



**2001-2002 Motorcycle & ATV**

**Engine Service Manual**

## ABOUT THE MANUAL

This is an "engine" service manual. It has been developed to address major mechanical service issues (example: component and systems removal, inspection, disassembly, assembly, and reinstallation.)

This manual can be used for 2001 and 2002 Cannondale vehicles (motorcycles & ATVs).

You must possess significant mechanical knowledge, skills, and tools to perform most of the procedures found in this document.

This manual was accurate at the time of publication. Any supplemental information developed or written after printing may be available on our web site as a "manual supplement." Service bulletins and technical notes are also published as required. These are also posted on the website.

You may find that this service manual uses technical terms and part names slightly different from published parts catalogs or microfiche.

Most sections of this manual begin with illustrations (line art or photograph) of the assemblies considered in the section.

All the procedures in this manual are organized in a numbered (step-by-step) easy to read format with accompanying photographs, line art, torque values and specifications. The numbered steps of a few procedures are likely to be separate procedures themselves. When this is the case, the numbered step will include a page reference number.

## OTHER TYPES OF MANUALS AVAILABLE

Vehicles using the same engine also have a "chassis" manual which includes the specific periodic maintenance, engine removal, engine installation, operating, and/or tuning procedures relevant to the installed engine. This type of manual is also designed to be used by qualified service technicians.

An "Owner's" manuals for all vehicles include basic vehicle maintenance and service information. This manual is designed for the vehicle owner.

## UPDATES

Supplements to this manual are published on an ongoing basis. A list of supplements to this manual are maintained at [www.cannondale.com](http://www.cannondale.com)

## COMMENTS?

We invite your comments and suggestions on this or any other publication offered by Cannondale Motorsports.

When giving us your comments, please include the publication title and date.

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# Safety Alerts

- **FAILURE TO FOLLOW THE WARNINGS CONTAINED IN THIS MANUAL CAN RESULT IN SERIOUS INJURY OR DEATH.**

## Messages with the Safety Alert Symbol

- **Pay special attention to all messages preceded by the Safety Alert Symbol. It means: ATTENTION! BECOME ALERT! YOUR SAFETY IS INVOLVED.**

 <b>DANGER</b>	Indicates that severe personal injury or death <b>WILL</b> result if instructions are not followed.
 <b>WARNING</b>	Indicates a potential hazard that <b>COULD</b> result in serious injury or death.

### CAUTION

Indicates a potential hazard that could result in vehicle damage if instructions are not followed.

*NOTE : Provides helpful information*

This manual is written for Cannondale motorsports dealers and qualified service technicians.

This is not a comprehensive shop safety manual and should not be used by anyone who is not familiar with standard safety practices and service techniques. This manual does include warnings and cautions (see descriptions above) that if ignored, could result in **SEVERE PERSONAL INJURY** to the service technician or significant damage to the vehicle rendering it unsafe to operate. Anyone operating an “unsafe” vehicle can be seriously injured or **KILLED**.

We have done our best to identify situations where warnings or cautions are needed and will continue to do so in future publications. But, **YOU** must always exercise good judgement, and follow safe shop practices when performing service procedures as described in this manual.



## Death by Carbon Monoxide

### **DANGER**

#### POTENTIAL HAZARD

Running the engine indoors.  
Breathing exhaust fumes

#### WHAT CAN HAPPEN

Running the engine indoors will expose you to dangerous exhaust gases. Breathing carbon monoxide gas leads to poisoning, asphyxiation, and death. This will happen rapidly and without notice.

#### HOW TO AVOID THE HAZARD

Never operate the vehicle indoors even for brief periods.

## Respect the environment

It's illegal and clearly environmentally irresponsible to dispose of used engine and transmission oils, coolant and other discarded parts improperly.

Cannondale strongly suggests that you help protect and preserve the environment. Take the extra step necessary and find out the proper way to dispose of these potentially toxic substances in your area.

For information on "recycling" and "hazardous material disposal" in your area consult your local phone book.

## Protect your eyes

The golden rule here is "Always wear safety glasses." You can never predict and certainly can't avoid all instances when a part, snapping, clip, dirt, debris, or fluid will injure your unprotected eyes.

