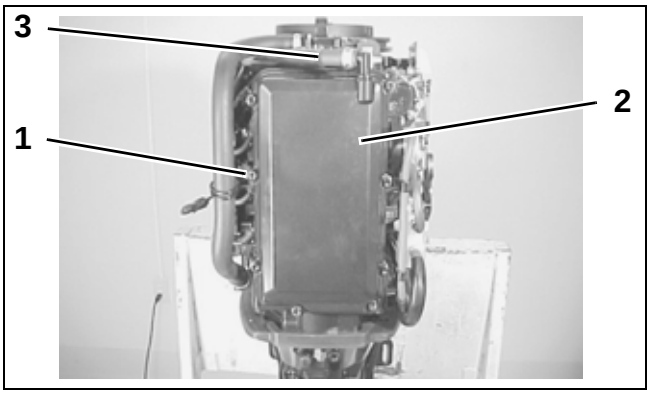
IMPORTANT: The cylinder head cover gasket is reusable. Check the gasket for any wear or damage before installation.



1. Cylinder head cover gasket 001420

Install the cover on the cylinder head. Install and tighten the bolts to a torque of 89 in. lbs. (10 N·m).

Connect the breather hose to the cylinder head cover.

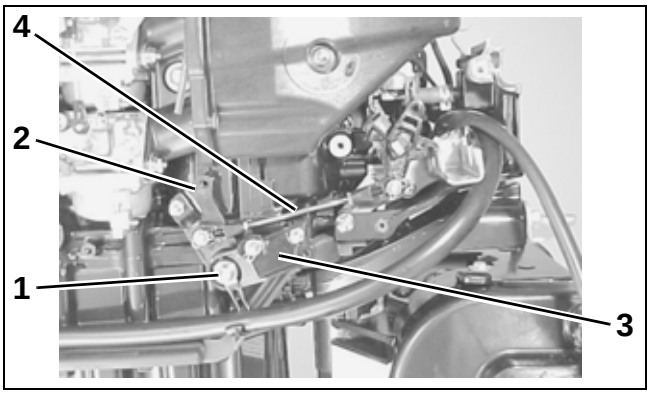


1. *Bolts (8)* 001395
2. *Cylinder head cover*
3. *Breather hose*

IMPORTANT: After installation, make sure that the throttle controls are adjusted correctly. Refer to the **FUEL SYSTEM** section for the adjustment procedures.

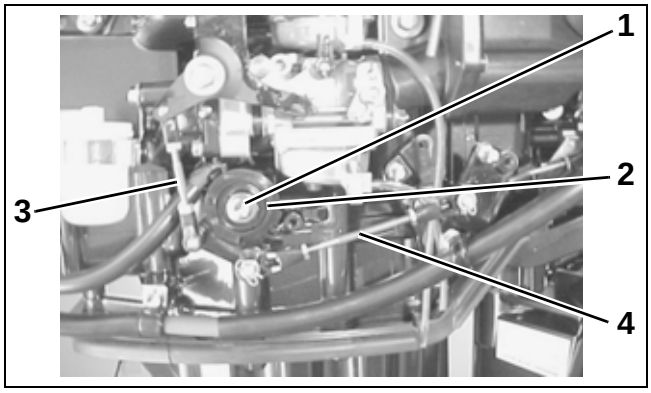
REMOTE CONTROL MODELS

Install the throttle control rod, the throttle lever, the throttle control lever, and the bolt.



1. *Bolt* 001399
2. *Throttle control lever*
3. *Throttle lever*
4. *Throttle control rod*

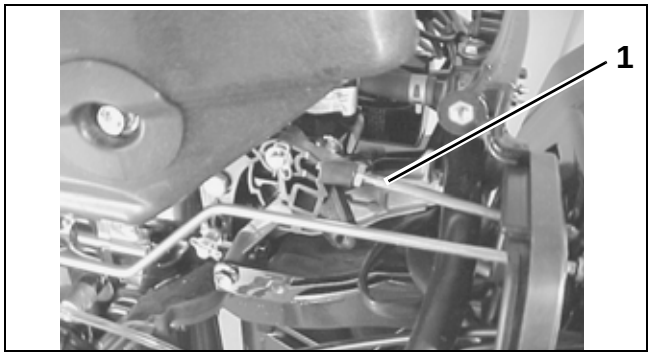
Install the throttle control rod, the throttle lever rod, the throttle drum, and the bolt.



1. *Bolt* 001398
2. *Throttle drum*
3. *Throttle lever rod*
4. *Throttle control rod*

TILLER HANDLE MODELS

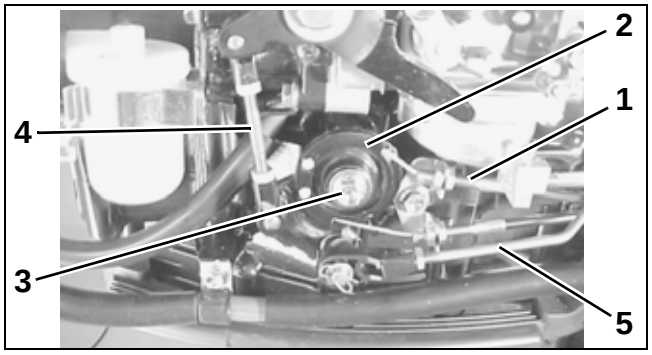
Install the shift lever link.



1. *Shift lever link* 001397

Install the throttle limiter rod, the throttle lever rod, the throttle drum, and the bolt.

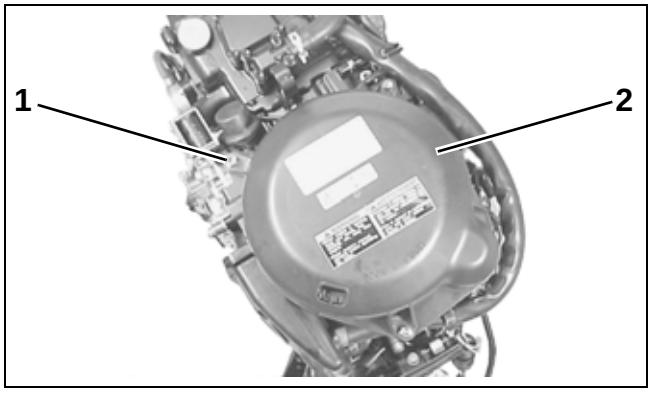
Install the throttle cables to the throttle drum. Refer to the **FUEL SYSTEM** section.



1. *Throttle cables*
2. *Throttle drum*
3. *Bolt*
4. *Throttle lever rod*
5. *Throttle limiter rod*

001396

Install the flywheel cover and three (3) bolts.



1. *Bolts (3)*
2. *Flywheel cover*

001394

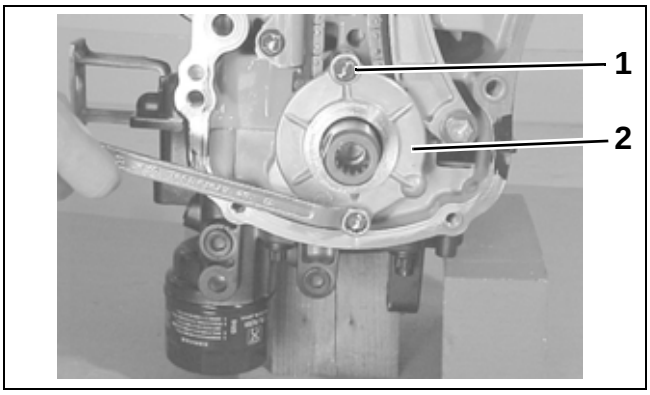
Install the side covers. Refer to the **MAINTENANCE** section.

TIMING CHAIN AND TENSIONER

Removal

Remove the powerhead.

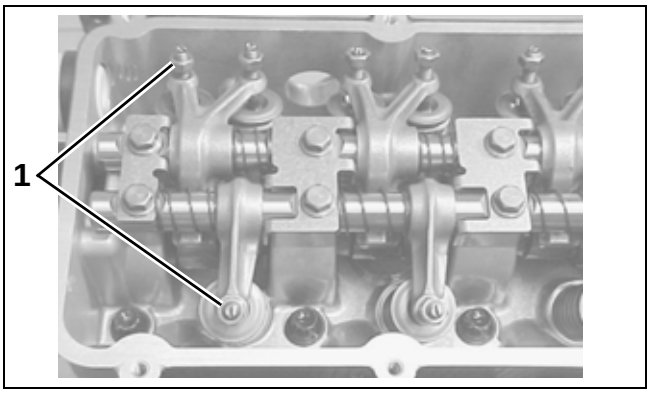
Remove two (2) bolts, the dowels, and the upper oil seal housing.



1. *Bolts (2)*
2. *Upper oil seal housing*

001422

Loosen all nine (9) valve adjusting locknuts and valve adjusting screws fully. Leave the screws in place.

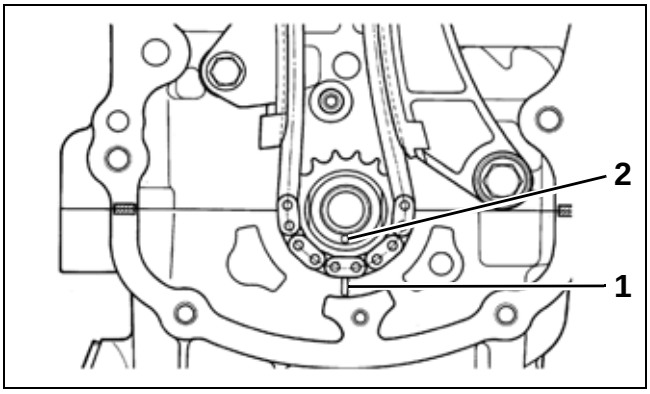


1. *Valve adjusting screws (9)*

001423

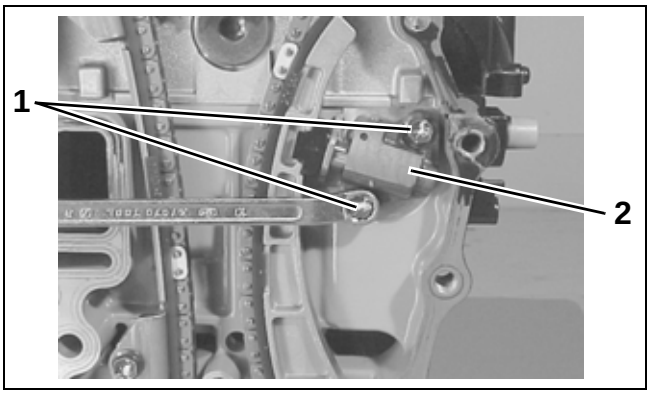
Turn the crankshaft in its normal running direction until the No.1 cylinder reaches top dead center.

The No. 1 cylinder will be at top dead center when the match mark on the crankshaft is aligned with the match mark on the crankcase.



1. *Match mark on crankcase* 001424
2. *Match mark on crankshaft*

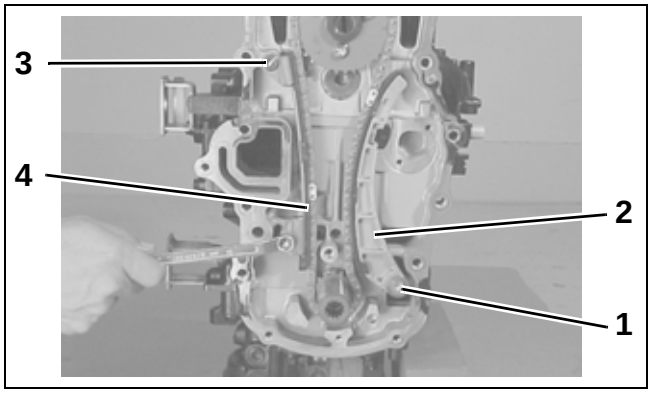
Remove two (2) bolts and the tensioner adjuster.



1. *Bolts (2)* 001425
2. *Tensioner adjuster*

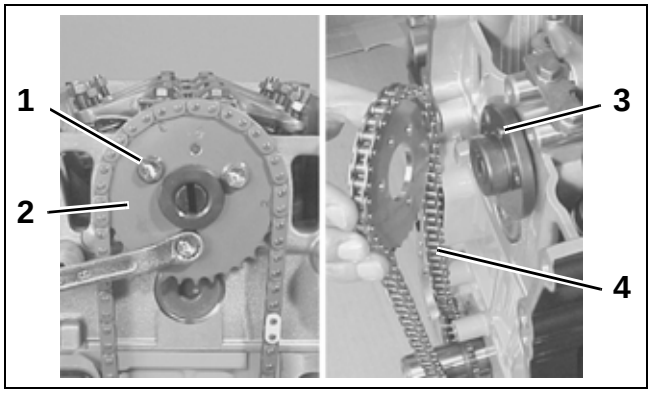
Remove the bolt, the washer, the spacer, and the timing chain tensioner.

Remove two (2) bolts and the timing chain guide.



1. *Bolt* 001426
2. *Timing chain tensioner*
3. *Bolts (2)*
4. *Timing chain guide*

Remove three (3) bolts that secure the timing sprocket to the camshaft. Remove the timing sprocket, the dowel pin, and the timing chain.



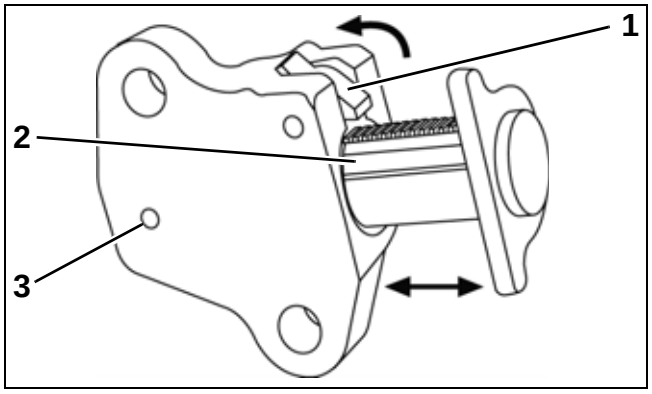
1. *Bolts (3)* 001427
2. *Timing sprocket*
3. *Dowel pin*
4. *Timing chain*

Inspection

Inspect the timing chain, the tensioner, the guide, and the sprockets for wear and damage.

Inspect the plunger and the latch of the tensioner adjuster for smooth operation.

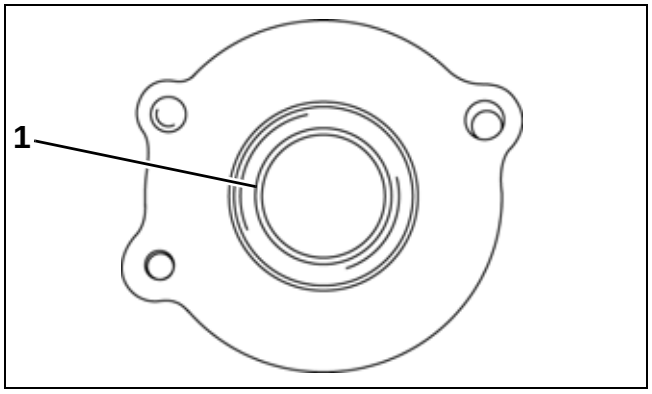
Check the oil passage with a syringe filler with isopropyl alcohol.



1. Latch 001429
2. Plunger
3. Oil passage

Check the upper oil seal for wear or damage. Replace the oil seal if necessary.

IMPORTANT: The oil seal lip must face toward the sprocket when the housing is installed.

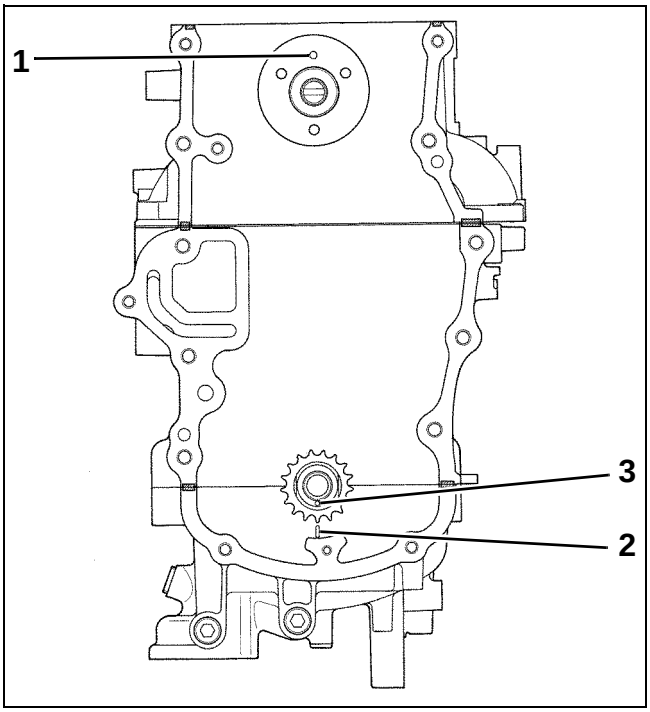


1. Upper oil seal 001432

Installation

Align the crankshaft timing mark with the crankcase timing mark by turning crankshaft.

Install the dowel pin into the camshaft. Make sure that the dowel pin is at the top.

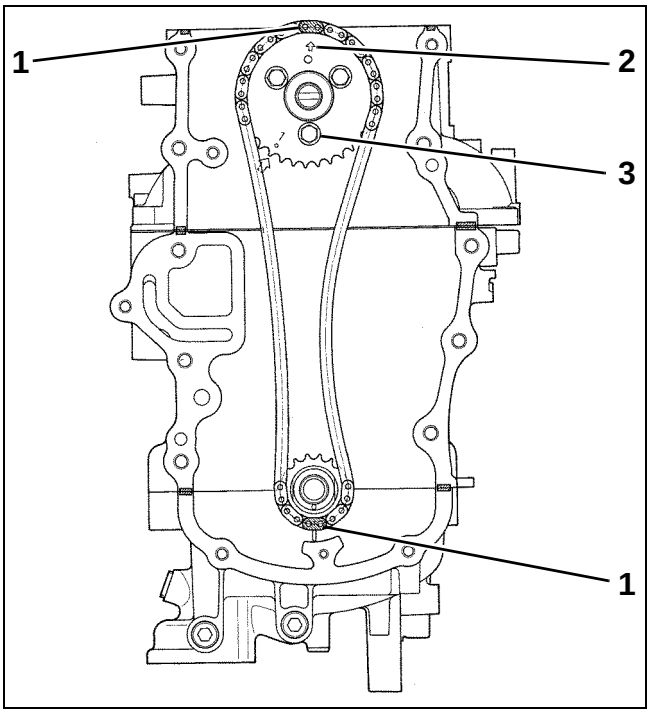


1. Dowel pin 001433
2. Crankcase timing mark
3. Crankshaft timing mark

Install the timing chain on the crankshaft. Make sure that one of the yellow plates of the timing chain is aligned with the crankshaft timing mark.

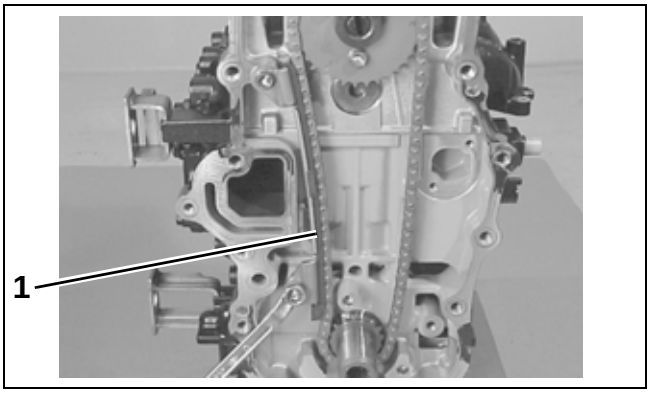
Install the timing chain on the timing sprocket. Make sure that the other yellow plate of the timing chain is aligned with the arrow mark on the timing sprocket. Install the timing sprocket onto the camshaft as shown.

Apply *Nut Lock* to the threads of three (3) timing sprocket bolts. Install and tighten the bolts to a torque of 97 in. lbs. (11 N·m).



1. Yellow plates on timing chain 001434
2. Arrow mark on timing sprocket
3. Bolts (3)

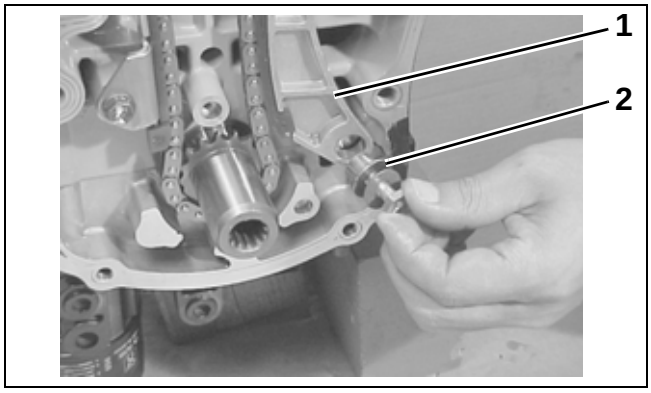
Install the timing chain guide. Install and tighten two (2) bolts securely.



1. Timing chain guide 001435

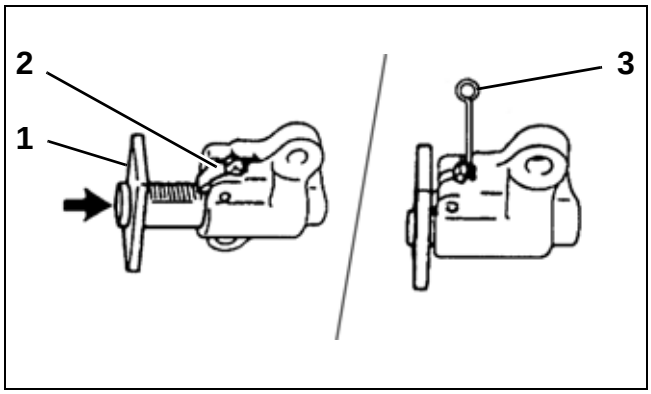
Insert the spacer, the washer, and the bolt into the timing chain tensioner. Install the tensioner and tighten the bolt securely.

After installation, apply oil to the timing chain and the tensioner.



1. Timing chain tensioner 001436
2. Spacer, washer and bolt

With the latch of the tensioner adjuster returned and the plunger pushed into the body, insert the stopper into the latch and the body. Make sure that the plunger will not come out.

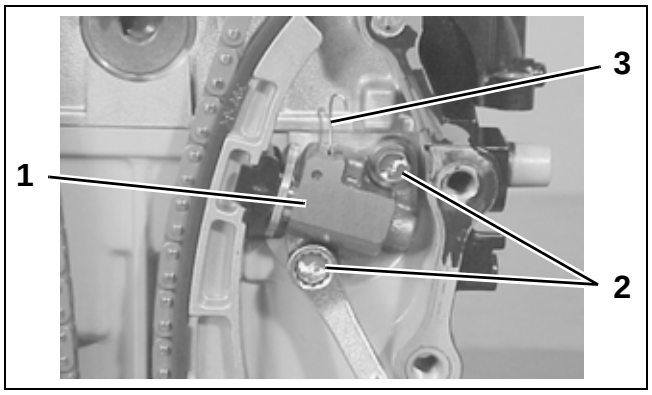


1. Plunger 001437
2. Latch
3. Stopper

Install the timing chain tensioner adjuster.

Apply *Nut Lock* to the threads of two (2) bolts. Install and tighten the bolts to a torque of 97 in. lbs. (11 N·m).

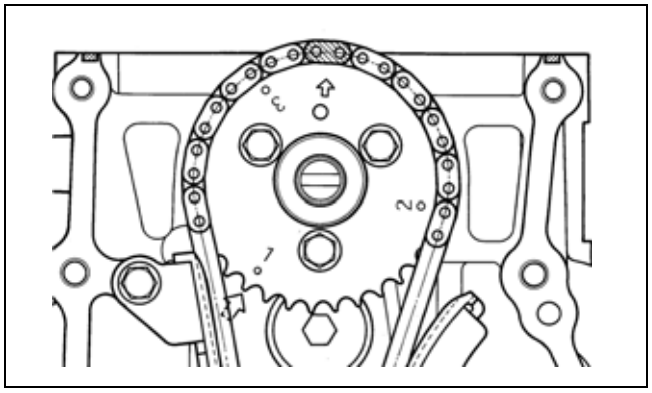
Pull the stopper out of the tension adjuster.