### **WARNING**

#### POTENTIAL HAZARD

Blindness, eye injury

#### WHAT CAN HAPPEN

There are thousands of scenarios in the work shop where working with a tool, a fluid, or a part can result in a serious injury to your eyes. Here are just a few:

You can have fluids sprayed into your eyes when you least expect it (pressurized fuel or coolant)

When cleaning the oil filters, objects being propelled by compressed air can strike your eyes and cause serious eye injury or blindness.

You can poke your eye out with a tool by using it incorrectly or by using a tool that is not designed or suitable for the job.

Small parts such as a snap ring or circlip can "fling" off and strike your eye while you are working.

#### HOW TO AVOID THE HAZARD

Always wear safety glasses.

When working with compressed air - use short bursts and direct the tip of the air nozzle away from yourself.

Use tools appropriately. There's always "the right tool for the right job." If you do not have the tools necessary to complete a procedure - get them before attempting it.

## Coolant is hazardous

### **WARNING**

#### POTENTIAL HAZARD(S)

- (1) Scalding coolant sprayed onto YOU
- (2) Serious eye or skin injury, ingestion
- (3) (drinking or swallowing) coolant

#### WHAT CAN HAPPEN

- (1) Hot coolant being sprayed from under high pressure when the bottle is opened.
- (2) Coolant is poisonous. If it gets in your eyes or contacts your skin the fluid can cause irritation or severe injury.
- (3) Coolant is sweet tasting and is very attractive to small children and pets. It is very poisonous and its ingestion will cause serious injury or death.

#### HOW TO AVOID THE HAZARD

- (1) Wait for engine to cool before removing the cap or servicing the coolant system. Be sure to wear eye protection, a long-sleeve shirt, and hand protection (e.g. rubber gloves) when working with coolant. Place a thick rag or towel over the radiator cap and slowly turn the cap counterclockwise to the detent. This procedure allows any residual pressure to escape. Wait for the hissing to stop then press down on the cap while turning it counterclockwise and remove it.
- (2) Always wear eye protection and protective clothing when working with any components of the cooling system. Keep coolant away from children and pets. Call a doctor immediately if coolant is swallowed and induce vomiting. Flush eyes and skin with water if coolant gets in eyes or comes into contact with skin.
- (3) If coolant is swallowed induce vomiting, rinse the mouth and throat with water, and seek immediate medical attention.

## Engine oil is hazardous

### **WARNING**

#### POTENTIAL HAZARD(S)

- (1) Serious injury or irritation to the skin or eyes
- (2) Death if swallowed.

#### WHAT CAN HAPPEN

- (1) Engine oil is a hazardous substance. If it comes into contact with your skin or eyes you can suffer serious injury or irritation. Prolonged contact with skin may cause skin cancer.
- (2) If it is swallowed it can cause death.

#### HOW TO AVOID THE HAZARD

- (1) Wear hand protection and safety glasses when working with engine oil. If you touch engine oil, wash it off immediately with soap and water. Clean clothes or rags contaminated with engine oil.
- (2) If swallowed seek immediate medical attention. **KEEP ENGINE OIL AWAY FROM CHILDREN AND ANIMALS.**

## Transmission oil is hazardous

### **WARNING**

#### POTENTIAL HAZARD(S)

- Serious injury or irritation to the skin or eyes.
- Death if swallowed.

#### WHAT CAN HAPPEN

- Transmission oil is a hazardous substance. If it comes into contact with your skin or eyes you can suffer serious injury or irritation. If swallowed it can cause death.

#### HOW TO AVOID THE HAZARD

- Wear hand protection and safety glasses when working with engine oil.
- If you touch transmission oil, wash it off immediately with soap and water.
- Clean clothes or rags contaminated with engine oil.
- If swallowed seek immediate medical attention. **KEEP TRANSMISSION OIL AWAY FROM CHILDREN AND ANIMALS.**



Gasoline is VERY hazardous


 **WARNING**

POTENTIAL HAZARD(S)  
(1) Fire or explosion

WHAT CAN HAPPEN  
(1) Gasoline is extremely flammable. Handling it inappropriately or near cigarettes, flame, sparks, welders, or other sources of ignition can result in a fire or explosion where you can be seriously injured or killed.

HOW TO AVOID THE HAZARD  
(1) Only handle gasoline outdoors and away from cigarettes, flame, sparks, welders, or other sources of ignition.

Heated components can give you SEVERE burns

 **WARNING**


POTENTIAL HAZARD(S)  
Severe burns

WHAT CAN HAPPEN  
Some procedures require that components be heated (a normal assembly/disassembly technique). Anytime you work with heated components you risk burning yourself severely.

HOW TO AVOID THE HAZARD  
Generally, but not always, working with heated components in a procedure means that the procedure is not a simple one (ie., not something for the home mechanic or hobbyist). Leave any procedure where heating components are a part to the specialists (e.g., machine and specialty mechanic shops).

Wear thermally protective gloves and arm coverings when working with heated components.

Breathing dust and fiber is hazardous

 **WARNING**

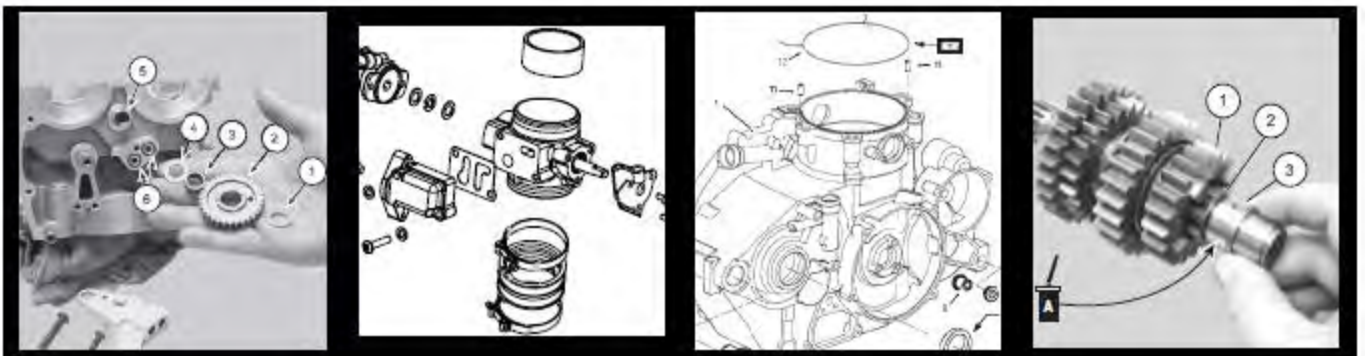
POTENTIAL HAZARD(S)  
Respiratory disease and cancer

WHAT CAN HAPPEN  
Certain components (e.g., brake pads, gaskets, clutch linings) produce dust and fibers that when inhaled may cause respiratory disease and cancer. You could become very sick and die!

HOW TO AVOID THE HAZARD  
Always wear an OSHA-approved mask or ventilator when working on these components.

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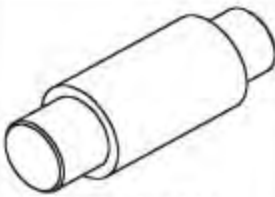
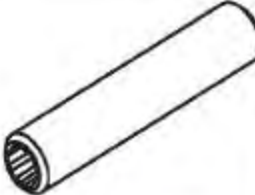


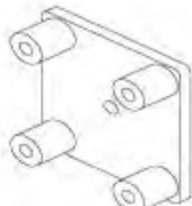
## SPECIAL TOOLS




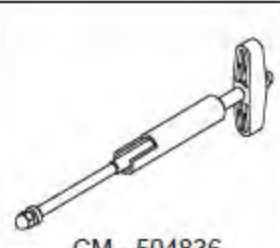
The following is a list of special tools available to service the engine. Special tools are developed on an ongoing basis. For an up-to-date listing of special tools developed to service Cannondale vehicles, contact Cannondale dealer service.