1. Timing chain tensioner adjuster 001438
2. Bolts (2)
3. Stopper

Turn the crankshaft two (2) revolutions in its normal running direction. Make sure that the match marks on the crankcase and the crankshaft are aligned. Also check that the arrow on the cylinder head is aligned with the 1 on the timing sprocket as shown. This indicates that the No. 1 cylinder piston is at top dead center (TDC) on the compression stroke.

To bring each piston to TDC on the compression stroke, align each corresponding number on the timing sprocket with the arrow on the cylinder head.

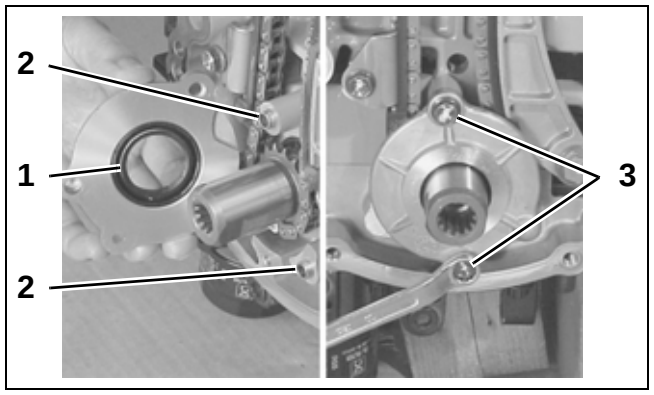


001440

Adjust the valve clearance.

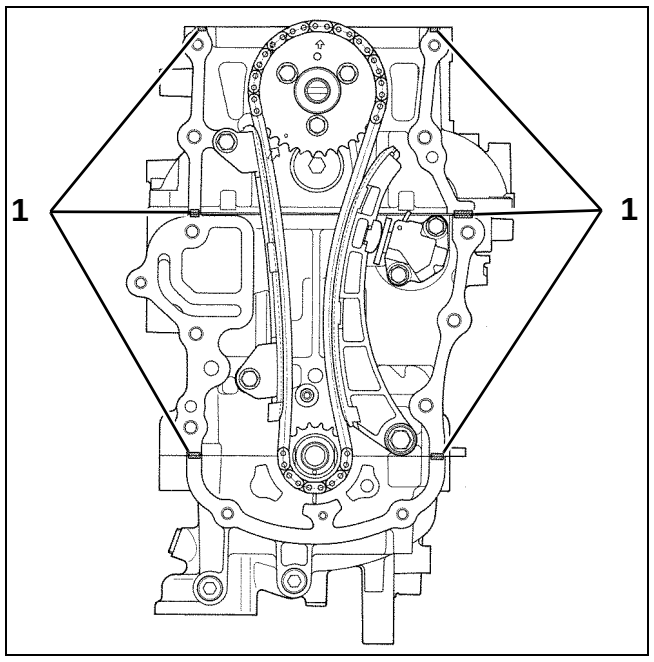
Apply oil to the lip of the upper oil seal.

Install two (2) dowel pins and the upper oil seal housing. Install and tighten the bolts securely.



1. Oil seal 001441
2. Dowel pins (2)
3. Bolts (2)

Apply *Triple Bond No. 1207B* to six (6) locations on the engine holder mating surface. Then install the powerhead.



1. Sealant locations 001439

7

CYLINDER HEAD

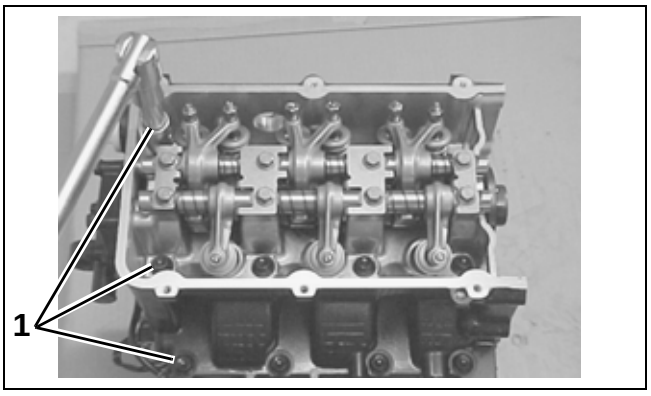
Removal

Remove the powerhead.

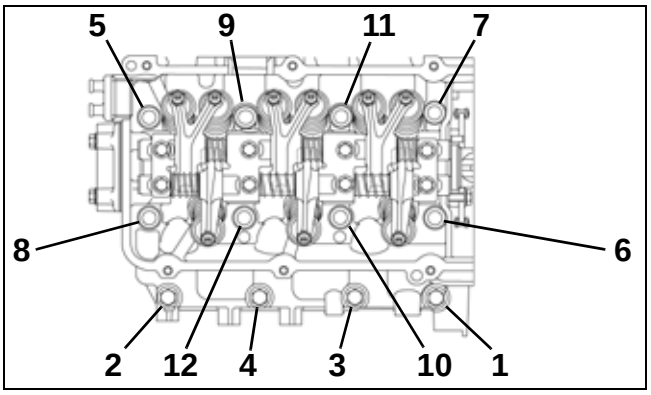
Remove the timing chain.

Use a 10 mm deep socket wrench to loosen twelve (12) cylinder head bolts in the order indicated below. Then remove the bolts.

Remove the cylinder head and the cylinder head gasket.



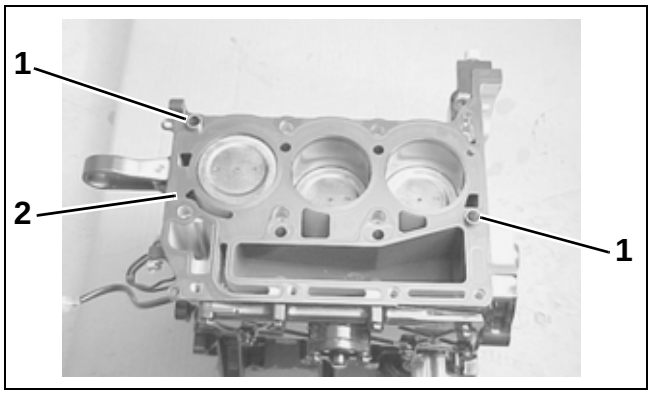
1. Cylinder head bolts (12) 001457



Bolt Loosening Sequence 001458

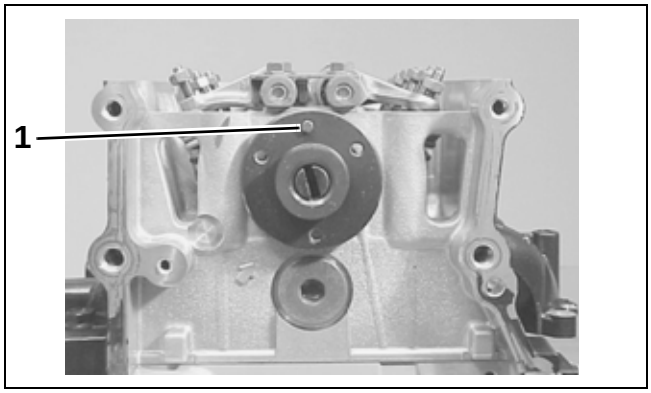
Installation

Insert two (2) dowel pins. Install a **new** cylinder head gasket on the cylinder head.



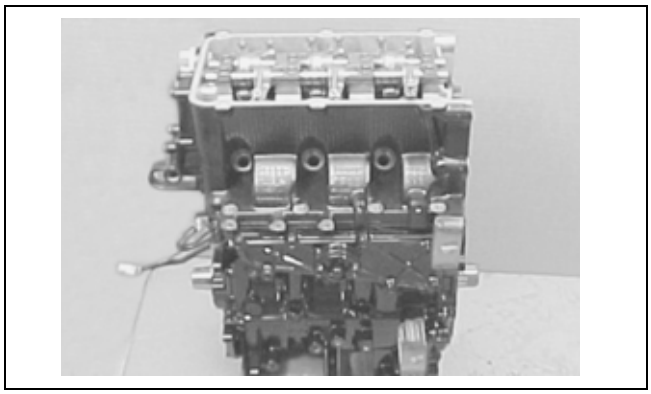
1. Dowel pins (2) 001459
2. Cylinder head gasket

Make sure that the No. 1 cylinder piston is at top dead center. Turn the camshaft to locate the dowel pin at the top as shown.



1. Camshaft dowel pin 001460

Position the cylinder head on the engine holder.

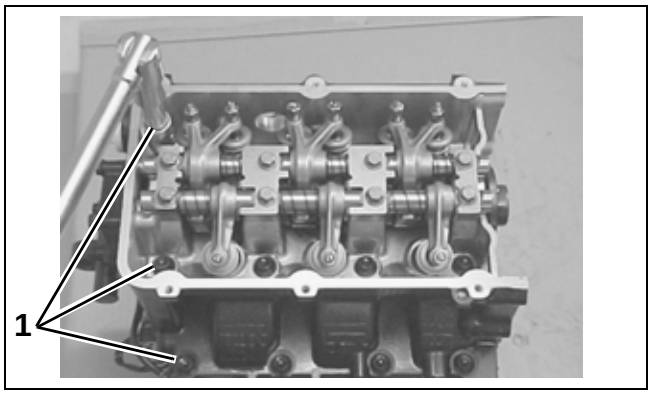


001461

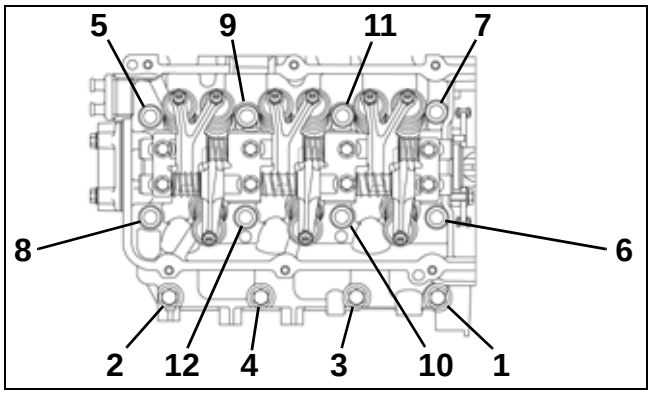
Apply engine oil to the cylinder head bolts and place them in the bolt holes. Then tighten the bolts in the following manner:

- **STEP 1** – Tighten the bolts to the initial torque according to the tightening sequence. Then completely loosen the bolts in reverse order.
- **STEP 2** – Tighten the bolts again to the initial torque according to the tightening sequence.
- **STEP 3** – Finally, tighten the bolts to the final torque according to the tightening sequence.

Cylinder Head Bolt Torques		
Bolt size	**Initial**	**Final**
8 mm	9 ft. lbs. (12 N·m)	18 ft. lbs. (25 N·m)
10 mm	22 ft. lbs. (30 N·m)	45 ft. lbs. (61 N·m)



1. Cylinder head bolts (12) 001457



Bolt Tightening Sequence 001458

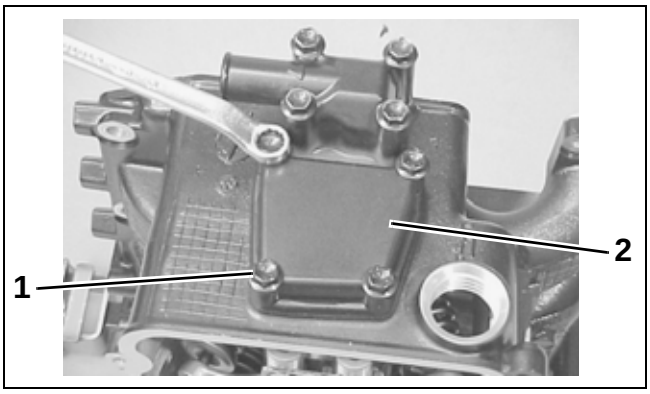
Install the timing chain. Refer to “TIMING CHAIN AND TENSIONER” on page 131.

Check the valve clearance of each valve. Refer to the **MAINTENANCE** section.

Disassembly

Remove the cylinder head.

Remove four (4) bolts and the upper cylinder head cover.

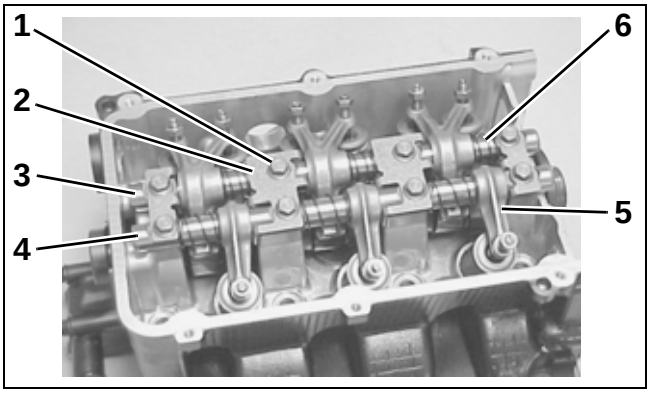


1. Bolts (4) 001462
2. Upper cylinder head cover

Remove eight (8) bolts and the rocker arm shaft brackets.

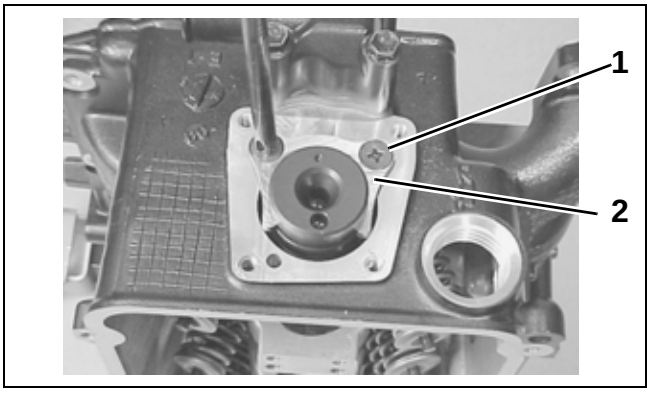
Remove the intake rocker arm shaft and the exhaust rocker arm shaft. Remove all rocker arms and springs.

IMPORTANT: Mark the location of each rocker arm within the cylinder head. Each rocker arm and its components must be installed in their original locations during assembly.



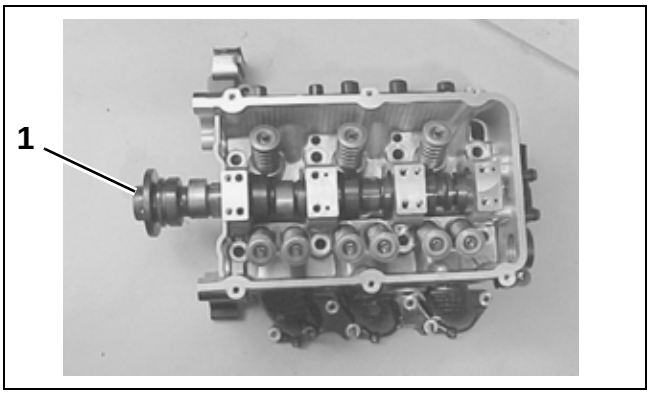
1. Bolts (8) 001463
2. Rocker arm shaft brackets (4)
3. Intake rocker arm shaft
4. Exhaust rocker arm shaft
5. Rocker arms (6)
6. Springs (6)

Remove two (2) screws and the camshaft thrust plate.



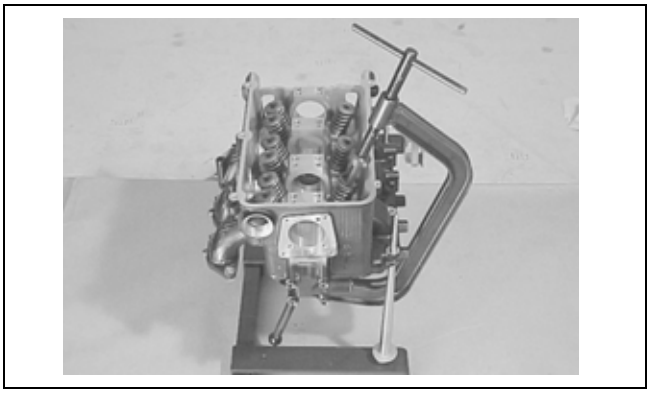
1. Screws (2)
2. Camshaft thrust plate
001465

Remove the camshaft by pulling it out toward the timing sprocket side.



1. Camshaft
001466

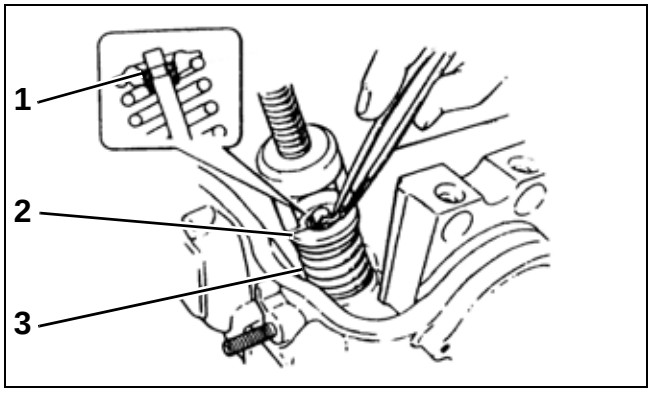
Use a Valve Lifter, P/N 346186, and Attachment, P/N 5000899, to compress the valve springs.



001467

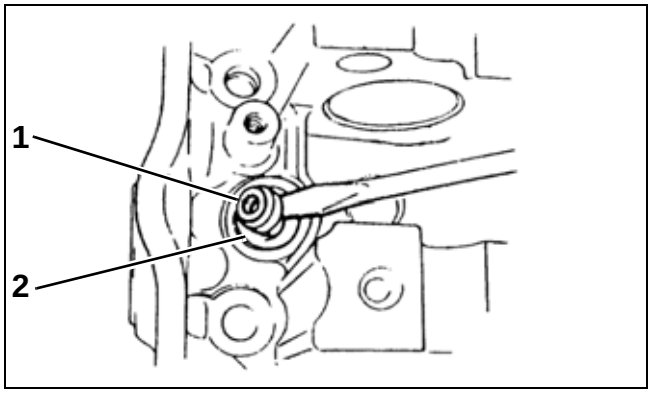
Use tweezers to remove the valve cotters while the valve springs are compressed.

Remove the valve spring retainer, the valve spring, and the valve.

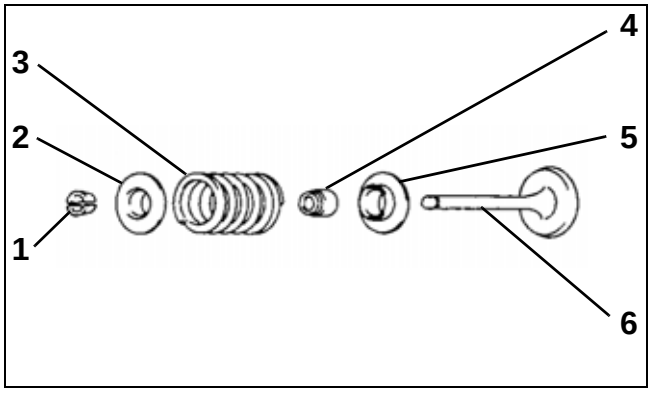


1. Cotters
2. Valve spring retainer
3. Valve spring
001468

Use a screwdriver to remove valve stem seal and the valve spring seat from the cylinder head.



1. Valve stem seal
2. Valve spring seat
001470

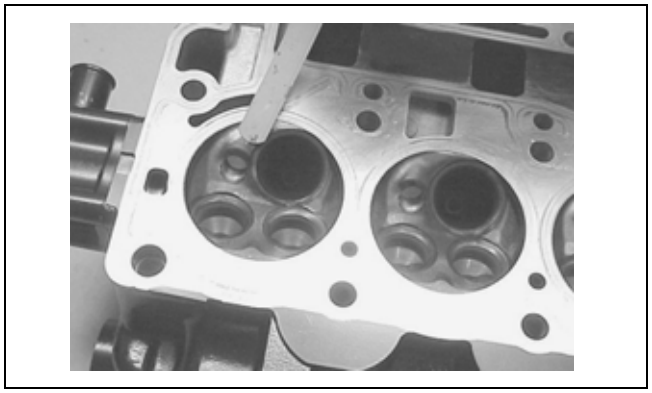


1. Cotters
2. Valve spring retainer
3. Vale spring
4. Valve stem seal
5. Valve spring seat
6. Valve
001469

Inspection and Servicing

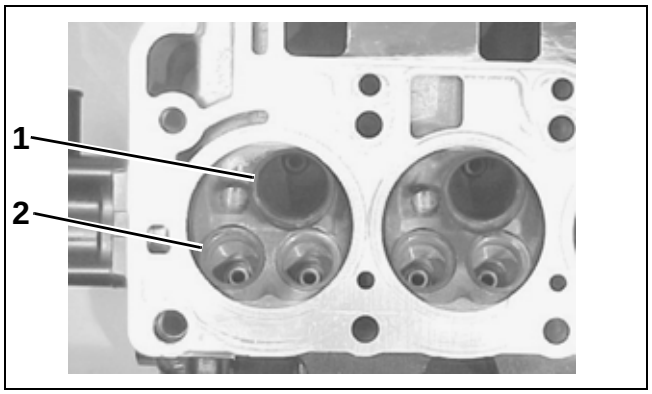
Cylinder Head

Remove all carbon deposits from the combustion chambers. DO NOT use any sharp edged tool to scrape off carbon. Be careful not to scuff or nick the metal surfaces.



001471

Check for cracks in the intake and exhaust ports, the valve seats, the combustion chambers, and the surface of the cylinder head.

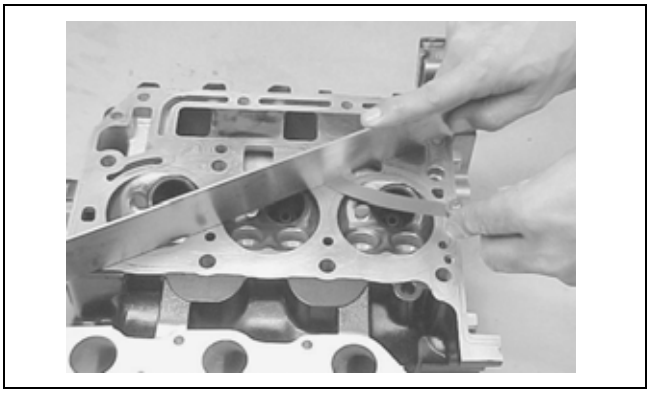


1. Exhaust valve seat 001473
2. Intake valve seat

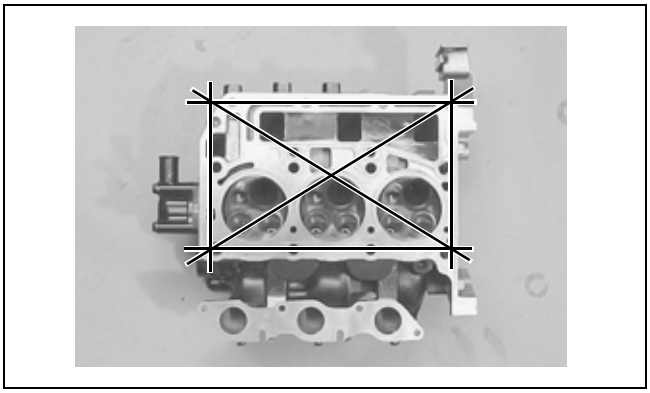
Use a straightedge and a thickness gauge to measure the cylinder head distortion on the gasket surface at six (6) locations as shown.

The service limit for distortion is 0.002 in. (0.05 mm). If any measurement exceeds this specification, resurface or replace the cylinder head.

The cylinder head can be resurfaced using a surface plate and #400 grit wet sandpaper. Move the cylinder head in a figure eight pattern when sanding.

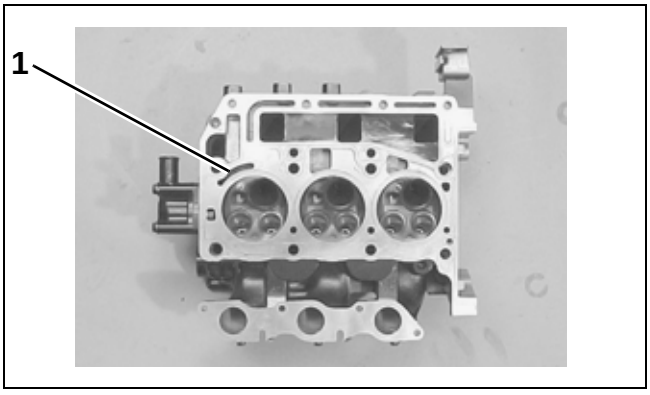


001474



001473

Check the water jackets for clogs or obstructions.



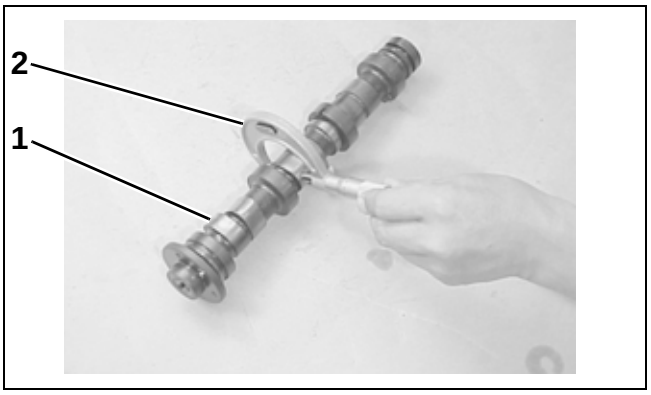
1. Water jacket 001473

Camshaft

Inspect the cam face, the camshaft journals, and the journal bores for pitting, scratches, wear, or damage. If any such conditions are found, replace the camshaft and/or the cylinder head.

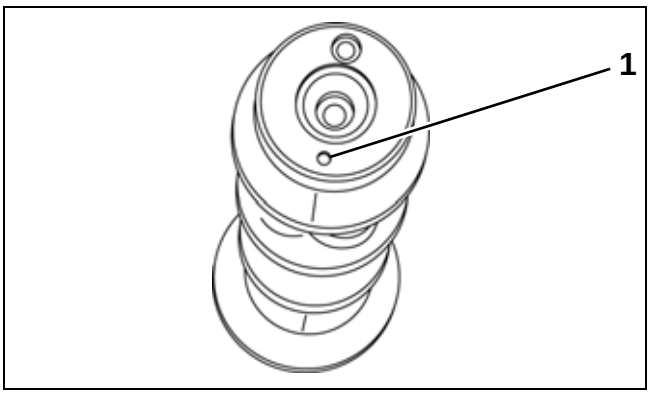
Use a micrometer to measure the cam height. If the measurement exceeds the specification, replace the camshaft.

Cam Height Specifications			
Model		**Standard**	**Service Limit**
30	IN	1.4203 – 1.4266 in. (36.076 – 36.236 mm)	1.4164 in. (35.976 mm)
	EX	1.3886 – 1.3949 in. (35.271 – 35.431 mm)	1.3847 in. (35.171 mm)



1. Cam
2. Micrometer
001475

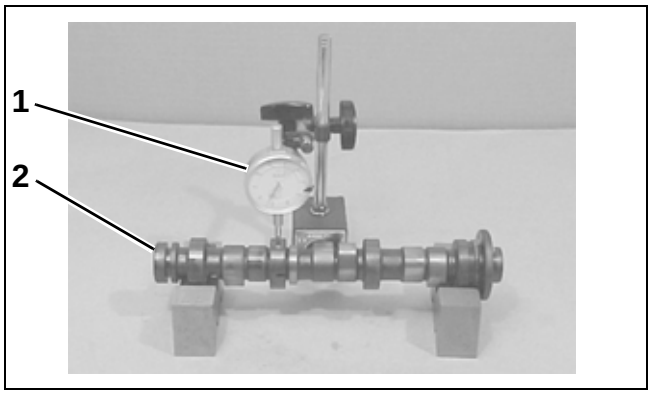
IMPORTANT: 30 HP model camshafts have a dent.



1. Dent on camshaft (DF30 models only)
001476

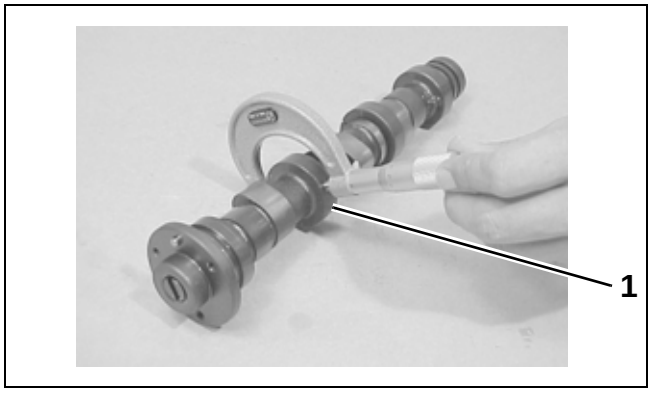
Use a set of “V” blocks to support the camshaft on a surface plate. Use a dial gauge to measure the camshaft runout.

The service limit for camshaft runout is 0.004 in. (0.10 mm). If the measurement exceeds this specification, replace the camshaft.



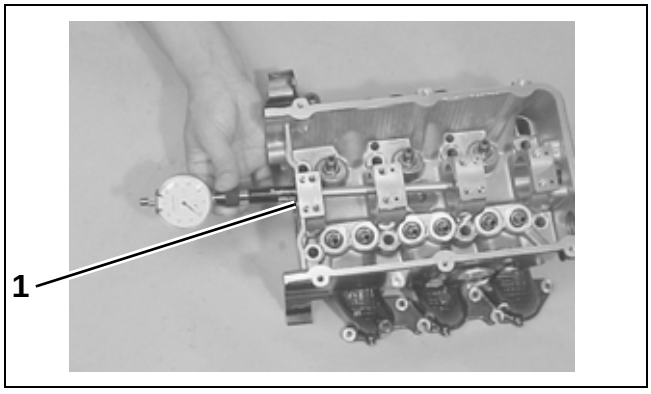
1. Dial gauge
2. Camshaft
001477

Use a micrometer to measure the outside diameters of the journals in two directions at four places.



1. Camshaft journal
001479

Use a bore gauge to measure the inside diameters of the journal bores in the cylinder head.



1. Camshaft journal bore
001480

IMPORTANT: The journal are numbered are in order from the flywheel magnet to the bottom of the cylinder.

Camshaft Journal Outside Diameter		
Journal No.	**Standard**	**Service Limit**
Top	1.7096 – 1.7106 in. (43.425 – 43.450 mm)	1.7077 in. (43.375 mm)
2nd	1.7175 – 1.7185 in. (43.625 – 43.650 mm)	1.7156 in. (43.575 mm)
3rd	1.7254 – 1.7264 in. (43.825 – 43.850 mm)	1.7234 in. (43.775 mm)
4th	1.7333 – 1.7343 in. (44.025 – 44.050 mm)	1.7313 in. (43.975 mm)

Camshaft Journal Bore Inside Diameter		
Journal No.	**Standard**	**Service Limit**
Top	1.7126 – 1.7136 in. (43.500 – 43.525 mm)	1.7139 in. (43.534 mm)
2nd	1.7205 – 1.7215 in. (43.700 – 43.725 mm)	1.7218 in. (43.734 mm)
3rd	1.7283 – 1.7293 in. (43.900 – 43.925 mm)	1.7300 in. (43.934 mm)
4th	1.7362 – 1.7372 in. (44.100 – 44.125 mm)	1.7376 in. (44.134 mm)

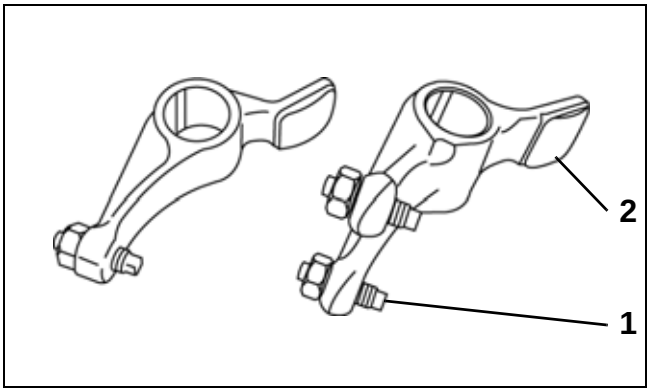
Subtract the camshaft journal outside diameter measurement from the camshaft journal bore inside diameter measurement to determine the journal oil clearance.

If the camshaft journal oil clearance exceeds the service limit, replace the camshaft and/or the cylinder head.

Camshaft Journal Oil Clearance	
Standard	0.002 – 0.004 in. (0.05 – 0.10 mm)
Service Limit	0.006 in. (0.16 mm)

Rocker Arm and Shaft

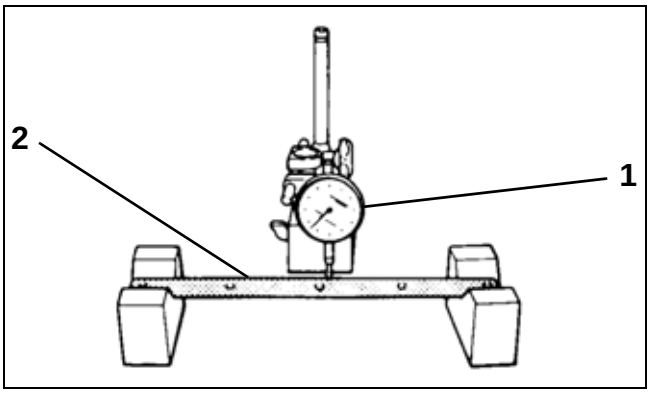
Inspect each rocker arm. If the tip of the adjusting screw is excessively worn, replace the screw. If the cam riding face is excessively worn, replace the rocker arm.



1. Adjusting screw 001481
2. Cam riding face

Use a set of “V” blocks to support the rocker arm shaft on a surface plate. Use a dial gauge to measure the shaft runout.

The service limit for rocker arm shaft runout is 0.005 in. (0.12 mm). If the measurement exceeds this specification, replace the shaft.



1. Dial gauge 001482
2. Rocker arm shaft

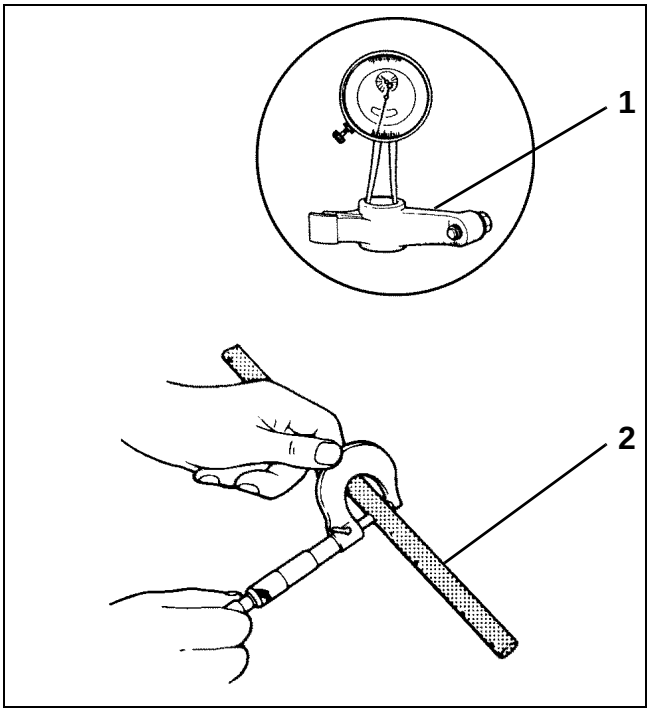
Use a micrometer and a bore gauge to measure the rocker arm shaft outside diameter and the rocker arm bore inside diameter.

Rocker Arm and Shaft Specifications	
Rocker Arm Shaft Outside Diameter	0.6289 – 0.6294 in. (15.973 – 15.988 mm)
Rocker Arm Bore Inside Diameter	0.6299 – 0.6306 in. (16.000 – 16.018 mm)

Subtract the rocker arm shaft outside diameter from the rocker arm bore inside diameter to determine the rocker arm-to-shaft clearance.

If the measurement exceeds the service limit, replace the rocker arm and/or the shaft.

Rocker Arm-to-Shaft Clearance	
Standard	0.0005 – 0.0018 in. (0.012 – 0.045 mm)
Service Limit	0.0035 in. (0.090 mm)



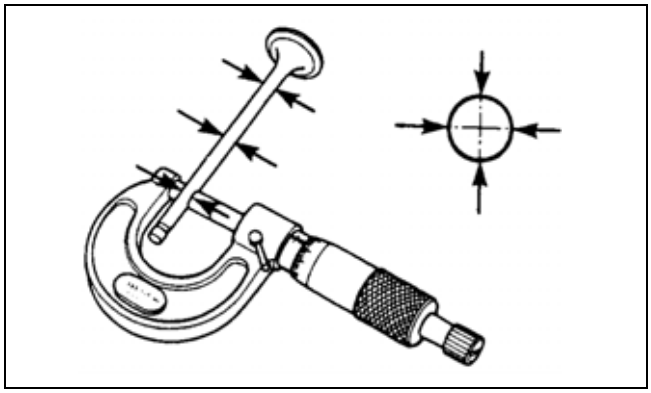
1. Rocker arm
2. Rocker arm shaft

001483

Valve Stem and Valve Guide

Use a micrometer to measure the outside diameter of the valve stems. Be sure to take readings at more than one place along the length of each valve stem.

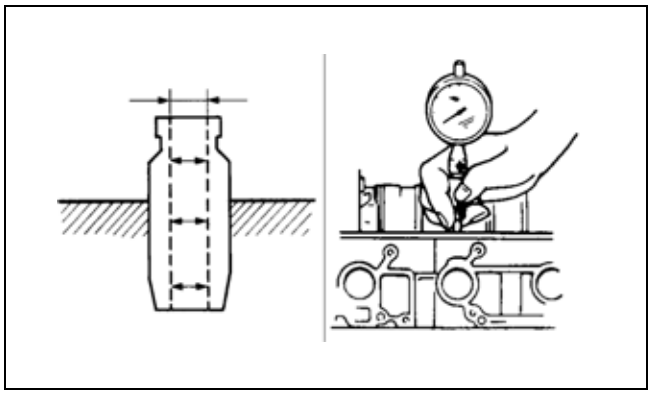
Valve Stem Outside Diameter	
Intake valve	0.2152 – 0.2157 in. (5.465 – 5.480 mm)
Exhaust valve	0.2146 – 0.2152 in. (5.450 – 5.465 mm)



001491

Use a bore gauge to measure the inside diameter of the valve guides. Be sure to take readings at more than one place along the length of each valve guide.

Valve Guide Inside Diameter	
Intake valve	0.2165 – 0.2170 in. (5.500 – 5.512 mm)
Exhaust valve	0.2165 – 0.2170 in. (5.500 – 5.512 mm)



001492

Subtract the valve stem outside diameter from the valve guide inside diameter to determine the valve guide-to-stem clearance.

If the measurement exceeds the service limit, replace the valve guide and/or the valve.

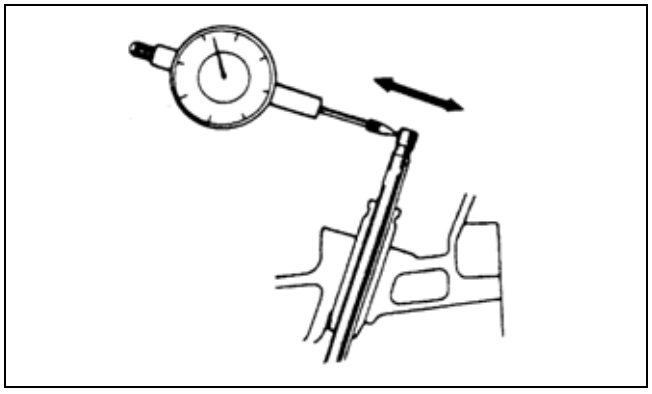
Valve Guide-to-Stem Clearance		
Standard	IN	0.0008 – 0.0019 in. (0.020 – 0.047 mm)
	EX	0.0014 – 0.0024 in. (0.035 – 0.062 mm)
Service Limit	IN	0.0028 in. (0.070 mm)
	EX	0.0035 in. (0.090 mm)

If the valve guide inside diameter cannot be measured, use a dial gauge to check the valve stem end deflection to determine whether the valve guide-to-stem clearance is adequate.

- Install the valve into the valve guide.
- Position the valve head approximately 0.2 in. (5.0 mm) away from the valve seat.
- Move the stem end back and forth and measure the deflection.

If the measurement exceeds the service limit, replace the valve. If the measurement still exceeds the service limit with a new valve installed, replace the valve guide.

Valve Stem End Deflection		
Service Limit	IN	0.006 in. (0.14 mm)
	EX	0.007 in. (0.18 mm)

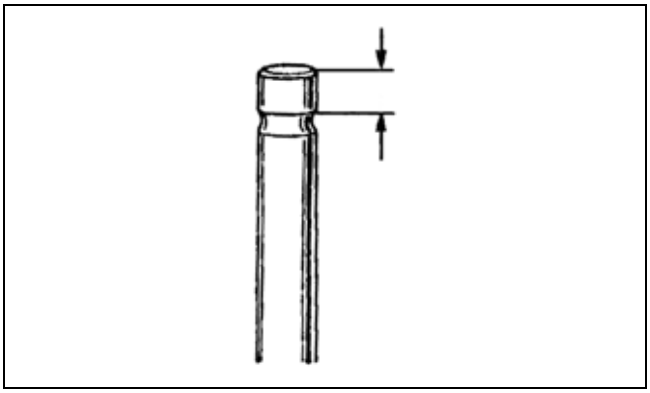


001493

Inspect the valve stem end face for pitting and wear. The valve stem end may be refaced. Be careful not to wear down the chamfer too far.

Use vernier calipers to measure the valve stem end length. If the measurement is less than the specification, the chamfer is too worn. Replace the valve.

Valve Stem End Length		
Service Limit	IN	0.276 in. (7.00 mm)
	EX	0.236 in. (6.00 mm)

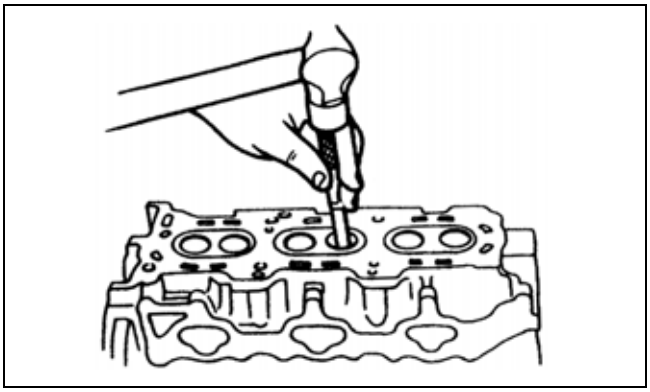


001494

Valve Guide Replacement

Use a valve guide remover to drive out the valve guide from the combustion chamber side of the cylinder head toward the valve spring side.

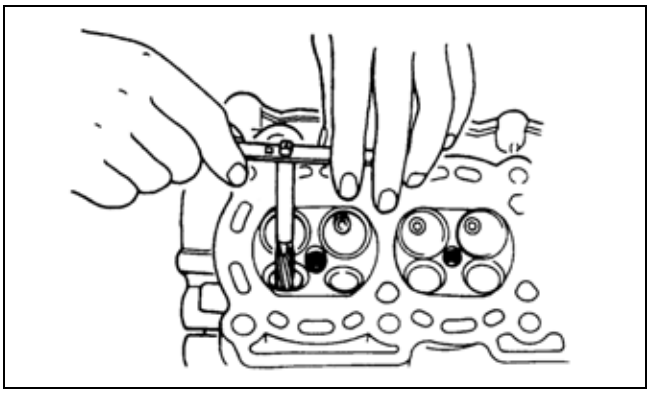
IMPORTANT: Do not reuse a valve guide once it has been removed. Always use a **new** oversize valve guide when assembling.



001504

Ream the valve guide hole with a 10.5 mm reamer to true the hole and remove any burrs.

IMPORTANT: Turn the reamer in a clockwise direction, NEVER counterclockwise.

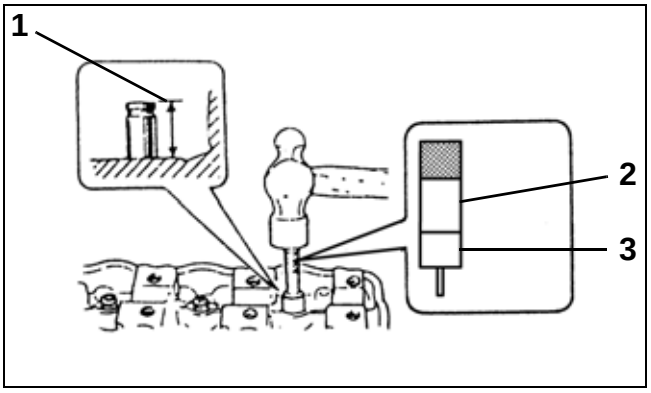


001505

Heat the cylinder head to a temperature of 80 to 100°C (176 to 212°F). Apply heat uniformly so the head will not become distorted.

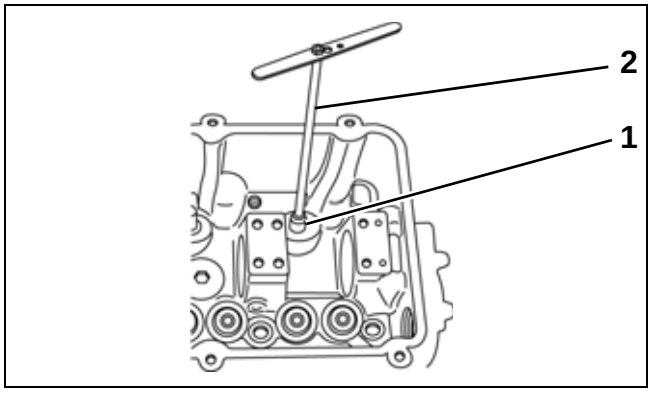
Use a valve guide installer to drive the new valve guide into the hole until the attachment contacts the cylinder head.

After installation, check the valve guide protrusion. The protrusion for the intake and exhaust valves should be 0.55 in. (14 mm).



1. Valve guide protrusion 001506
2. Valve guide installer handle
3. Valve guide installer attachment

Ream the valve guide bore with a 5.5 mm reamer. Clean and oil the valve guide bore after reaming.

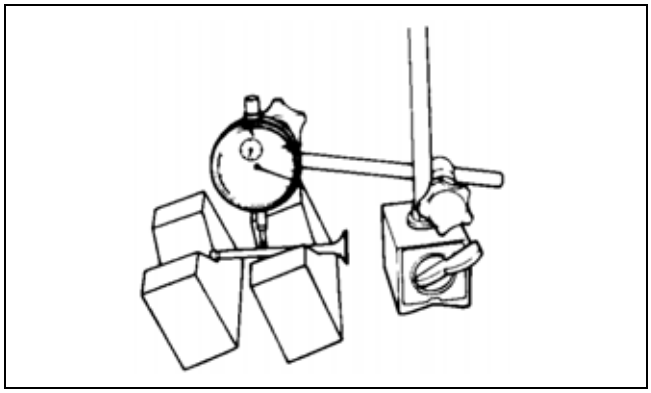


1. Valve guide 001507
2. Reamer

Valve Head and Valve Seat

Use a set of “V” blocks to support the valve on a surface plate. Use a dial gauge to measure the valve stem runout.

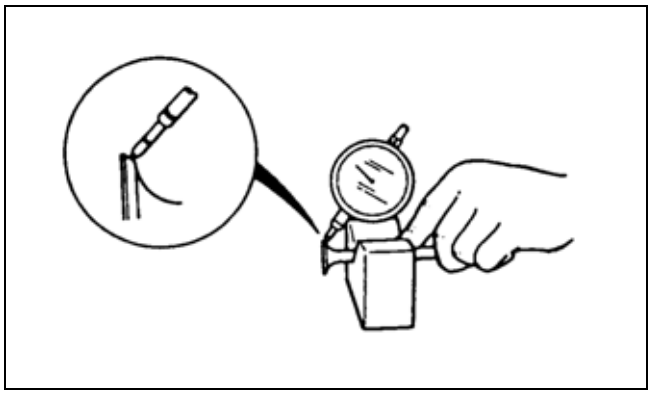
The service limit for valve stem runout is 0.002 in. (0.05 mm). If the measurement exceeds this specification, replace the valve.