 CM - 504828	Valve spring compressor  This tool is used to compress the valve springs.
 CM - 501000	This tool is a driver kit containing the following individual tools: CM-502451, CM-502452, CM-502453, CM-502454, CM502455, CM502463, CM-502449, CM-502464, CM-502458, CM-502450, CM-502462, CM-502457
 CM - 502451	25mm Bearing installer
 CM - 502452	31.5mm Bearing installer
 CM - 502453	20mm Bearing installer

 <p>CM - 502455</p>	<p>36mm clutch bearing installer</p>
 <p>CM - 502457</p>	<p>15mm clutch bearing installer</p>
 <p>CM - 502458</p>	<p>33.5mm clutch bearing installer</p>
 <p>CM - 502462</p>	<p>Drive handle This tool is used with a variety of bearing drivers.</p>
 <p>CM - 502463</p>	<p>33mm oil seal installer</p>
 <p>CM - 502464</p>	<p>20mm oil seal installer</p>











 <p>CM - 503869</p>	<p>Degree wheel</p> <p>This tool is used when inspecting/adjusting the camshaft timing.</p>
 <p>CM - 503872</p>	<p>Clutch basket bushing driver</p> <p>This tool is used to remove and install the clutch basket (housing) bushing.</p>
 <p>CM - 503874</p>	<p>Crankshaft cartridge plate alignment pin(s)</p> <p>This tool is used to assist in the installation of the crankshaft cartridge plate.</p> <p>Two are required.</p>
 <p>CM_503873</p>	<p>Crankshaft bearing installer</p> <p>This tool is used to install the bearing races onto the crankshaft.</p>
 <p>CM_502449</p>	<p>32mm oil seal installer</p>
 <p>CM - 504826</p>	<p>Sleeve press plate</p> <p>This tool is used to press the cylinder sleeve into the crankcase.</p>

 <p>CM - 506551</p>	<p><b>Flywheel holder</b></p> <p>This tool is used to hold the flywheel when removing the flywheel nut.</p>
 <p>CM - 503877</p>	<p><b>Flywheel remover</b></p> <p>This tool is used to remove the flywheel from the crankshaft end.</p>
 <p>CM - 504829</p>	<p><b>Valve guide driver</b></p> <p>This tool is used to remove and install the cylinder head valve guides.</p>
 <p>CM - 504836</p>	<p><b>Wrist pin extractor</b></p> <p>This tool is used to extract the wrist pin from the piston/connecting rod.</p>

## SYMBOLS

The following symbols are used in illustrations and photos in this manual.

	<p>Apply silicone sealant</p> <p>Example: Three Bond 1207D</p>
	<p>Torque value</p>
	<p>Apply assembly lubricant</p>
	<p>Apply a locking agent. Use a mid-strength removable locking agent unless otherwise specified. Example: Loctite #242</p> <p>NOTE :</p> <hr/> <p><i>For thread locking compound to be effective, old compound must be removed and thread surfaces free of lubricants the old compound and cleaned of any contaminants.</i></p> <hr/>
	<p>Apply an "anti-seize" thread compound.</p>
	<p>Apply clean engine oil</p>
	<p>Apply O-ring lubricant</p> <p>Dielectric grease</p>
	<p>Specification or service limit</p>



	<p>Apply transmission oil</p>
---	-------------------------------

## SERVICING

Keep the following tips in mind when servicing the engine.

### Basics

1. Make sure the work-area is clean: especially the floors, and always clean the engine of soil and grime before working on it.
2. Read each procedure carefully, and look over the part or assembly that will be worked on. Do not start working until you completely understand the procedure. Then, follow it step-by-step.
3. Do not rush through a job or improvise.
4. Keep a supply of clean, lint-free rags to wipe up any spills. Also, have some containers to catch drained fluids.
5. When a job is finished, make sure all fasteners are secure and all components operate properly.

### Tools

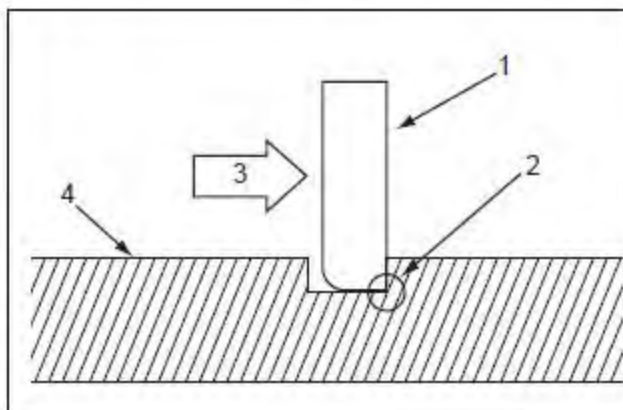
1. If a procedure requires a special tool, acquire it before starting the job.
2. Never improvise by using something in place of the recommended tool; this can cause an injury or damage.