001495

Use a “V” block to support the valve on a surface plate. Use a dial gauge to measure the valve head radial runout.

The service limit for valve head radial runout is 0.003 in. (0.08 mm). If the measurement exceeds this specification, replace the valve.

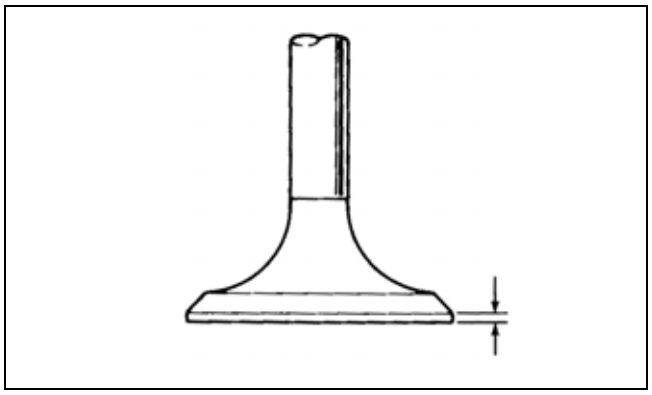


001496

Use vernier calipers to measure the thickness of the valve head.

If the measurement exceeds the service limit, replace the valve.

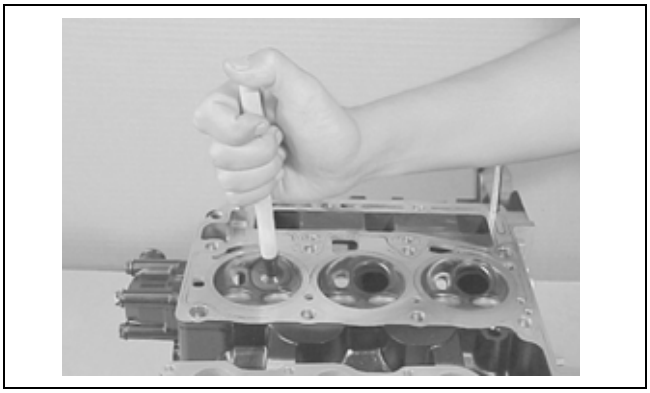
Valve Head Thickness		
Standard	IN	0.04 in. (1.0 mm)
	EX	0.05 in. (1.3 mm)
Service Limit	IN	0.02 in. (0.5 mm)
	EX	0.03 in. (0.7 mm)



001497

Measure the valve seat contact width as follows:

- Remove all carbon deposits from the valve and the valve seat.
- Coat the valve seat evenly with Prussian blue (or equivalent).
- Install the valve into the valve guide.
- Place a valve lapper on the valve.
- Rotate the valve while gently tapping the valve contact area against the seat. Repeat until a continuous pattern in the Prussian Blue is seen.

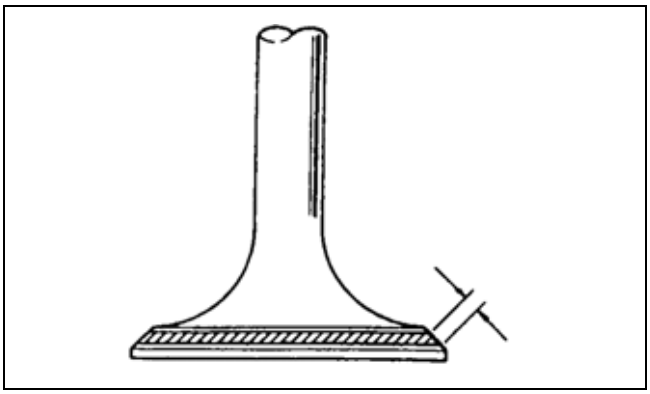


001498

Use vernier calipers to measure the valve seat contact width.

If the measurement exceeds the specification, reface the valve seat.

Valve Seat Contact Width	
Intake valve	0.05 – 0.06 in. (1.3 – 1.5 mm)
Exhaust valve	0.05 – 0.06 in. (1.3 – 1.5 mm)



001499

Valve Seat Refacing

WARNING

To avoid personal injury, wear eye protection when using a cutter.

Remove all carbon deposits from the valve and the valve seat.

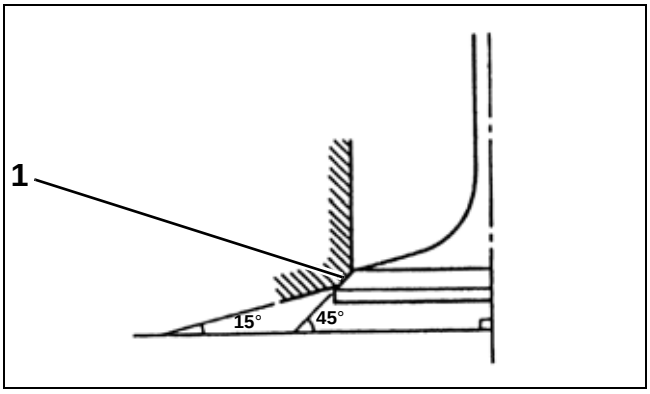
Use a 45° angle cutter to reface valve seat.

IMPORTANT: Turn the cutter in a clockwise direction, NEVER counterclockwise.

Check the valve seat contact width.

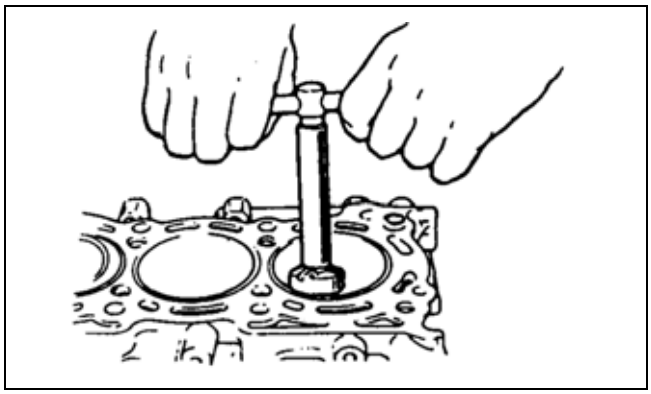
- If the width is greater than the specification, reface the valve seat using a 15° angle cutter.
- If the width is less than the specification, reface the valve seat using a 45° angle cutter again.

Clean up any burrs by using a 45° angle cutter very lightly.



1. Valve seat 001500

Lap the valve on the valve seat in two steps: first with coarse grit lapping compound applied to the face, and then with fine grit lapping compound.



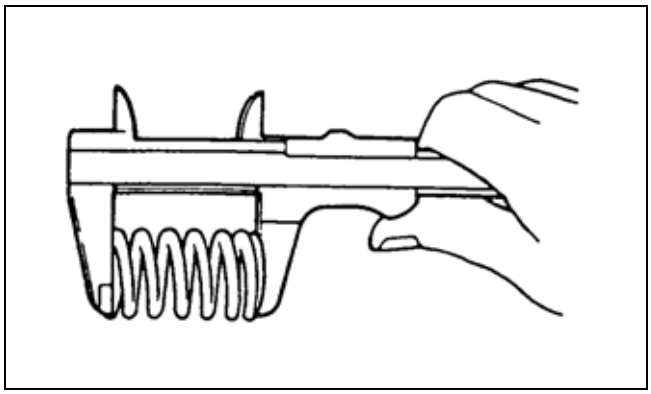
001502

Valve Spring

Check the strength of the valve spring by measuring its free length with vernier calipers.

If the spring's free length is less than the service limit, replace the valve spring.

Valve Spring Free Length	
Standard	1.865 in. (47.38 mm)
Service Limit	1.791 in. (45.48 mm)

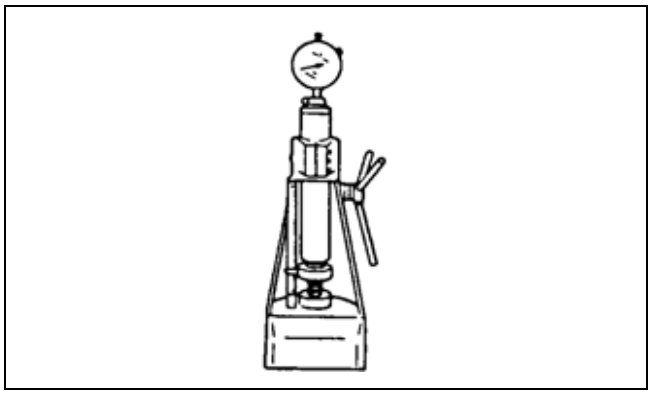


001508

Use a spring tester to measure the valve spring preload.

If the spring's preload is less than the service limit, replace the valve spring.

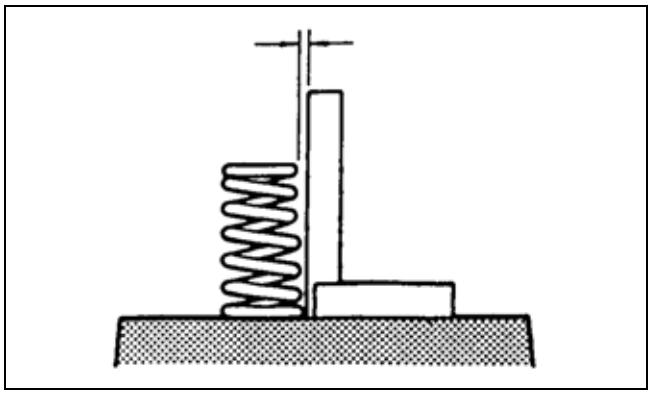
Valve Spring Preload	
Standard	43 to 50 lbs. (193 to 223 N) for 1.48 in. (37.5 mm)
Service Limit	40 lbs. (177 N) for 1.48 in. (37.5 mm)



001509

Use a square and a surface plate to check each spring for squareness (clearance between the end of the valve spring and the square).

The service limit for valve spring squareness is 0.08 in. (2.0 mm). If the measurement exceeds this specification, replace the valve spring.



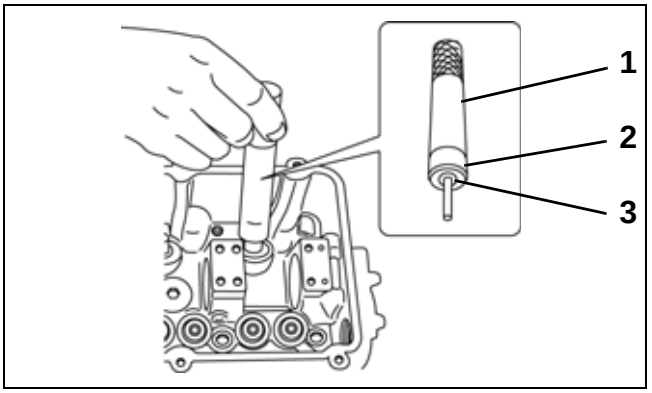
001510

Assembly

IMPORTANT: Before assembling the cylinder head, inspect and service the components. Refer to "Inspection and Servicing" on page 139.

Install the valve spring seat to the cylinder head.

Apply engine oil to a new valve stem seal and the spindle of the valve guide installer attachment. Fit the seal to the spindle, then install the seal to the valve guide by pushing on the installer by hand. Make sure that the seal is properly fixed to the valve guide.

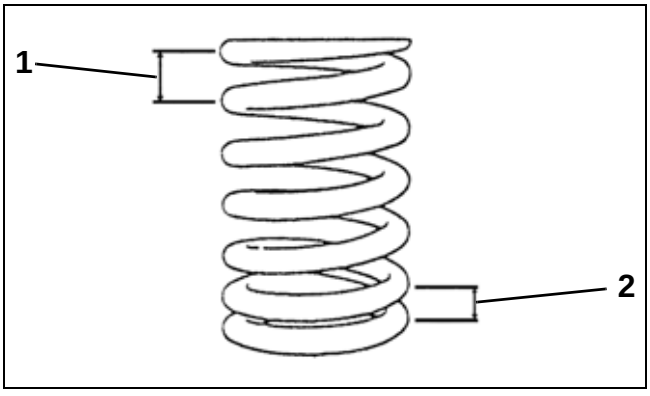


1. *Valve guide installer handle*
2. *Valve guide installer attachment*
3. *Valve stem seal*

001518

Apply engine oil to the valve stem and the valve guide bore. Install the valve in the valve guide bore.

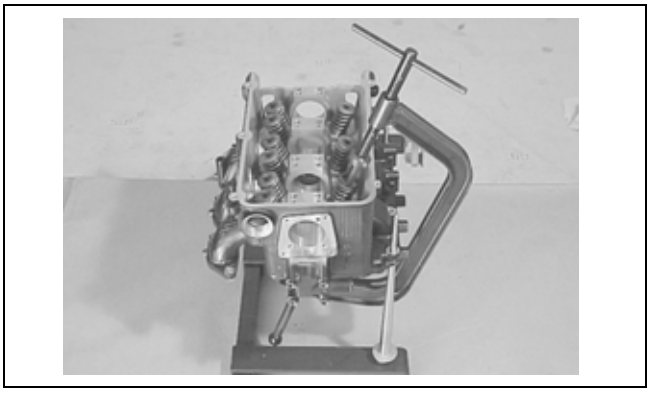
Install the valve spring and the valve retainer. Make sure that the narrow spiral area of the valve spring is facing toward the valve seat.



1. *Wide-pitch spiral (retainer side)*
2. *Narrow-pitch spiral (seat side)*

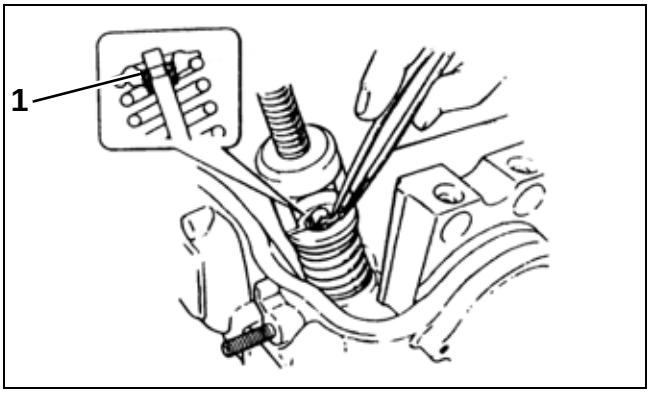
001520

Use a Valve Lifter, P/N 346186, and Attachment, P/N 5000899, to compress the valve springs.

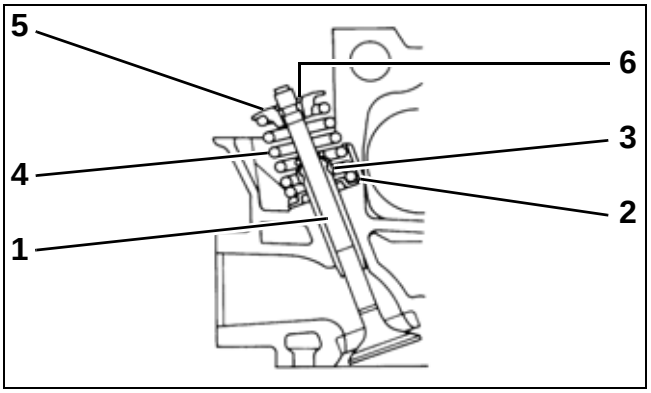


001467

Use tweezers to install the valve cotters while the valve springs are compressed. Make sure that the valve cotters are properly seated in the valve stem groove.

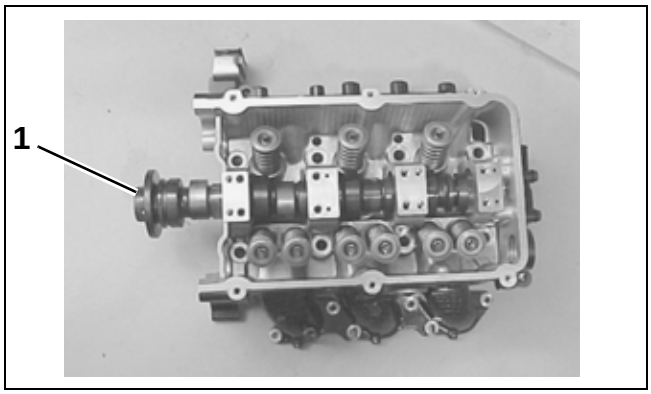


1. Cotters 001468



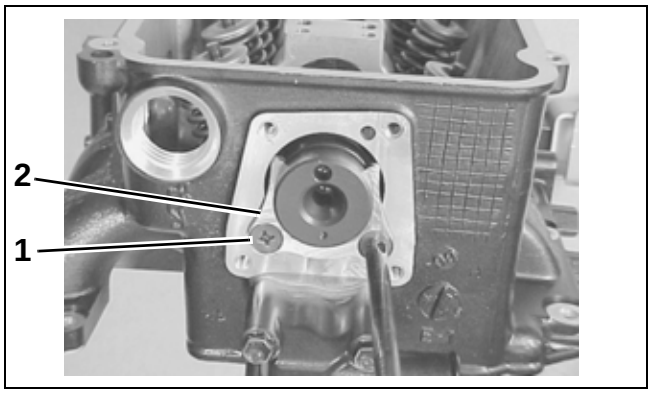
1. Valve 001517
2. Valve spring seat
3. Valve stem seal
4. Valve spring
5. Valve retainer
6. Cotters

Apply engine oil to the surface of each camshaft lobe and journal. Install the camshaft from timing sprocket side of the cylinder head.



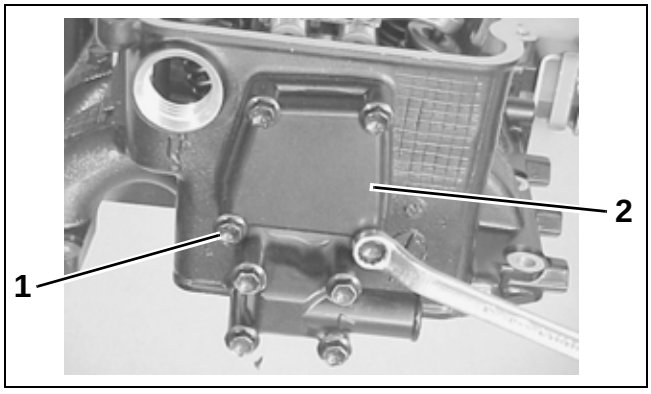
1. Camshaft 001466

Install the camshaft thrust plate. Install and tighten the screws securely.



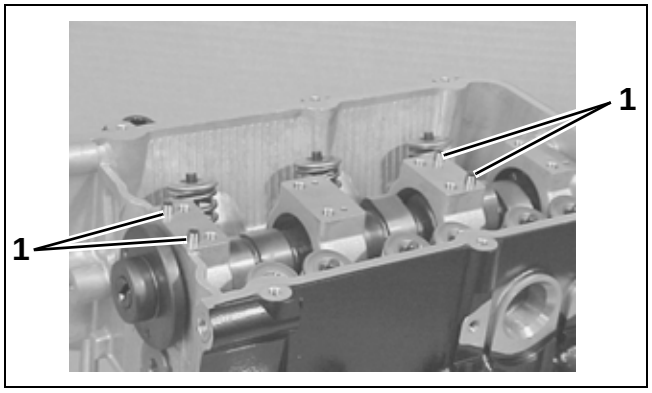
1. Screws (2) 001465
2. Camshaft thrust plate

Install the upper cylinder head cover. Install and tighten four (4) bolts securely.



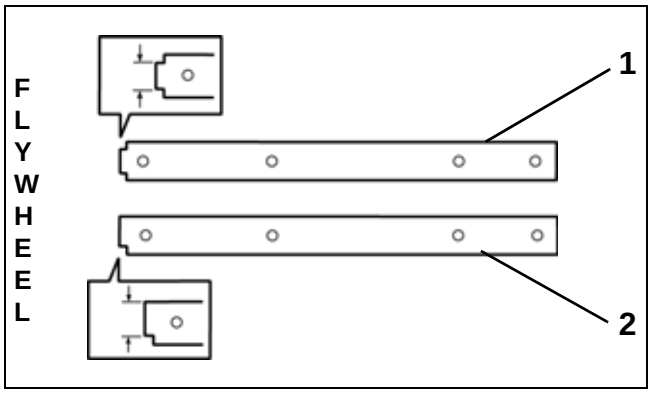
1. Bolts (4) 001462
2. Upper cylinder head cover

Install four (4) dowel pins in the rocker arm shaft brackets.



1. Dowel pins (4) 001522

IMPORTANT: The intake rocker arm shaft differs from the exhaust rocker arm shaft as shown. During assembly, make sure that each shaft is being installed in the correct location and direction.

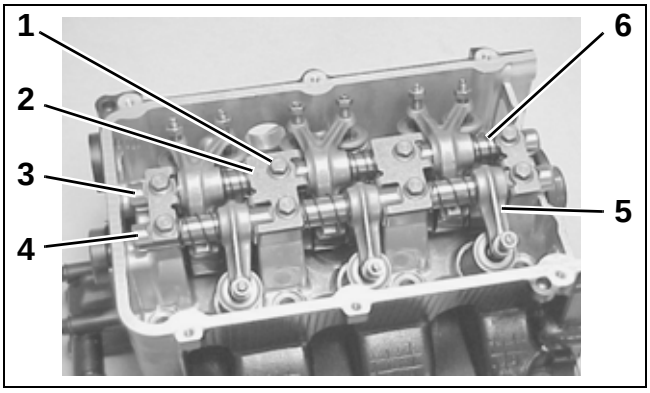


1. Intake rocker arm shaft 001464
2. Exhaust rocker arm shaft

Apply engine oil to the rocker arms and the rocker arm shaft. Install the rocker arms, the rocker arm springs, the intake rocker arm shaft, and the exhaust rocker arm shaft.

IMPORTANT: Make sure that each rocker arm and its components are installed in their original locations.

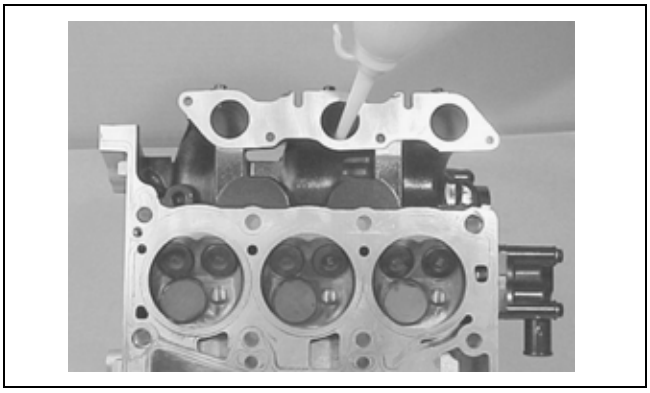
Install the rocker arm shaft brackets and the bolts. Tighten the bolts to a torque of 14 ft. lbs. (19 N·m).



1. Bolts (8) 001463
2. Rocker arm shaft brackets (4)
3. Intake rocker arm shaft
4. Exhaust rocker arm shaft
5. Rocker arms (6)
6. Springs (6)

Fill the intake and exhaust ports with solvent to check for leaks between the valve seats and the valve face.

If a leak occurs, inspect the valve seat and the valve face for burrs or other deposits that could prevent the valve from sealing.