## Snap Rings, Circlips, Seals, Gaskets, Cotter pins

### CAUTION

Always replace snap rings, circlips, oil seals, gaskets, lock washers, cotter pins, and other specified parts with new ones after removal.

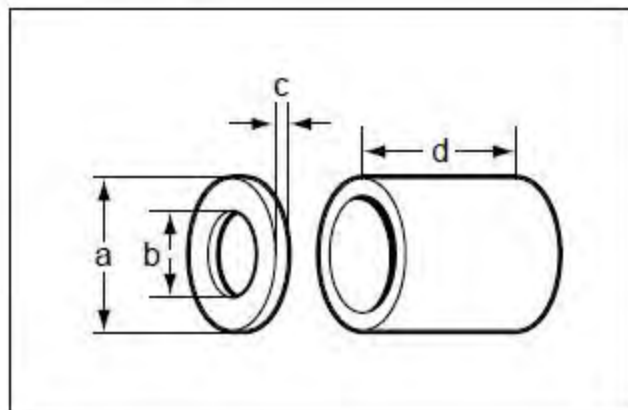
Install circlips (1) with the sharp-edged corner (2) facing opposite to the thrust (3) it receives on the shaft (4).



1. Circlips
2. Sharp-edged corner
3. Thrust
4. Shaft

## Fasteners and spacers

1. To loosen tight or frozen bolts, apply penetrating oil and then strike the bolt a few times with a hammer. Avoid using heat since it can melt, warp, or affect the temper of the part.
2. When tightening bolts or nuts, begin with the larger diameter or inner bolt first. Then, tighten the fasteners to the specified torque in a criss-cross pattern (i.e., diagonally), in incremental steps unless a specified sequence is mentioned.
3. Never replace an original equipment fastener with one of lesser quality or of a different material. Using a lower quality fastener will make the vehicle unsafe to ride and may result in an accident, injury, or death.
4. Always clean removed fasteners before reinstallation.
5. Washer and spacer dimensions are outside diameter (a), inside diameter (b), thickness (c), and length (d).



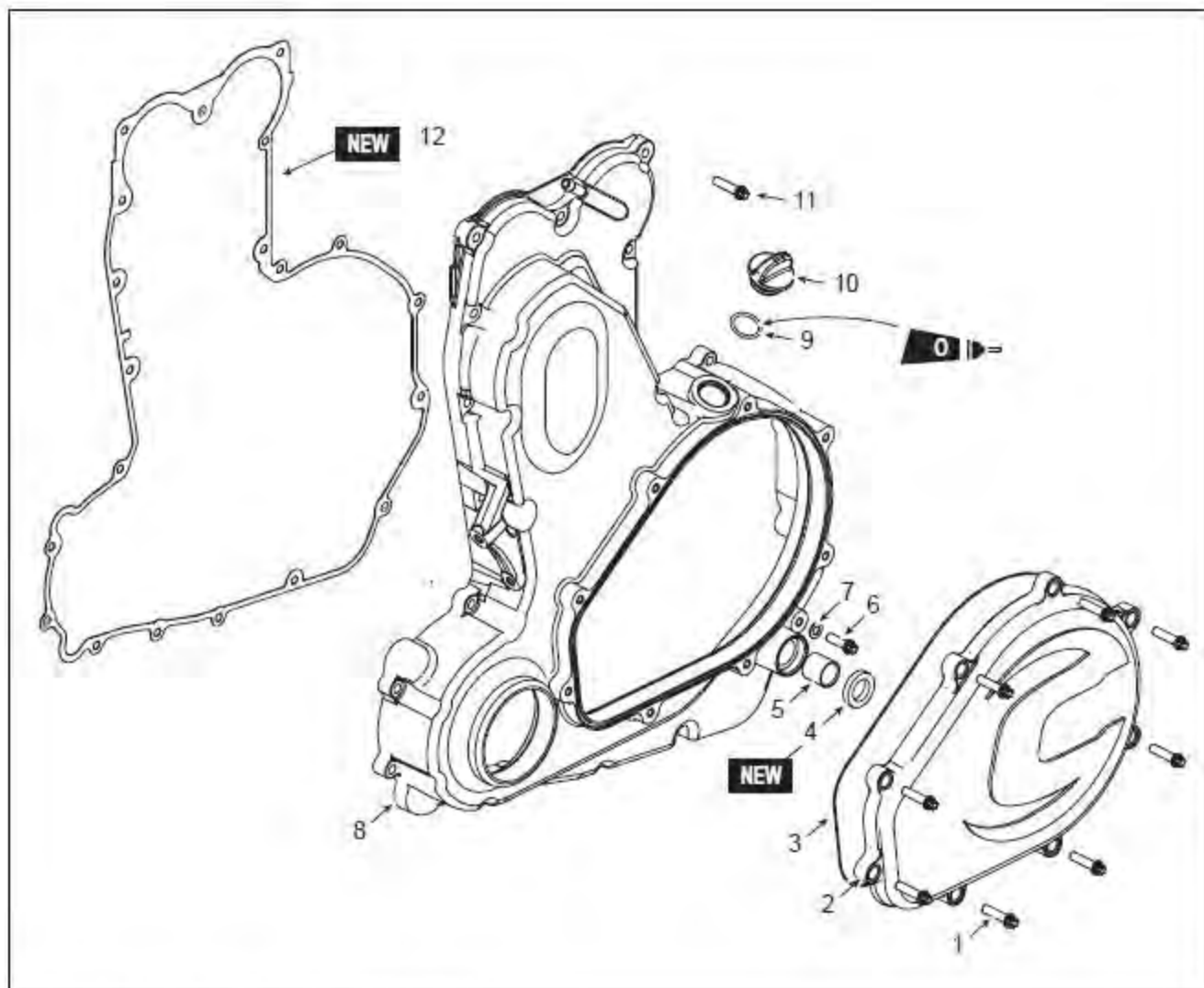
- a. Outside diameter (O.D.)
- b. Inside diameter (I.D.)
- c. Thickness
- d. Length