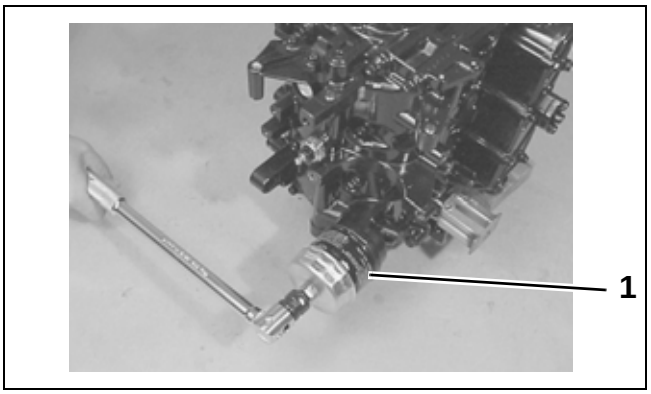
001503

PISTON, CYLINDER, AND CRANKSHAFT

Removal

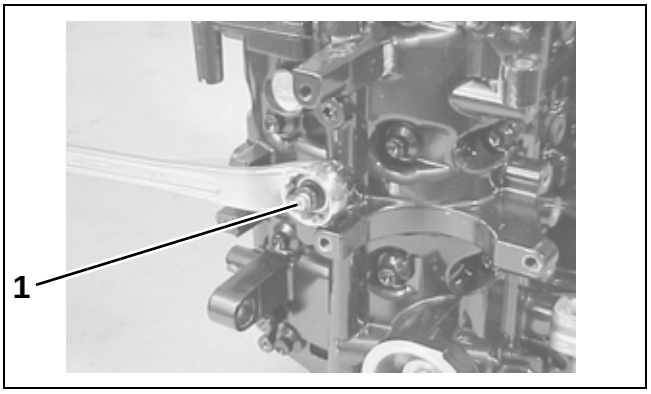
First, remove the powerhead, the timing chain, and the cylinder head.

Remove the oil filter.



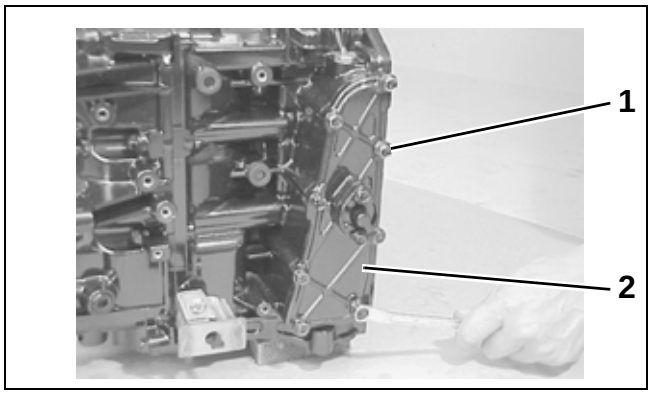
1. Oil filter 001529

Remove the oil pressure switch.



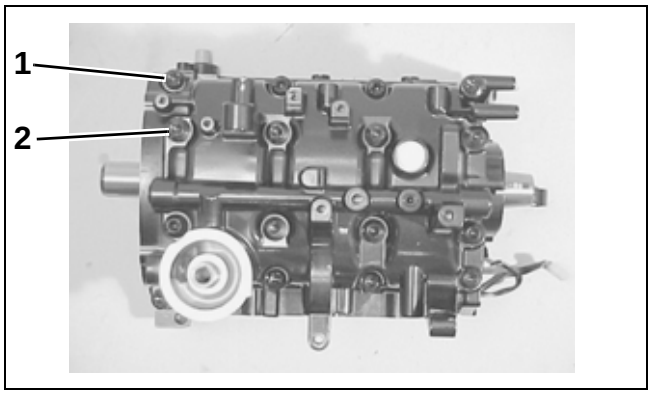
1. Oil pressure switch 001530

Remove eight (8) bolts and the exhaust cover.



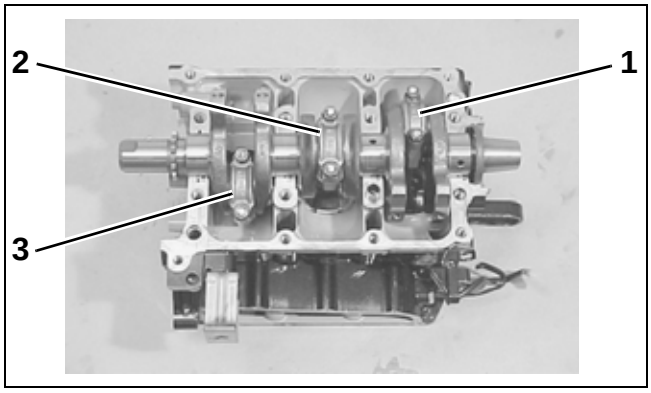
1. Bolts (8) 001531
2. Exhaust cover

Remove eight (8) outer bolts, then eight (8) inner bolts. Remove the crankcase from the cylinder block.



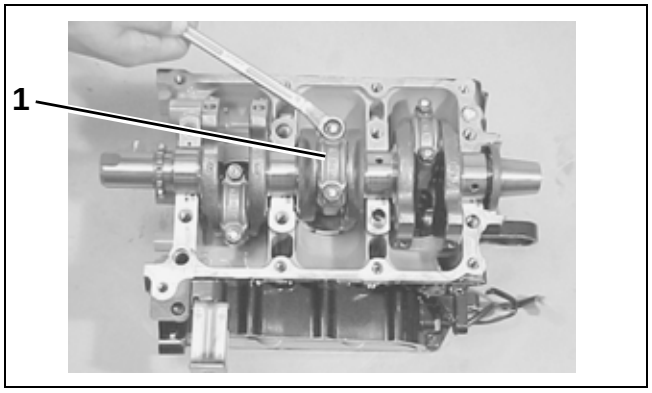
1. Outer bolts (8) 001532
2. Inner bolts (8)

For proper assembly, use quick drying paint to mark the corresponding cylinder number on each connecting rod and connecting rod cap.



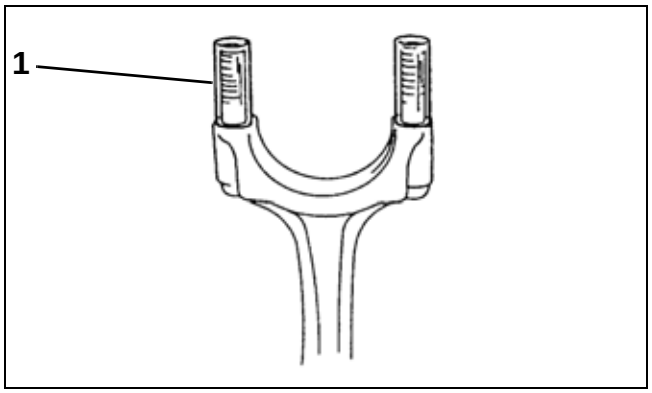
1. Cylinder No. 1 001533
2. Cylinder No. 2
3. Cylinder No. 3

Remove connecting rod cap nuts and the connecting rod caps.



1. Connecting rod cap (3) 001534

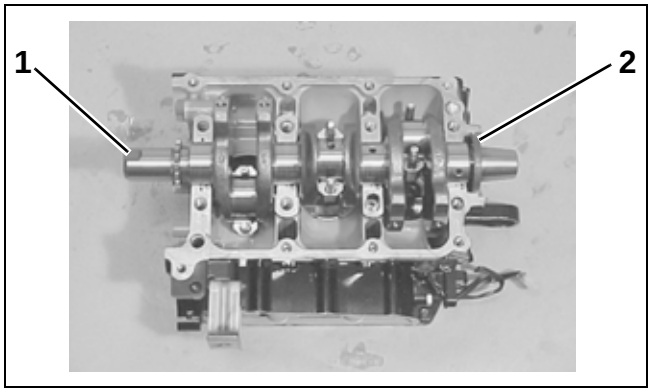
To prevent damage to the crank pin and the cylinder walls, install a piece of hose over the threads of the connecting rod bolts.



1. Connecting rod bolt 001535

Remove the crankshaft.

Remove the oil seal form the crankshaft.



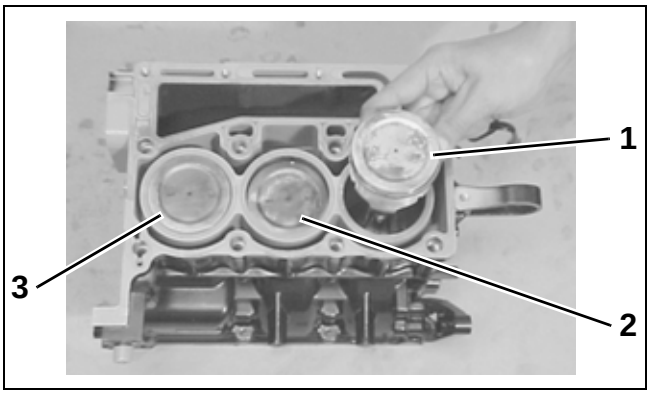
1. Crankshaft 001536
2. Oil seal

IMPORTANT: To prevent damage to the piston rings, remove any carbon deposits from the top of the cylinder bore wall before removing the piston.

Use quick drying paint to mark the corresponding cylinder number on each piston.

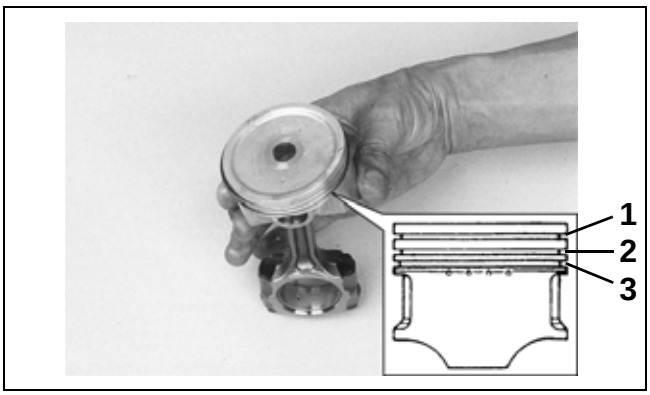
Push out each piston and connecting rod through the top of the cylinder bore.

Reassemble each connecting rod cap and nut onto its original connecting rod.



1. Cylinder No. 1 001537
2. Cylinder No. 2
3. Cylinder No. 3

Remove the top compression ring, the second compression ring, and the oil ring from the piston.

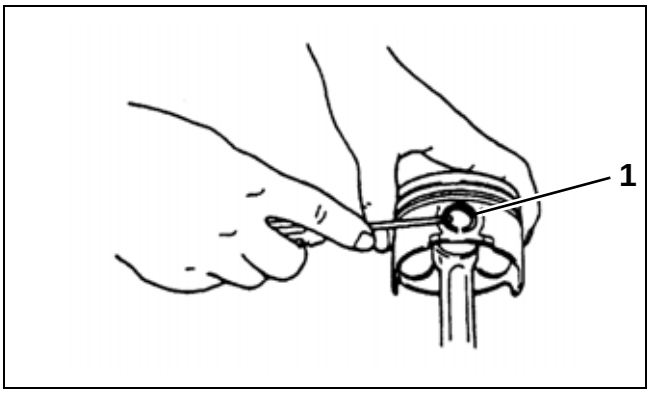


1. Top compression ring 001538
2. Second compression ring
3. Oil ring

⚠ WARNING ⚠

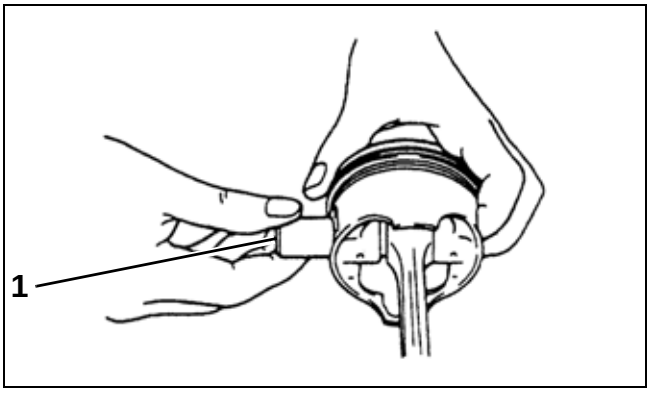
When removing or installing any type of retaining rings, wear eye protection to avoid personal injury.

Remove two (2) retaining rings from each piston as shown.



1. Retaining ring 001539

Remove the wrist pin from the connecting rod and the piston.



1. Wrist pin 001540

IMPORTANT: Keep the connecting rods and wrist pins with their respective pistons.

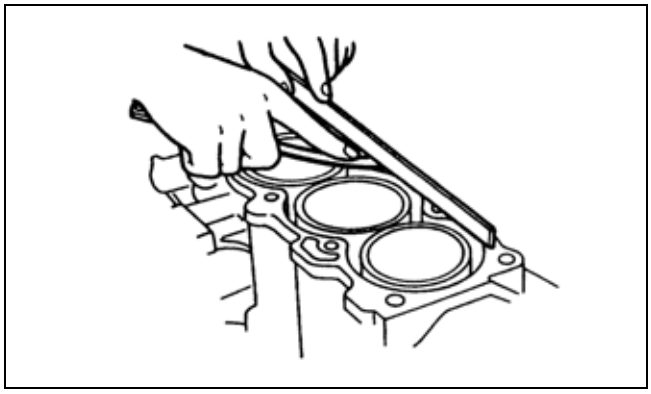
Inspection and Servicing

Cylinder

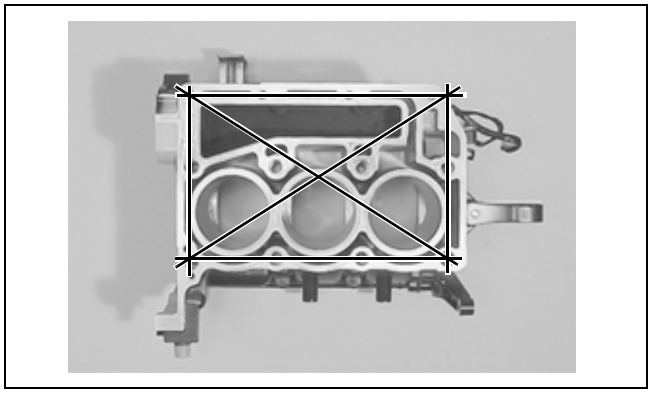
Use a straightedge and a thickness gauge to measure the cylinder distortion on the gasket surface at six (6) locations as shown.

The service limit for distortion is 0.0012 in. (0.03 mm). If any measurement exceeds this specification, resurface or replace the cylinder.

The cylinder can be resurfaced using a surface plate and #400 grit wet sandpaper. Move the cylinder in a figure eight pattern when sanding.

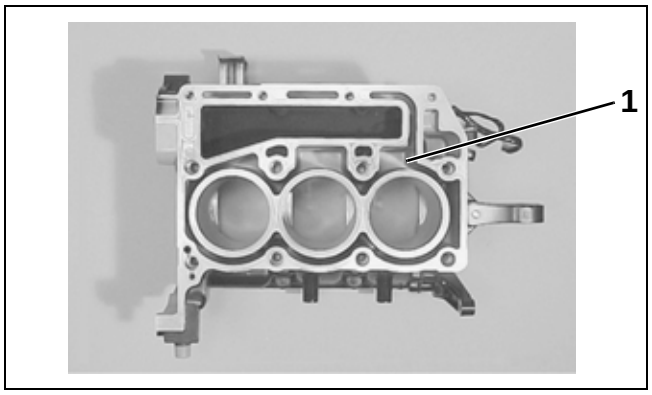


001543



001544

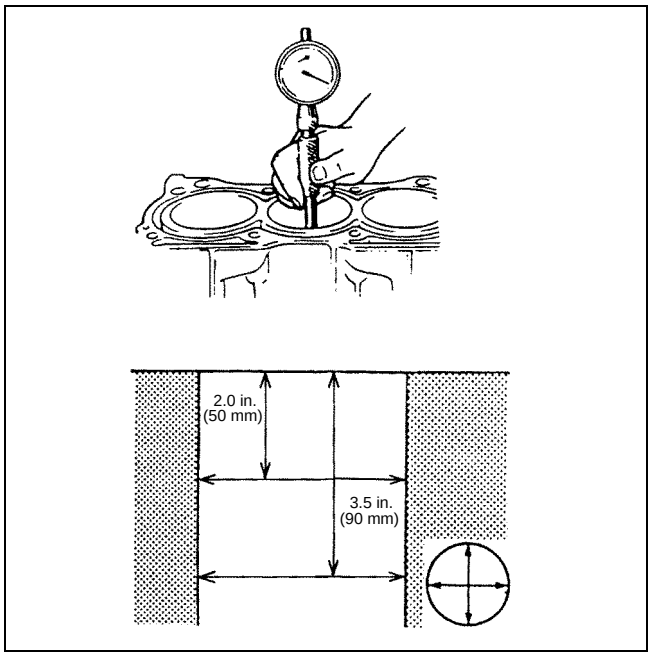
Check the water jackets for clogs or obstructions.



1. Water jacket 001544

Inspect the cylinder walls for scratches, roughness, or ridges which indicate excessive wear. If damaged or worn, rebore the cylinder and use an oversize piston.

Use a cylinder gauge to measure the cylinder bore in the axial direction (vertical line following crankshaft) and the transverse direction (horizontal line across crankshaft). Take measurements at two different depths: 2.0 in. (50 mm) and 3.5 in. (90 mm).



001545

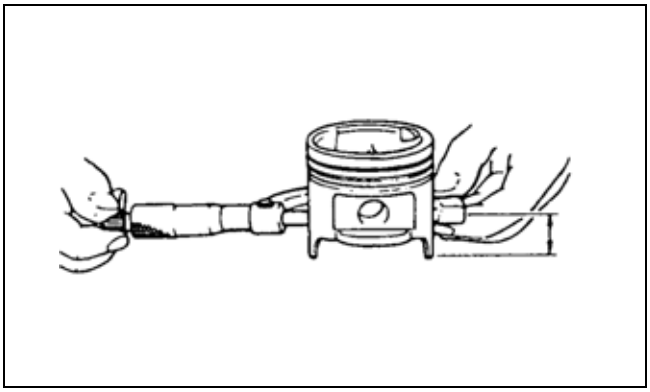
The difference between the two depth measurements is the cylinder bore taper.

The difference between the axial and transverse measurements is the cylinder bore out-of-round.

The service limit for cylinder bore wear is 0.004 in. (0.10 mm). If either the taper or out-of-round measurement exceeds this specification, rebore or replace the cylinder.

Use a micrometer to measure the piston diameter at a point 0.75 in. (19 mm) above the piston skirt at a 90° angle to the wrist pin bore.

Cylinder Bore and Piston Skirt Specifications	
Cylinder Bore Diameter	2.5591 to 2.5598 in. (65.000 to 65.020 mm)
Piston Skirt Diameter	2.5579 to 2.5587 in. (64.970 to 64.990 mm)



001546

To find the piston-to-cylinder bore clearance, subtract the piston skirt diameter from the previous cylinder bore measurement at a depth of 2.0 in. (50 mm).

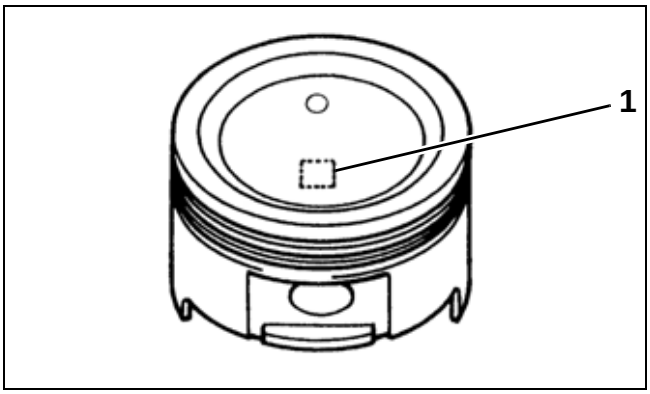
If the measurement exceeds the service limit, replace the piston and/or the cylinder, or rebore the cylinder.

Piston-to-Cylinder Bore Clearance	
Standard	0.0008 to 0.0016 in. (0.02 to 0.04 mm)
Service Limit	0.004 in. (0.10 mm)

Pistons and Rings

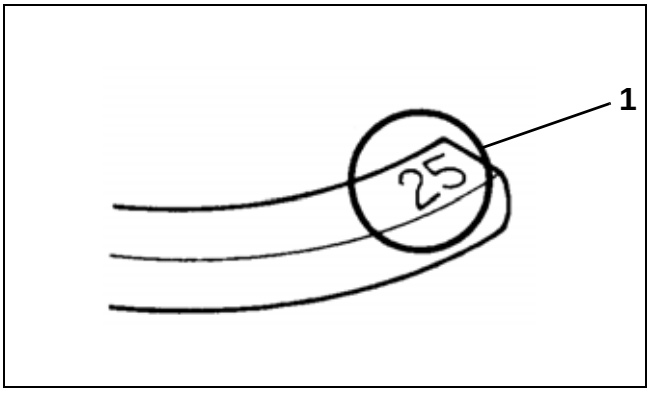
Two oversize piston and piston ring components are available. Oversize pistons and piston rings are marked as shown below.

Piston	
Oversize	**ID Mark**
0.25 mm	0.25
0.50 mm	0.50



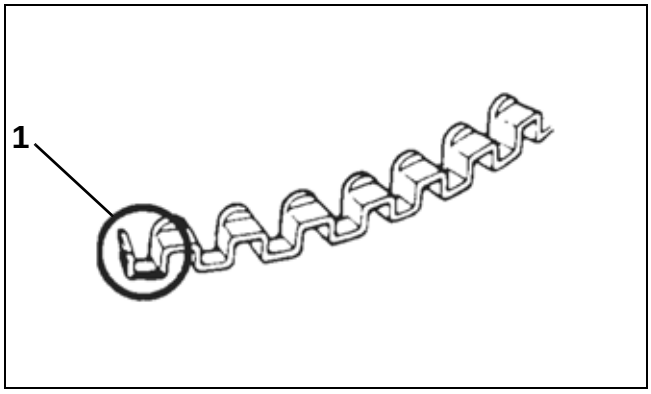
1. ID mark – piston 001548

Top and Second Compression Rings	
Oversize	**ID Mark**
0.25 mm	25
0.50 mm	50



1. ID mark – top and second compression rings 001549

Oil Ring	
Oversize	**ID Mark**
0.25 mm	Two blue marks
0.50 mm	Red mark



1. ID mark - oil ring 001550

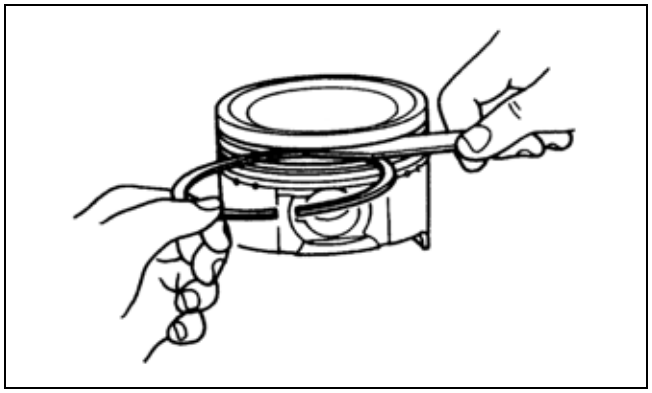
Inspect the pistons for faults, cracks, and other damage. Replace any damaged pistons.

Inspect the piston ring grooves. Remove any carbon deposits. Clean and dry the piston thoroughly.

Fit the compression ring into the groove. Use a thickness gauge to measure the clearance between the ring and the groove.

If the measurement exceeds the service limit, replace the piston and/or the piston rings.

Piston Ring-to-Groove Clearance		
Standard	Top	0.0012 to 0.0027 in. (0.03 to 0.07 mm)
	2nd	0.0008 to 0.0024 in. (0.02 to 0.06 mm)
Service Limit	Top	0.005 in. (0.12 mm)
	2nd	0.004 in. (0.10 mm)



001551

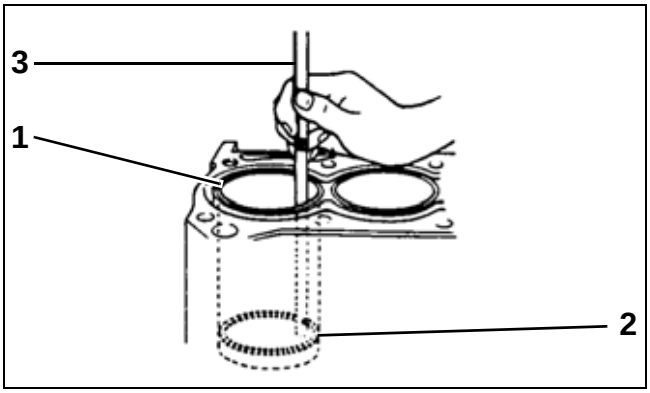
Piston Ring Groove Width	
Top compression ring	0.0400 to 0.0410 in. (1.02 to 1.04 mm)
2nd compression ring	0.0476 to 0.0484 in. (1.21 to 1.23 mm)
Oil ring	0.0790 to 0.0800 in. (2.01 to 2.03 mm)

Piston Ring Thickness	
Top compression ring	0.038 to 0.039 in. (0.97 to 0.99 mm)
2nd compression ring	0.046 to 0.047 in. (1.17 to 1.19 mm)

Insert the piston ring into the lowest position of the cylinder bore. Use a thickness gauge to measure the piston ring end gap.

If the measurement exceeds the service limit, replace the piston rings.

Piston Ring End Gap		
Standard	Top	0.005 to 0.011 in. (0.12 to 0.27 mm)
	2nd	0.014 to 0.020 in. (0.35 to 0.50 mm)
Service Limit	Top	0.028 in. (0.70 mm)
	2nd	0.039 in. (1.00 mm)



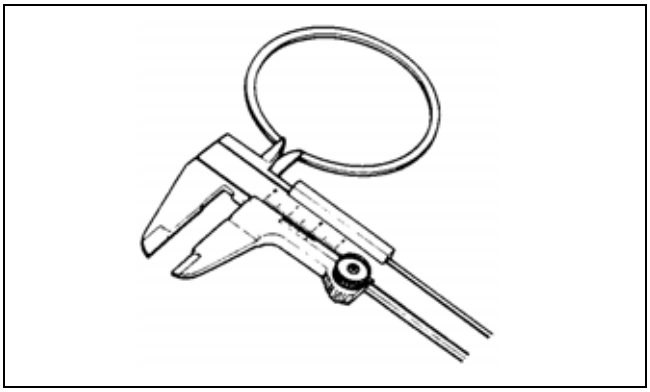
1. *Cylinder*
2. *Piston ring*
3. *Thickness gauge*

001552

Use vernier calipers to measure the piston ring free end gap.

If the measurement exceeds the service limit, replace the piston rings.

Piston Ring Free End Gap		
Standard	Top	0.36 in. (9.1 mm)
	2nd	0.35 in. (9.0 mm)
Service Limit	Top	0.29 in. (7.3 mm)
	2nd	0.28 in. (7.2 mm)



001553

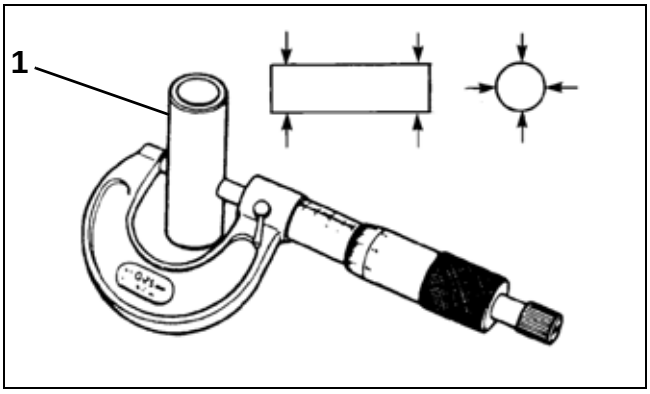
Wrist Pin and Bores

Inspect the wrist pin and the bores in the piston and the connecting rod for wear and damage.

Use a micrometer to check the wrist pin outside diameter.

If the measurement exceeds the service limit, replace the wrist pin.

Wrist Pin Outside Diameter	
Standard	0.6297 to 0.6299 in. (15.995 to 16.000 mm)
Service Limit	0.6291 in. (15.980 mm)

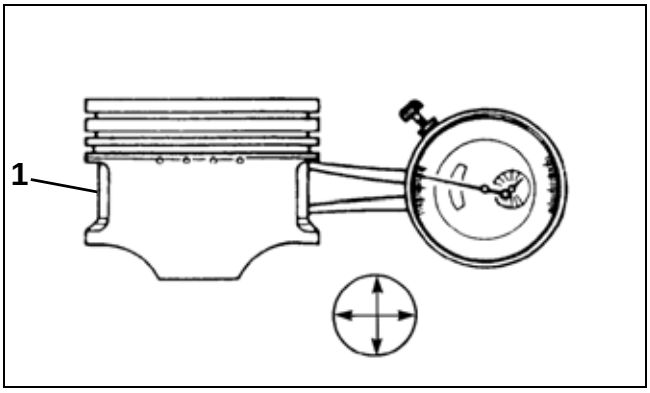


1. Wrist pin 001554

Use dial calipers to measure the piston bore inside diameter.

If the measurement exceeds the service limit, replace the piston assembly.

Piston Bore Inside Diameter	
Standard	0.6302 to 0.6305 in. (16.006 to 16.014 mm)
Service Limit	0.6311 in. (16.030 mm)

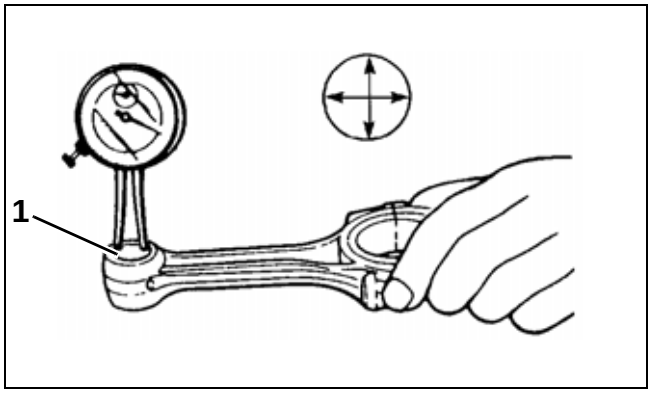


1. Piston bore 001555

Use dial calipers to measure the connecting rod small bore inside diameter.

If the measurement exceeds the service limit, replace the connecting rod.

Connecting Rod Small Bore Inside Diameter	
Standard	0.6300 to 0.6304 in. (16.003 to 16.011 mm)



1. Connecting rod small bore 001556

To check the wrist pin-to-piston bore clearance, subtract the wrist pin outside diameter from the piston bore inside diameter. To check the wrist pin-to-connecting rod small bore clearance, subtract the wrist pin outside diameter from the connecting rod small bore inside diameter.

If either measurement exceeds the service limit, replace the wrist pin or the piston assembly.

Wrist Pin-to-Piston Bore Clearance	
Standard	0.0002 to 0.0007 in. (0.006 to 0.019 mm)
Service Limit	0.0016 in. (0.040 mm)

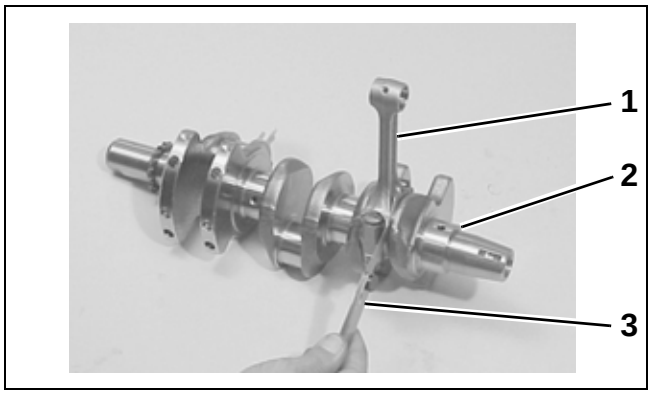
Wrist Pin-to-Connecting Rod Small Bore Clearance	
Standard	0.0001 to 0.0006 in. (0.003 to 0.016 mm)
Service Limit	0.0020 in. (0.050 mm)

Connecting Rod and Crankpin

Install a connecting rod (with bearing) on the crankshaft as shown. Use a thickness gauge to measure the connecting rod large bore side clearance.

If the measurement exceeds the service limit, replace the connecting rod and/or the crankshaft.

Connecting Rod Large Bore Side Clearance	
Standard	0.0039 to 0.0098 in. (0.100 to 0.0250 mm)
Service Limit	0.0138 in. (0.350 mm)



1. *Connecting rod* 001557
2. *Crankshaft*
3. *Thickness gauge*

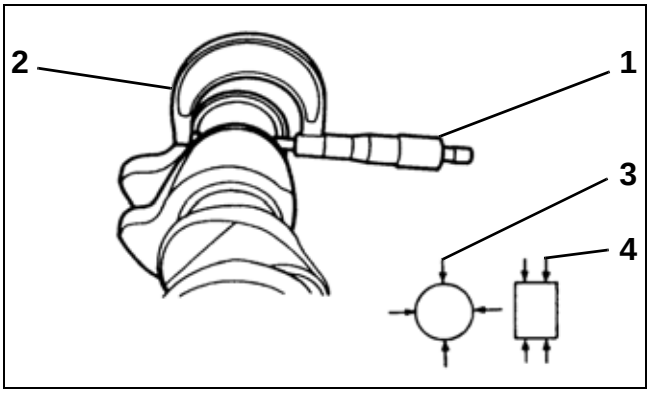
Inspect the crankpins for wear and damage.

Measure the width of the crankpins.

Use a micrometer to measure the crankpins for out-of-round and taper.

If any crankpin is worn or damaged, or the out-of-round or taper exceeds the service limit, replace the crankshaft.

Crankpin Specifications	
Standard Width	0.870 to 0.874 in. (22.10 to 22.20 mm)
Standard Diameter	1.4166 to 1.4173 in. (35.982 to 36.000 mm)
Out-of-Round and Taper Service Limit	0.0004 in. (0.010 mm)



1. *Micrometer* 001558
2. *Crankshaft*
3. *Out-of-round measurement*
4. *Taper measurement*

Use dial calipers to measure the connecting rod large bore inside diameter.

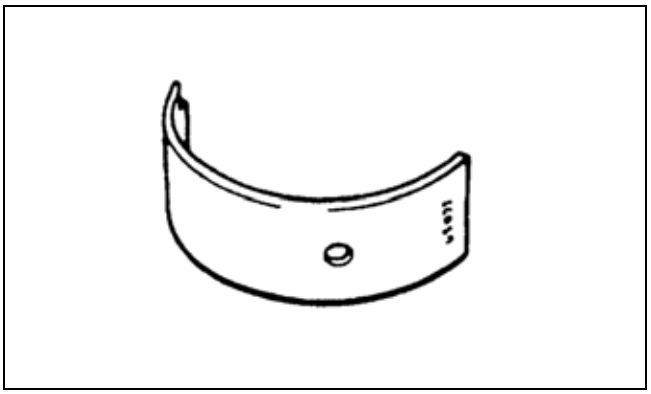
If the measurement exceeds the service limit, replace the connecting rod.

Connecting Rod Large Bore Inside Diameter	
Standard	0.8642 to 0.8661 in. (21.950 to 22.000 mm)

Connecting Rod Bearings

Inspect the bearing shells in the connecting rod large bores and connecting rod caps for the proper contact pattern and signs of fusion, pitting, burning, or flanking. Replace any damaged bearings.

IMPORTANT: NEVER replace only one bearing shell. Both halves of the bearing must be replaced if either is worn or damaged.

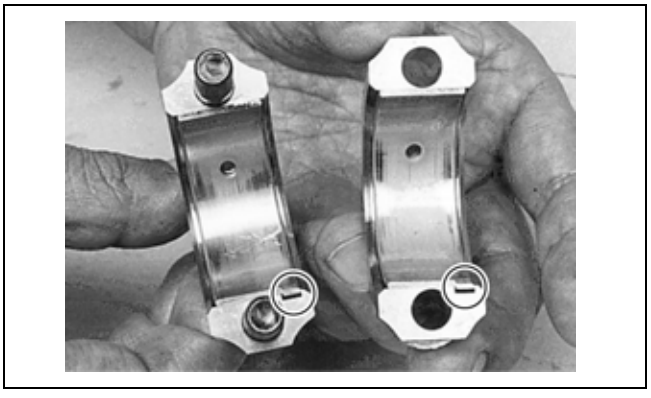


001559

Clean the surface of the connecting rod, the cap, the bearing, and the crankpin.

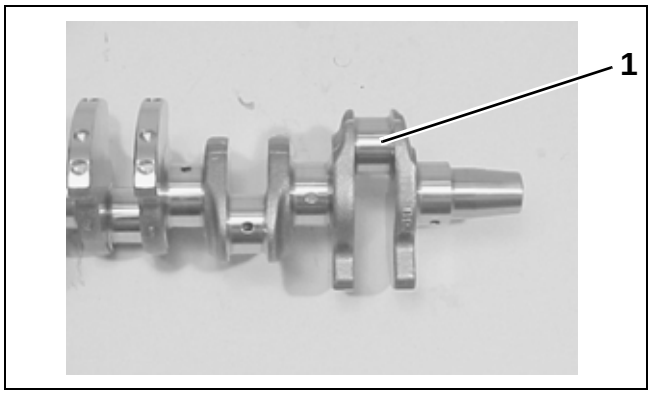
Install the connecting rod bearing shells into their original connecting rod and cap.

IMPORTANT: Make sure that the alignment tabs on the bearing shells properly engage the alignment notches in the connecting rod and cap. DO NOT apply oil to the bearing at this time.



001560

Place a piece of Plastigage on the crankpin, parallel to the crankshaft. DO NOT place the Plastigage over the oil hole.

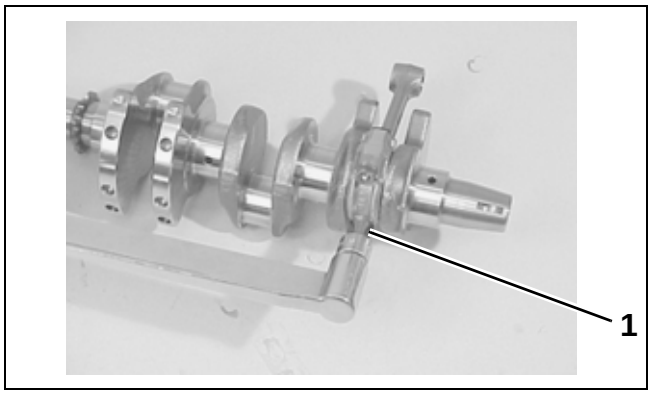


1. Crank pin 001561

Install the connecting rod cap to its corresponding connecting rod. Make sure that the arrow mark on the cap is pointing toward the flywheel side.

Apply engine oil to the connecting rod bolts. Install and tighten the connecting rod cap nuts in the following manner:

- **STEP 1** – Tighten the nuts to an initial torque of 13 ft. lbs. (18 N·m).
- **STEP 2** – Tighten the nuts to a final torque of 26 ft. lbs. (35 N·m).



1. Connecting rod bolts (2) 001563

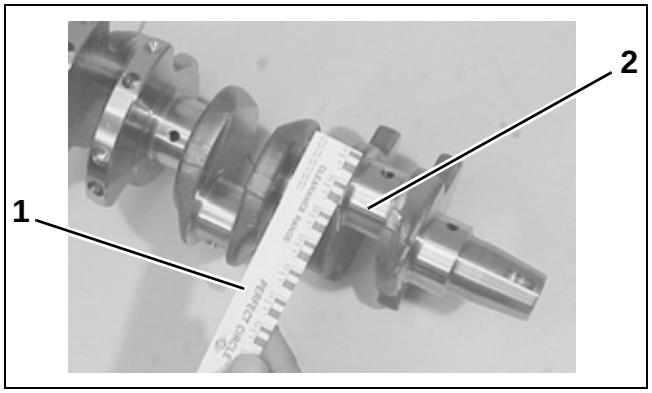
IMPORTANT: DO NOT rotate the connecting rod or the crankshaft while the Plastigage is in place.

Remove the connecting rod and the cap from the crankpin.

Use the scale on the Plastigage envelop to measure the Plastigage on the crankpin at its widest point.

If the measurement exceeds the service limit, replace the connecting rod bearing.

Connecting Rod Large Bore Oil Clearance	
Standard	0.0008 to 0.0016 in. (0.020 to 0.040 mm)
Service Limit	0.0026 in. (0.065 mm)



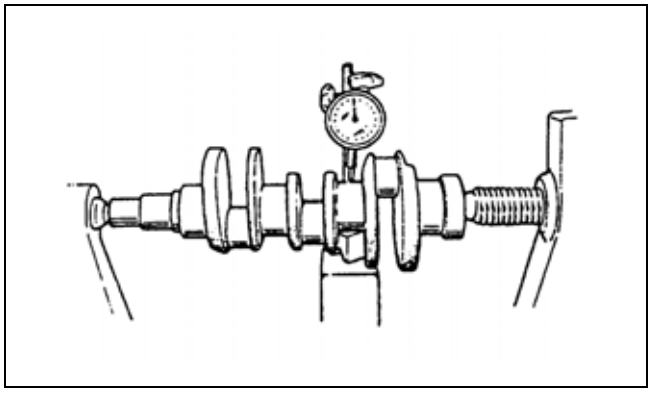
1. Scale
2. Plastigage

001564

Crankshaft

Use a dial gauge to measure the center journal runout.

The service limit for crankshaft center journal runout is 0.002 in. (0.04 mm). If the measurement exceeds the service limit, replace the crankshaft.

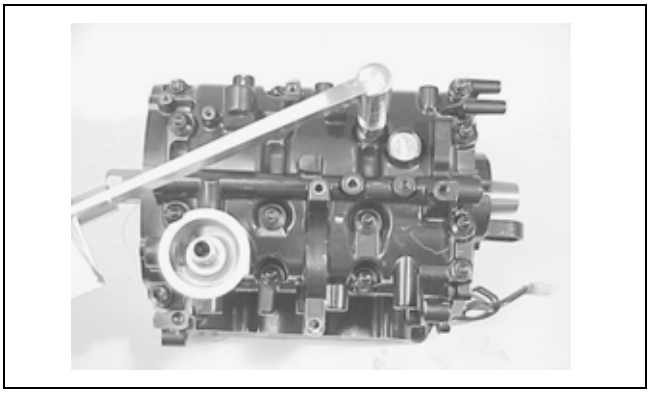


001565

Assemble the crankshaft thrust bearing, the crankshaft journal bearing, the crankshaft, and the crankcase to the cylinder block.

Apply engine oil to 16 crankcase bolts, then place the bolts in the bolt holes. Tighten the bolts to the specified torque.

Crankcase Bolt Torques	
8 mm	18 ft. lbs. (25 N·m)
10 mm	29 ft. lbs. (40 N·m)

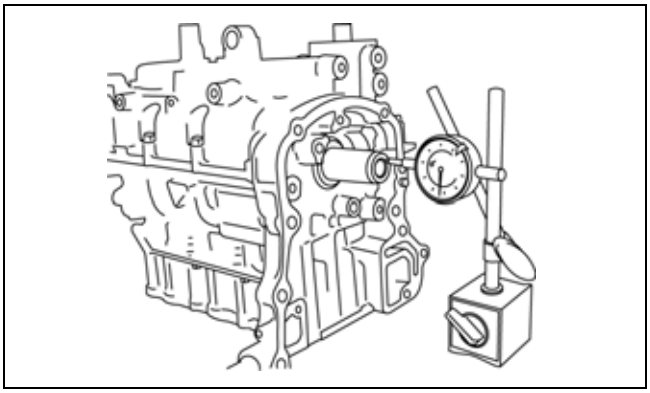


001574

Use a dial gauge to measure the play in the axial (thrust) direction of crankshaft.

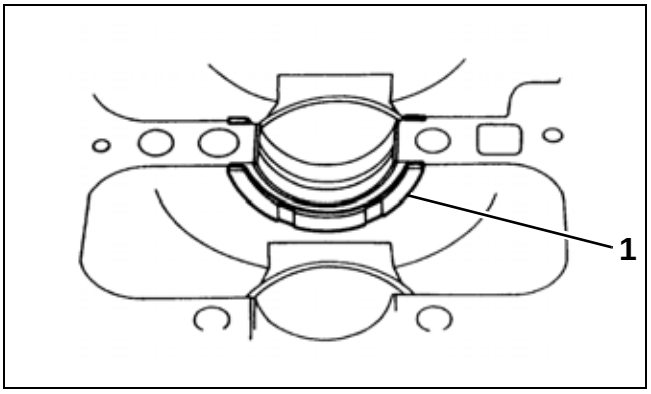
If the measurement exceeds the service limit, replace the crankshaft thrust bearing.

Crankshaft Thrust Play	
Standard	0.004 to 0.012 in. (0.11 to 0.31 mm)
Service Limit	0.014 in. (0.35 mm)



001566

Crankshaft Thrust Bearing Flange Thickness	
Standard	0.0972 to 0.0992 in. (2.470 to 2.520 mm)



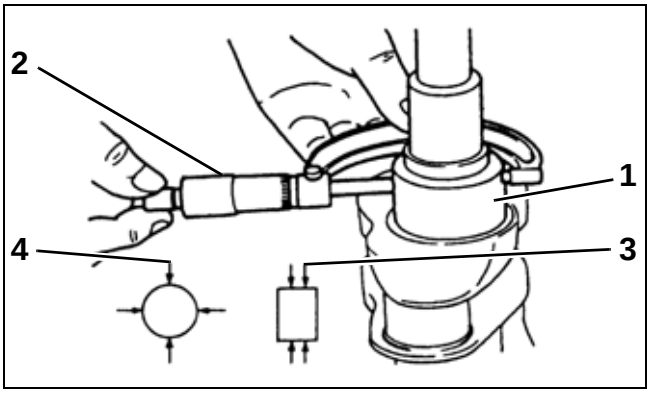
1. Crankshaft thrust bearing flange 001567

Inspect the crankshaft journals for wear and damage.

Use a micrometer to measure the crankshaft journal for out-of-round and taper.

If any crankshaft journal is worn or damaged, or the out-of-round or taper exceeds the service limit, replace the crankshaft.

Crankshaft Journal Specifications	
Standard Diameter	1.5741 to 1.5748 in. (39.982 to 40.000 mm)
Out-of-Round and Taper Service Limit	0.0004 in. (0.010 mm)

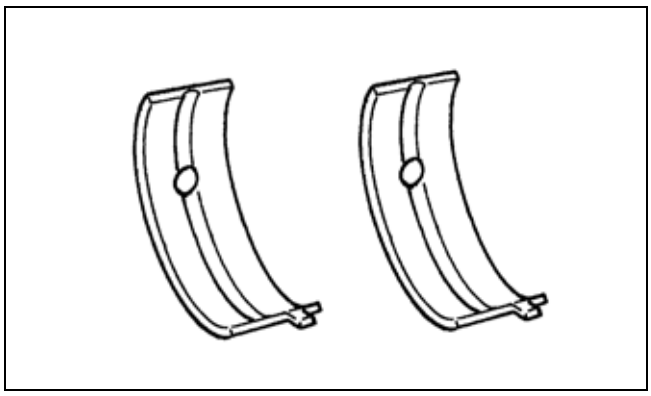


1. Crankshaft journal 001568
2. Micrometer
3. Taper measurement
4. Out-of-round measurement

Crankshaft Main Bearings

Inspect the crankshaft bearing shells for pitting, scratches, and wear. Replace any damaged bearings.

IMPORTANT: NEVER replace only one bearing shell. Both halves of the bearing must be replaced if either is worn or damaged.

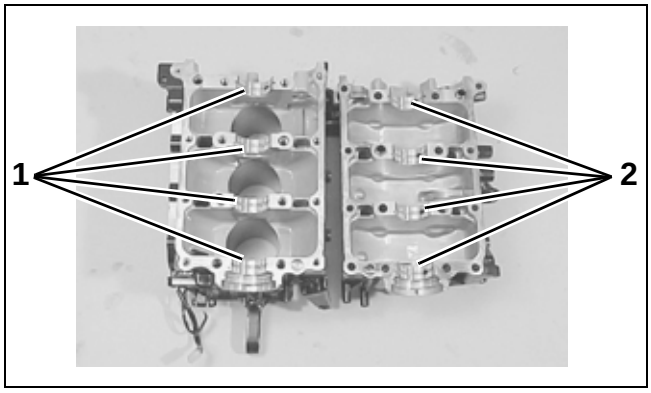


001569

Clean the surface of the bearing holders, the bearings, and the main bearing journals.