## Disassembly and assembly

1. Take photos or draw a diagram of the part that will be worked on. This will help with accurate assembly and installation procedures.
2. During disassembly, remember the location of each part, and always keep mated parts together.
3. To make assembly easier, place small parts in plastic bags or in an egg carton, and label them.
4. After disassembling any component, clean it in solvent.
5. Lubricate any sliding surface before assembly.
6. After assembly, make sure all components are installed and operate properly.

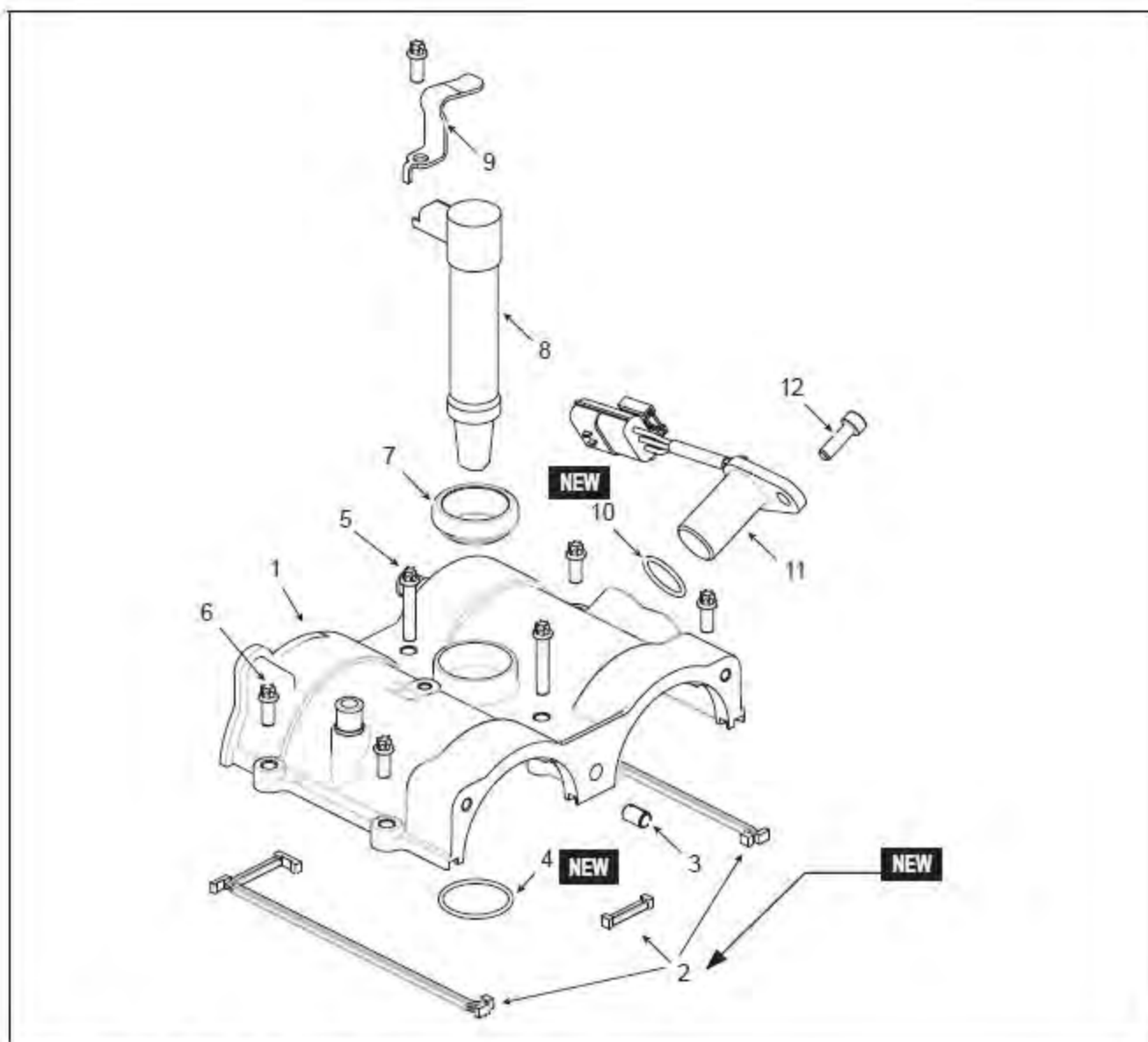


# Covers



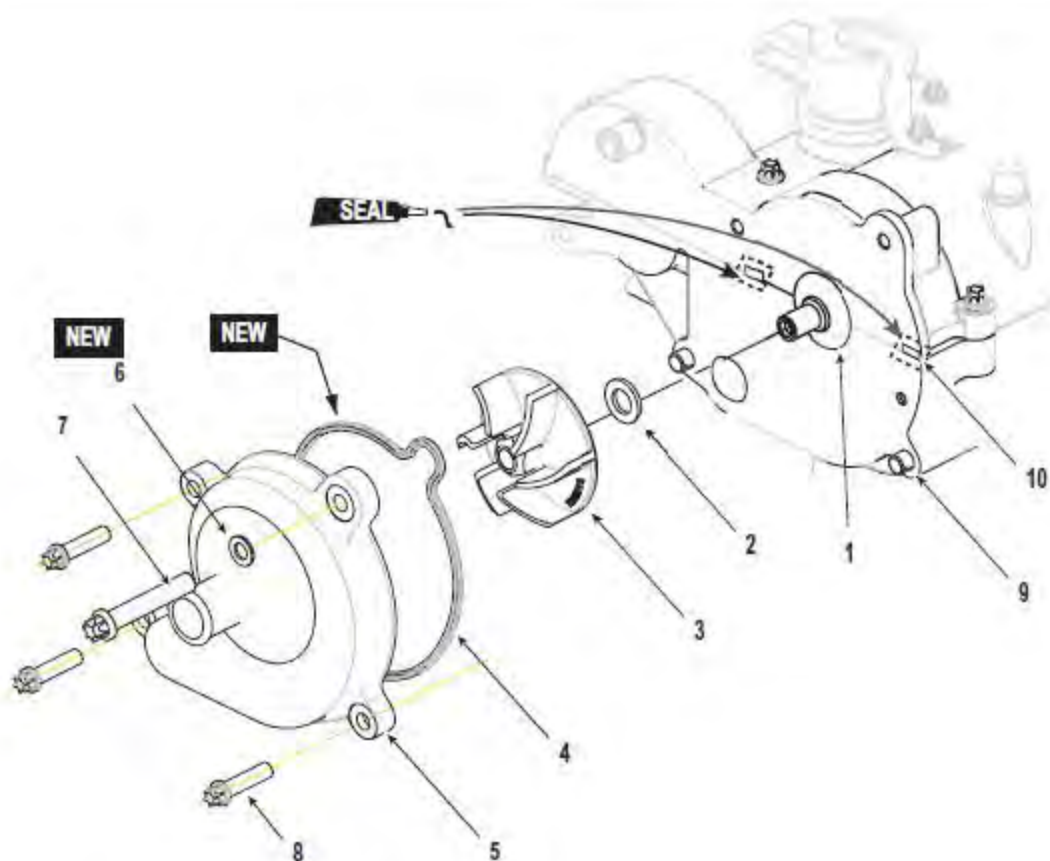
**ASSEMBLY VIEW : Crankcase & clutch covers**