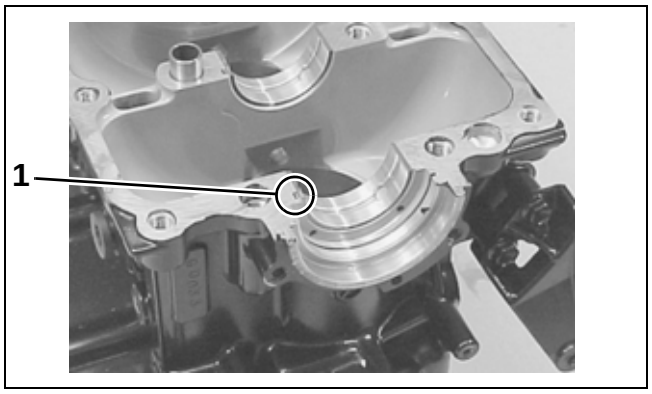
Install the bearing shells into their original locations.

Install the main bearings in the cylinder and the crankcase.



1. Upper bearing shells 001570
2. Lower bearing shells

IMPORTANT: Make sure that the alignment tabs on the bearing shells properly engage the alignment notches in the connecting rod and cap. DO NOT apply oil to the bearing at this time.

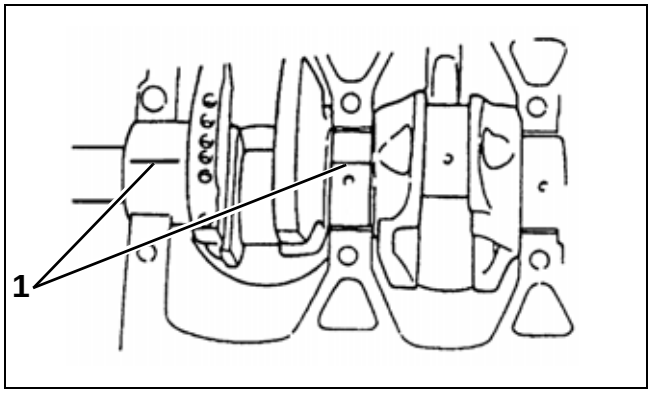


1. Bearing tab 001571

Install the crankshaft in the cylinder.

Place a piece of Plastigage across the full width of the bearing on the journal, parallel to the crankshaft. DO NOT place the Plastigage over the oil hole.

IMPORTANT: DO NOT rotate the crankshaft while the Plastigage is in place.



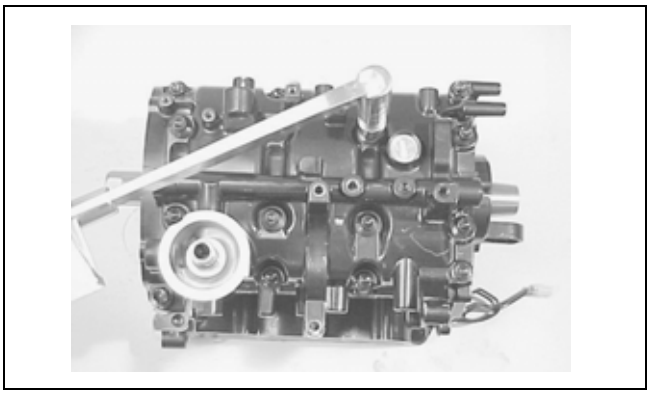
1. Plastigage 001572

Install the crankcase onto the cylinder.

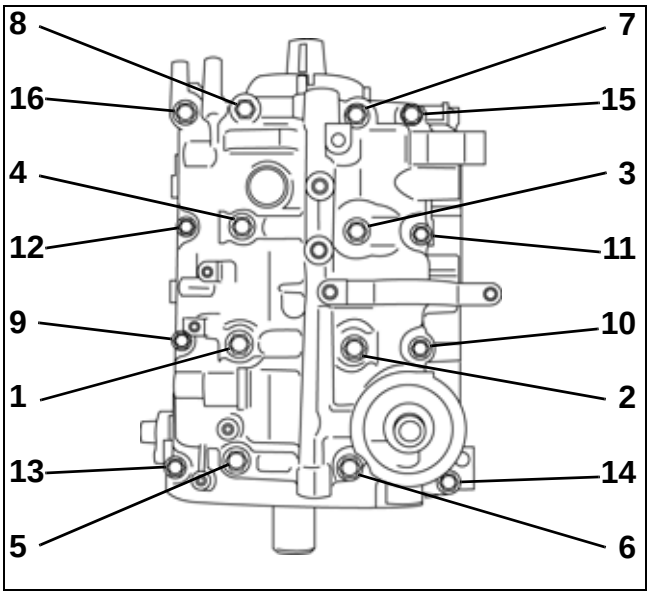
Apply engine oil to 16 crankcase bolts, then place the bolts in the bolt holes. Tighten the bolts in the following manner:

- **STEP 1** – Tighten the bolts to the initial torque according to the tightening sequence.
- **STEP 2** – Next, tighten the bolts to the second torque according to the tightening sequence.
- **STEP 3** – Finally, tighten the bolts to the final torque according to the tightening sequence.

Crankcase Bolt Torques			
Bolt size	**Initial**	**Second**	**Final**
8 mm	36 in. lbs. (4 N·m)	12 ft. lbs. (16 N·m)	15 ft. lbs. (20 N·m)
10 mm	71 in. lbs. (8 N·m)	24 ft. lbs. (32 N·m)	30 ft. lbs. (40 N·m)

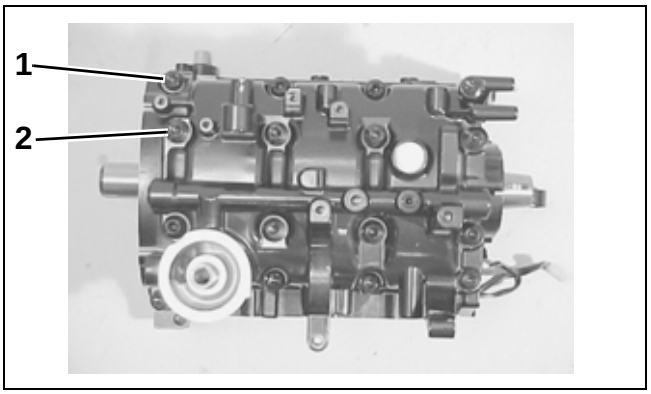


001574



001573

Remove eight (8) outer bolts, then eight (8) inner bolts. Remove the crankcase from the cylinder block.

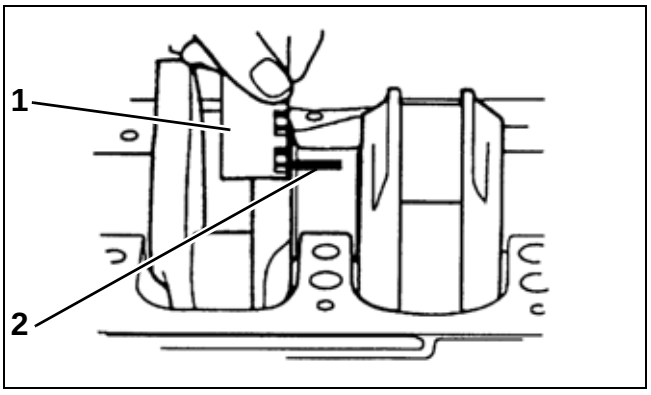


1. Outer bolts (8)
2. Inner bolts (8)
001532

Use the scale on the Plastigage envelop to measure the Plastigage on the journal at its widest point.

If the measurement exceeds the service limit, replace the crankshaft main bearing.

Crankshaft Journal Oil Clearance	
Standard	0.0008 to 0.0016 in. (0.020 to 0.040 mm)
Service Limit	0.0026 in. (0.065 mm)



1. Scale
2. Plastigage
001575

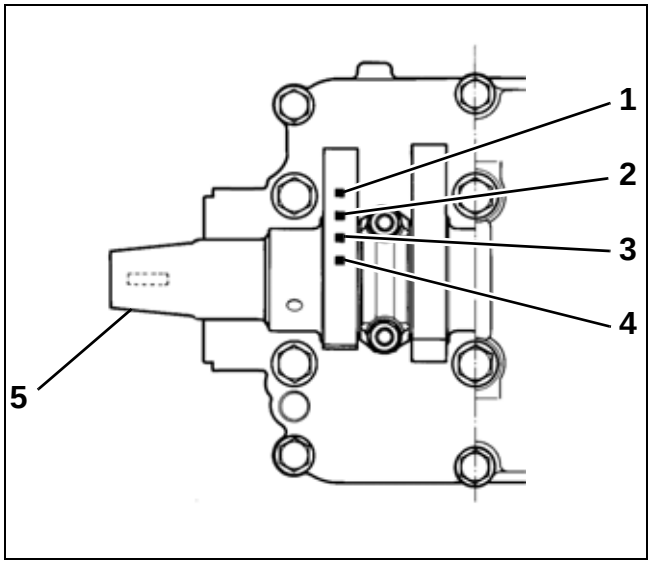
Selecting a Main Bearing

Whenever a main bearing requires replacement, select a new bearing according to following procedure.

- Check the main bearing journal diameter.

The upper (flywheel side) crank web of the No.1 cylinder has four (4) stamped numerals. The numerals 1, 2, and 3 represent the following journal diameters.

Numeral Stamped	Main Bearing Journal Diameter
1	1.5746 to 1.5748 in. (39.994 to 40.000 mm)
2	1.5743 to 1.5746 in. (39.998 to 39.994 mm)
3	1.5741 to 1.5743 in. (39.982 to 39.988 mm)

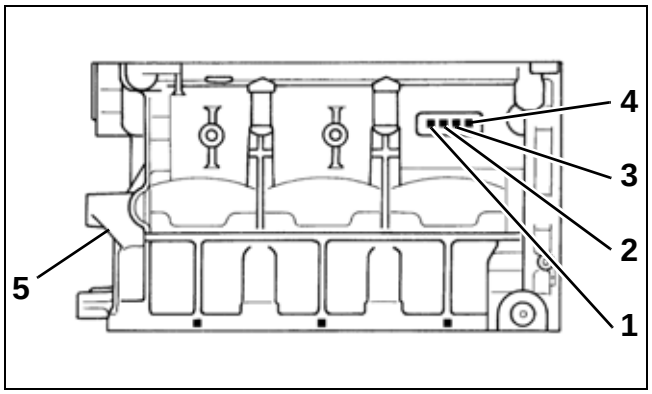


1. No. 1 journal code
2. No. 2 journal code
3. No. 3 journal code
4. No. 4 journal code
5. Crankshaft (flywheel side)
001576

- Check the inside diameter of the bearing holder **without** the bearing installed.

The starboard side of the cylinder block has four (4) stamped code letters. The letters A, B, and C represent the following bearing holder inside diameter shown below.

Code	Crankshaft Bearing Holder Diameter (without bearing)
A	1.7323 to 1.7325 in. (44.000 to 40.006 mm)
B	1.7325 to 1.7328 in. (40.006 to 40.012 mm)
C	1.7328 to 1.7330 in. (40.012 to 40.018 mm)

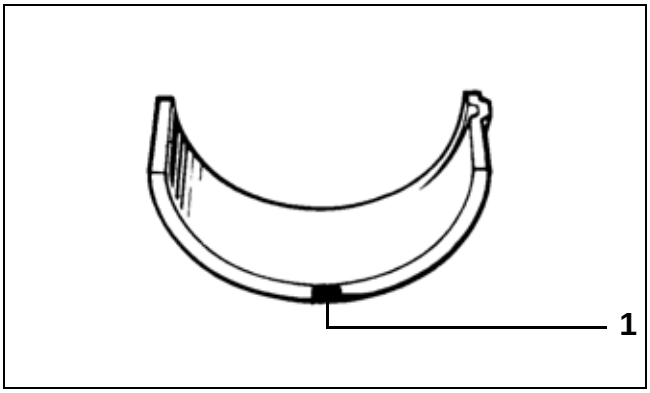


1. *No. 1 holder code*
2. *No. 2 holder code*
3. *No. 3 holder code*
4. *No. 4 holder code*
5. *Cylinder head (flywheel side)*

001577

- There are five main bearing available, each of a different thickness. To distinguish between them, a color mark is painted at the midpoint on the rim of the bearing. Each color represents the following thickness (measured at the center of the bearing).

Color Mark	Bearing Thickness
Green	0.0768 to 0.0787 in. (1.996 to 2.000 mm)
Black	0.0787 to 0.0789 in. (1.999 to 2.003 mm)
No color	0.0788 to 0.0790 in. (2.002 to 2.006 mm)
Yellow	0.0789 to 0.0791 in. (2.005 to 2.009 mm)
Blue	0.0791 to 0.0792 in. (2.008 to 2.012 mm)



1. *Color mark*

001578

- Select the correct crankshaft main bearing. Refer to the following table.

Holder Code	Journal Code		
	1	2	3
A	Green	Black	No color
B	Black	No color	Yellow
C	No color	Yellow	Blue

- Measure the crankshaft journal oil clearance again after selecting and installing the new bearing.

7

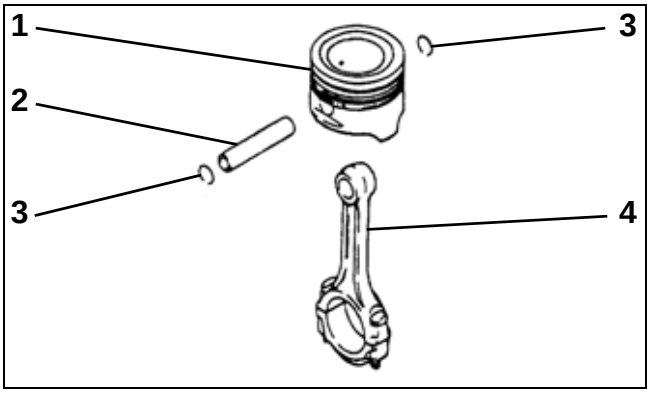
Installation

IMPORTANT: Before installing the pistons and the crankshaft, inspect and service the components. Refer to “Inspection and Servicing” on page 152.

IMPORTANT: If the original components are not replaced, each piston, wrist pin, connecting rod, and connecting rod cap must be assembled and installed in its original order and position.

Apply engine oil to the wrist pin and the pin bore in the connecting rod. Insert the wrist pin through the piston and the connecting rod.

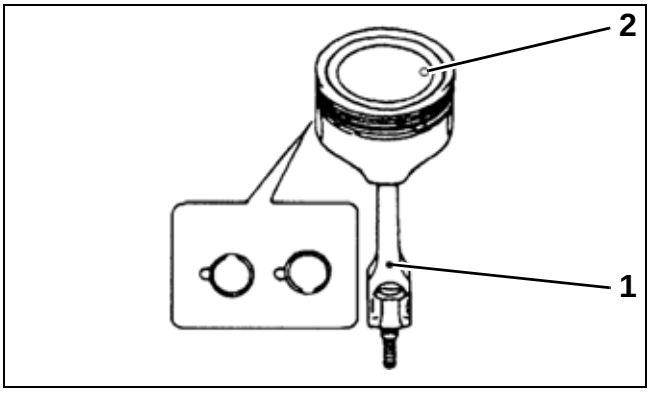
Install **new** retaining rings to secure the wrist pin.



1. *Piston* 001584
2. *Wrist pin*
3. *Piston pin retaining clip*
4. *Connecting rod*

Make sure the connecting rod is installed in the direction shown.

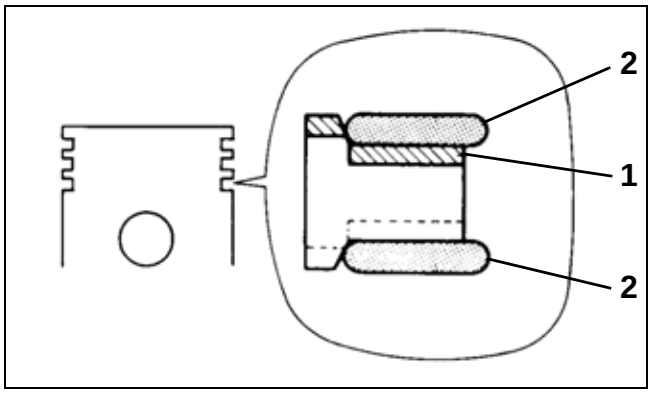
Make sure the retaining rings are installed with the gap facing either up or down.



1. *Oil hole* 001583
2. *“O” mark (flywheel side of piston)*

Apply engine oil to the oil ring.

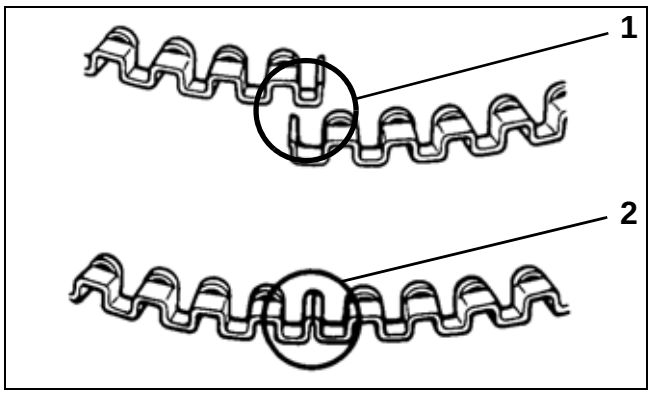
Install the spacer to the piston, then the side rails.



1. *Side rails* 001585
2. *Spacer*

⚠ CAUTION ⚠

When installing the spacer, do not allow the ends to overlap in the groove.

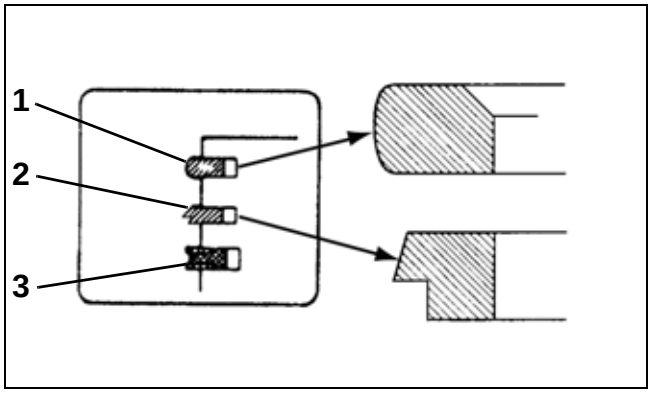


1. *Incorrect (overlapping ends)* 001586
2. *Correct (joined ends)*

Apply engine oil to the compression rings.

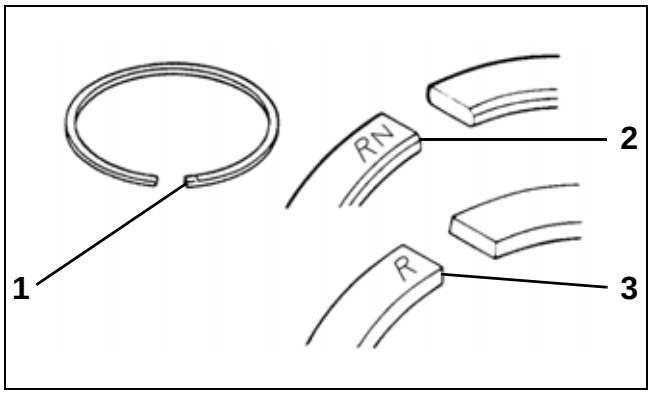
Install the second compression ring to the piston, then the top compression ring.

IMPORTANT: The top compression ring differs from the second compression ring in shape and color of the surface contacting the cylinder wall.



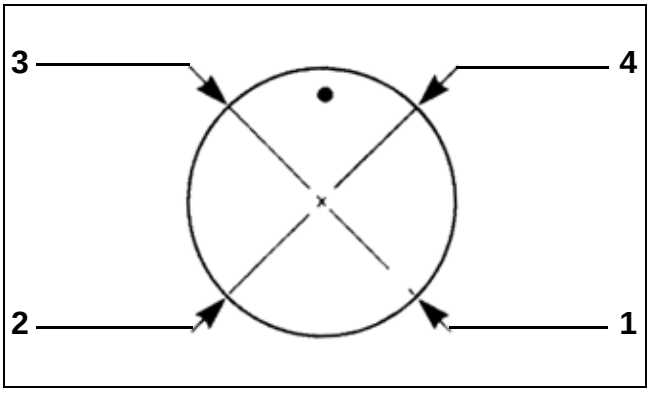
1. Top compression ring 001587
2. 2nd compression ring
3. Oil ring

IMPORTANT: The top compression ring and the second compression ring are marked “RN” or “R”. When installing these piston rings, the marked side must face toward the top of the piston.



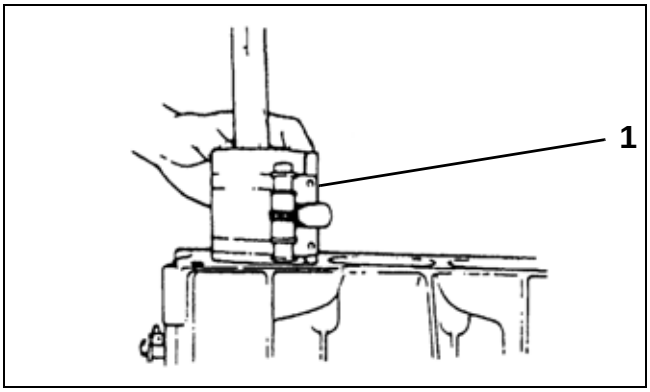
1. ID mark location 001588
2. Top compression ring (“RN”)
3. Second compression ring (“R”)

IMPORTANT: Position the piston rings so their gaps are each staggered by approximately 90°, as shown. Failure to stagger the piston ring gaps may result in crankcase oil dilution.

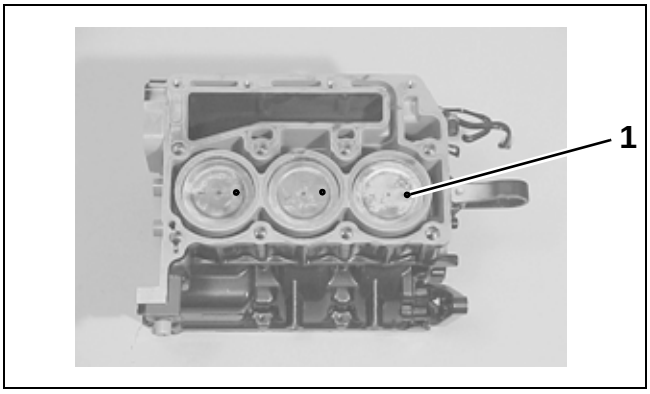


1. Top compression ring 001589
2. Oil ring lower side rail
3. 2nd compression ring
4. Oil ring upper side rail

Apply engine oil to the piston and the cylinder walls. Use a piston ring compressor to insert the piston and connecting rod assembly into the cylinder bore from the cylinder head side. Position the “O” mark on the top of the piston to the flywheel side.

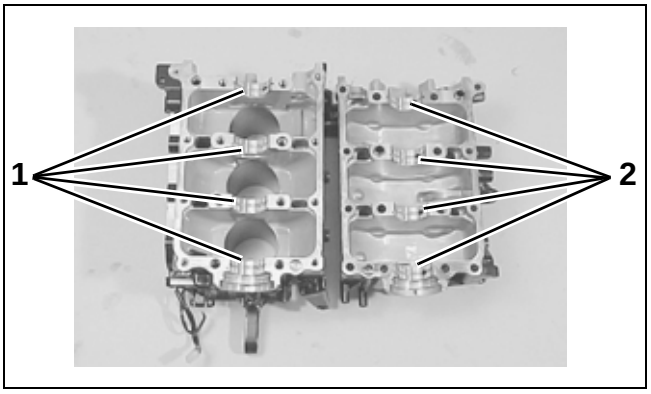


1. Piston ring compressor 001591



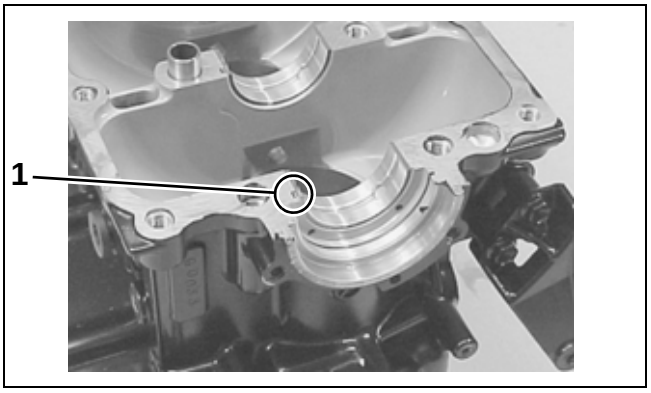
1. “O” mark (flywheel side of piston) 001592

If removed, install the crankshaft main bearings. Apply engine oil to the bearing wear surfaces. DO NOT apply oil between the bearing holder and the back of the bearing.



1. Upper bearing shells 001570
2. Lower bearing shells

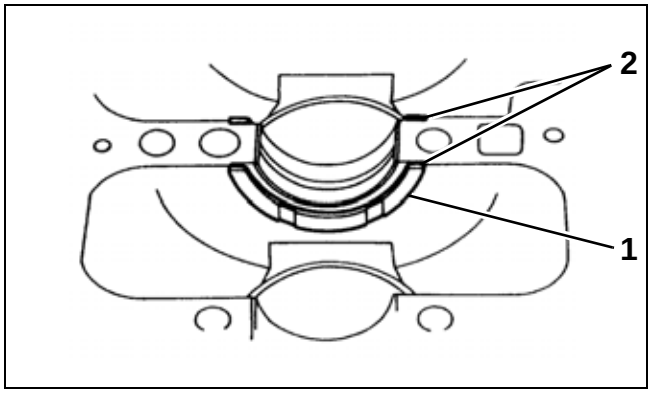
IMPORTANT: Make sure that the bearing tab is aligned with the notches in the cylinder and the crankcase.



1. Bearing tab 001571

If removed, install the main thrust bearing in the cylinder block between the No. 2 and No. 3 cylinders. Apply engine oil to the bearing.

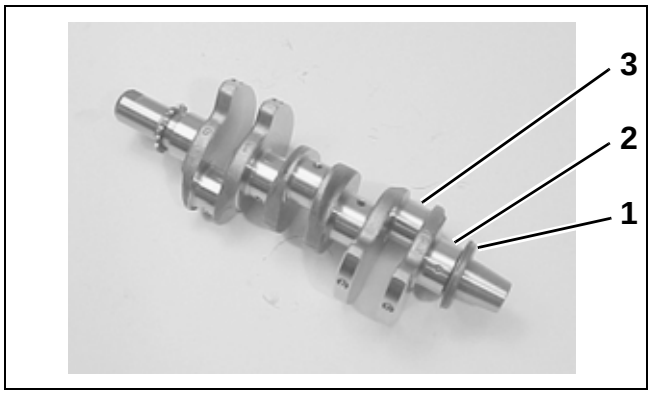
IMPORTANT: The oil groove sides of the thrust bearing must face toward the crank webs.



1. Thrust bearing 001567
2. Oil grooves

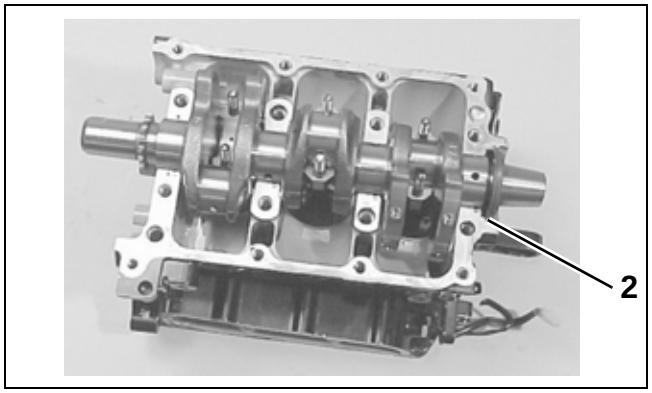
Apply engine oil to the lip of a **new** upper oil seal. Install the upper oil seal to the crankshaft. Make sure that the lip of the seal is facing inward.

Apply engine oil to the crank pin and the crankshaft main journal. Install the crankshaft in the cylinder.



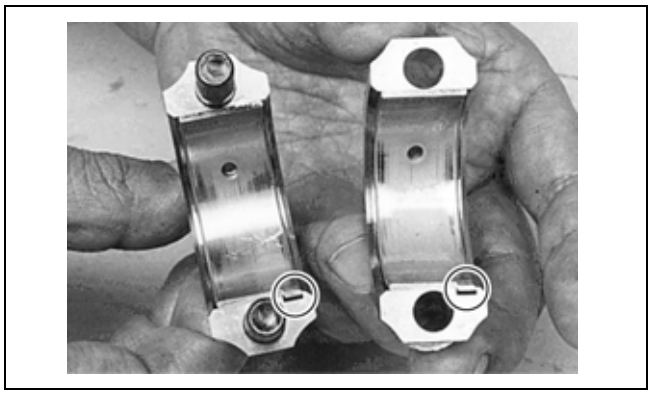
1. Oil seal 001593
2. Crankshaft main journal
3. Crank pin

IMPORTANT: Make sure that the tab of the oil seal fits into the groove in the cylinder.



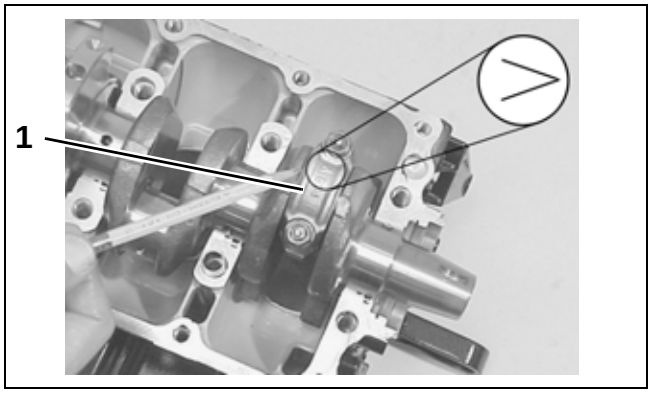
1. Cylinder groove 001594

Install the bearings. Make sure that the alignment tabs on the bearing shells properly engage the alignment notches in the connecting rod and cap.



001560

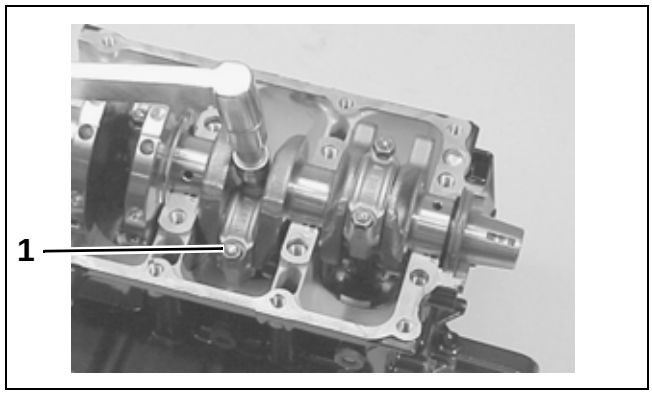
Apply engine oil to the crankpin and the connecting rod bearing. Install the connecting rod cap (with bearing installed) to its corresponding connecting rod. Make sure that the arrow mark on the cap is pointing toward the flywheel side.



1. Connecting rod cap 001562

Apply engine oil to the connecting rod bolts. Install and tighten the connecting rod cap nuts in the following manner:

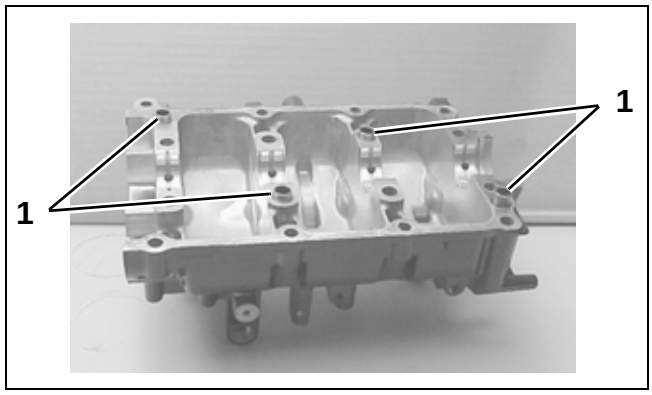
- **STEP 1** – Tighten the nuts to an initial torque of 13 ft. lbs. (18 N·m).
- **STEP 2** – Tighten the nuts to a final torque of 26 ft. lbs. (35 N·m).



1. Connecting rod cap nuts 001595

Clean the mating surfaces of the cylinder and the crankcase.

Apply *Three Bond No. 1207B* along the entire mating surface of the crankcase. DO NOT allow any bond to contact the thrust bearing.
Install four (4) dowel pins in the cylinder.



1. Dowel pins (4) 001597

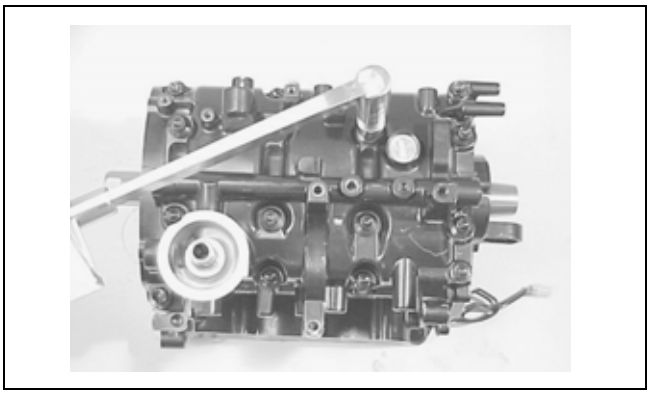
Install the crankcase onto the cylinder.

Apply engine oil to 16 crankcase bolts, then place the bolts in the bolt holes. Tighten the bolts in the following manner:

- **STEP 1** – Tighten the bolts to the initial torque according to the tightening sequence.
- **STEP 2** – Next, tighten the bolts to the second torque according to the tightening sequence.

- **STEP 3** – Finally, tighten the bolts to the final torque according to the tightening sequence.

Crankcase Bolt Torques			
Bolt size	**Initial**	**Second**	**Final**
8 mm	36 in. lbs. (4 N·m)	12 ft. lbs. (16 N·m)	15 ft. lbs. (20 N·m)
10 mm	71 in. lbs. (8 N·m)	24 ft. lbs. (32 N·m)	30 ft. lbs. (40 N·m)



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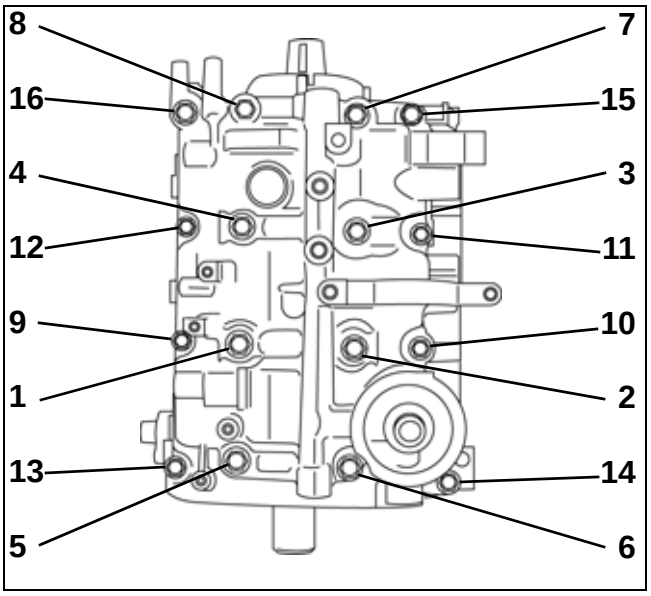

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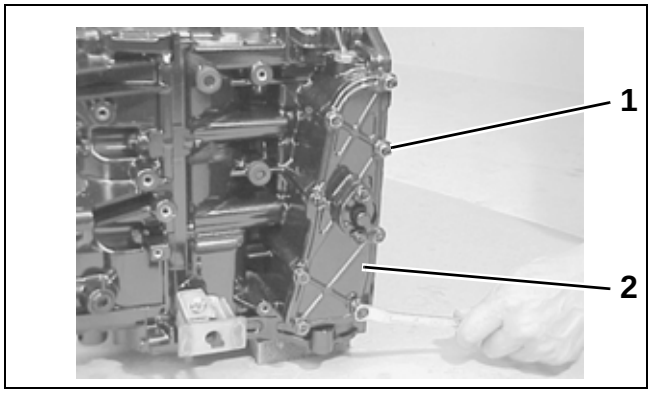
IMPORTANT: After tightening the crankcase bolts, make sure that the crankshaft rotates smoothly when turned by hand.

Install the gasket and the exhaust cover. Install and tighten the bolts securely.



1. Bolts (8) 001531
2. Exhaust cover plate

Install the cylinder head, the timing chain, and the powerhead.

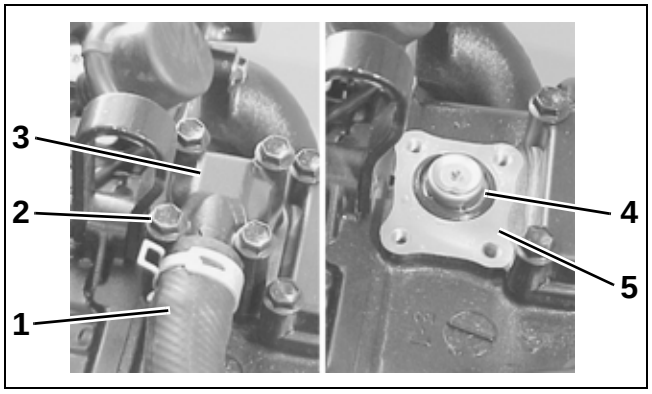
THERMOSTAT

Removal

Disconnect the water hose from the thermostat cover.

Remove four (4) bolts and the thermostat cover.

Remove the gasket and the thermostat.



1. *Water hose* 001598
2. *Bolts (4)*
3. *Thermostat cover*
4. *Thermostat*
5. *Gasket*

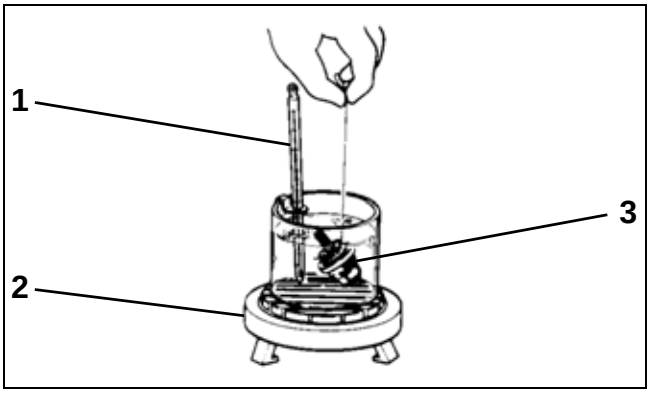
Inspection

Check the thermostat for salt deposits, corrosion, wear, or other damage.

To check the thermostat opening temperature, insert a length of thread between the thermostat valve and the body and suspend the thermostat in a container filled with water.

Place the thermometer in the container and heat the water. Observe the water temperature when the valve opens and releases the thread.

Thermostat Operating Temperature	
Standard	136 to 144°F (58 to 62°C)



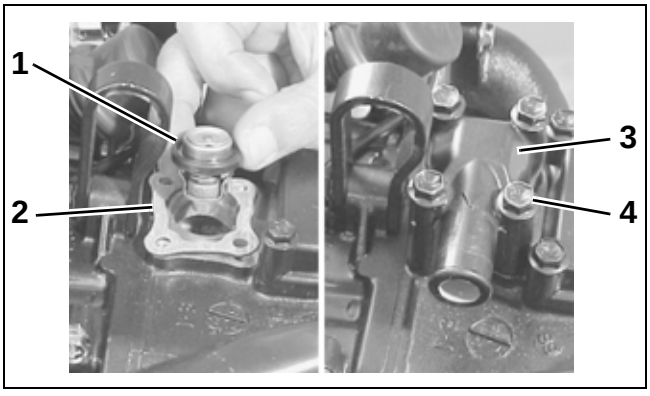
1. *Thermometer* 001600
2. *Heater*
3. *Thermostat*

Installation

Install the gasket and the thermostat.

Install the thermostat cover. Install and tighten the bolts and to a torque of 89 in. lbs. (10 N·m).

Connect the water hose to the thermostat cover.



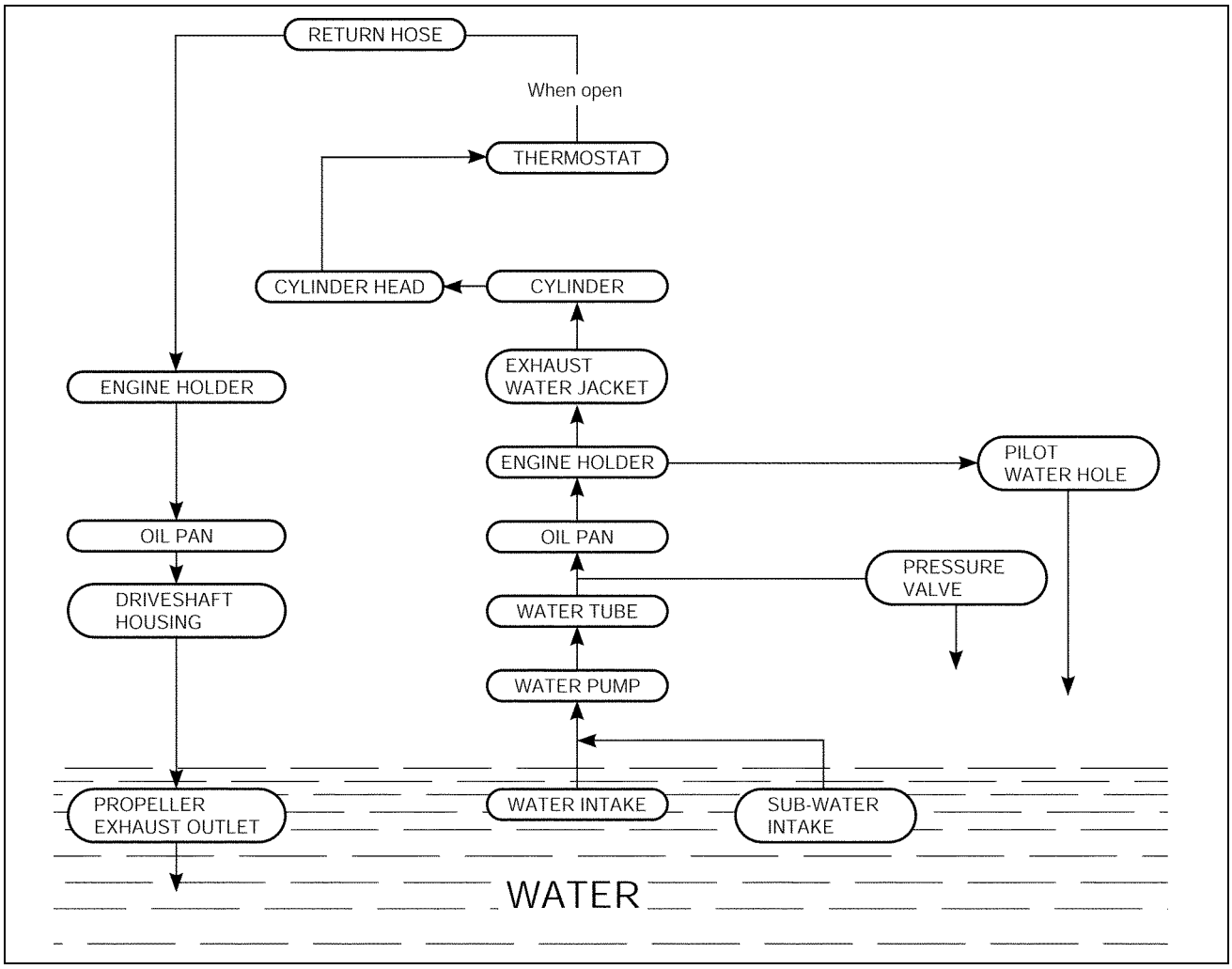
1. *Thermostat* 001601
2. *Gasket*
3. *Thermostat cover*
4. *Bolts (4)*

OPERATION

Water Cooling System

The water cooling system includes the water pump, the water supply tube, the water pressure valve, the powerhead water passages, and the thermostat.

This system cools both the powerhead and the midsection. If overheating occurs, the components of the cooling system must be inspected for blockage, corrosion buildup, or damage.



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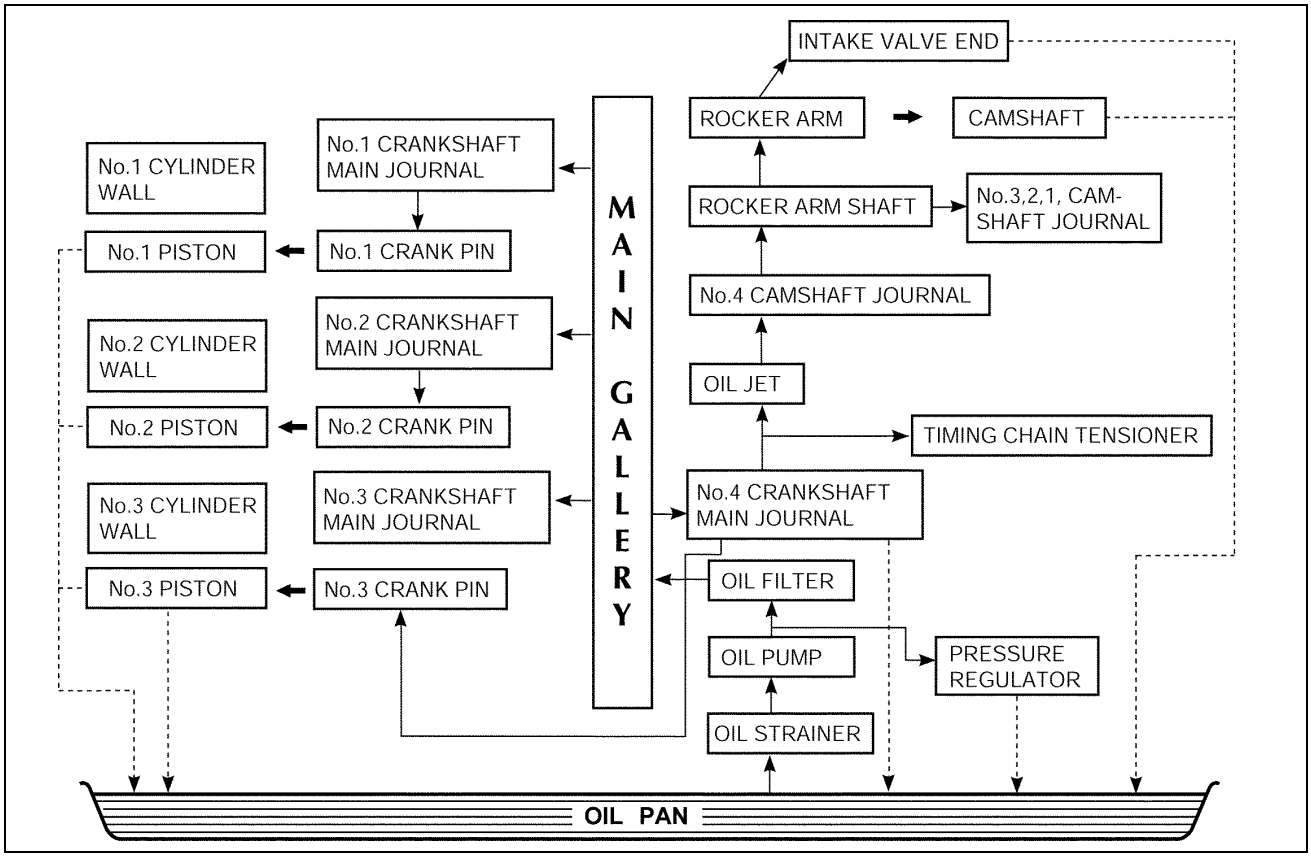
Engine Lubrication System

A camshaft driven, trochoid type pump provides engine oil to all powerhead components requiring lubrication. Oil from the oil pan is drawn though the oil strainer and passed through a spin-on type oil filter before entering the main oil gallery.

A pressure regulator (relief valve) is positioned between the oil pump and the oil filter to maintain the oil pressure at a constant level.

From the main gallery, oil flow is directed either through a drilled internal passage or by the splash method to those surfaces requiring lubrication.



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NOTES

Technician's Notes

Related Documents

Bulletins	
Instruction Sheets	
Other	