- |                                |                                 |
|--------------------------------|---------------------------------|
| 1. Bolts                       | 7. Sealing washer               |
| 2. Clutch cover                | 8. Crankcase cover              |
| 3. Seal (reusable)             | 9. O-ring (reusable)            |
| 4. Shift shaft seal            | 10. Transmission oil filler cap |
| 5. Bushing                     | 11. Bolts                       |
| 6. Transmission oil check bolt | 12. Gasket                      |



**ASSEMBLY VIEW : Cylinder head / camshafts cover**

- |                   |                              |
|-------------------|------------------------------|
| 1. Cover          | 7. Coil seal                 |
| 2. Seal (3 piece) | 8. Coil                      |
| 3. Dowel          | 9. Coil hold down bracket    |
| 4. O-ring         | 10. O-ring                   |
| 5. Inner bolts    | 11. Camshaft position sensor |
| 6. Bolts          | 12. Bolt                     |



### ASSEMBLY VIEW : Coolant pump & cover

- |   |                                    |
|---|------------------------------------|
| 1. Coolant pump seal (installed with cylinder head cover) | 6. Sealing washer (new bleed bolt) |
| 2. Stainless steel washer                                 | 7. Bleed bolt (socket head)        |
| 3. Impeller   | 8. Cover bolts (3) (socket head)   |
| 4. Cover seal (new)                                       | 9. Hollow dowels (2)               |
| 5. Coolant pump cover                                     | 10. Sealant application (2)        |



## CRANKCASE COVER, REMOVE - INSTALL

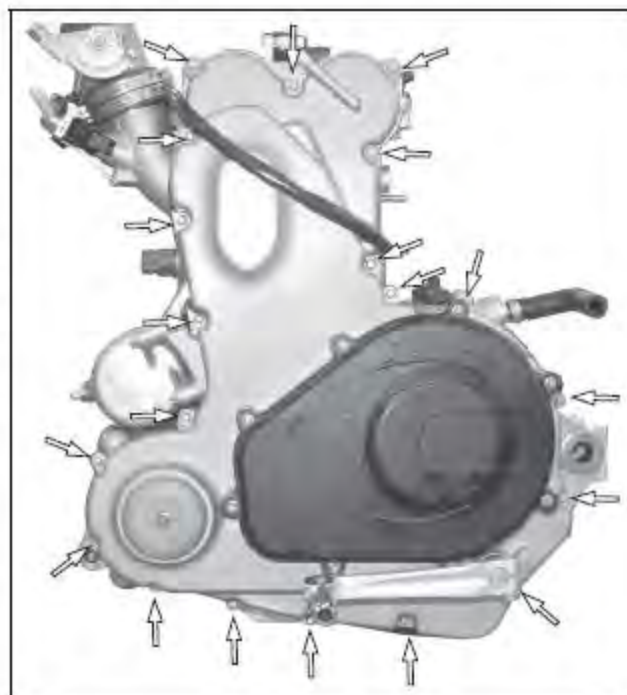
### CAUTION

The engine crankcase cover is not difficult to remove, but it will demand patience. Do not pry the cover off with a screwdriver or any other tool. This will result in damage to the cover or case mating surfaces. After all the cover bolts are removed, use a rubber mallet to carefully tap at the cover edges while working the perimeter. Loosen the cover slowly from several different points.

Be careful not to damage the shift shaft oil seal when removing the cover. The seal can catch on the shift shaft splines and tear if installed without patience or extra care.

Always replace old gaskets with new ones.

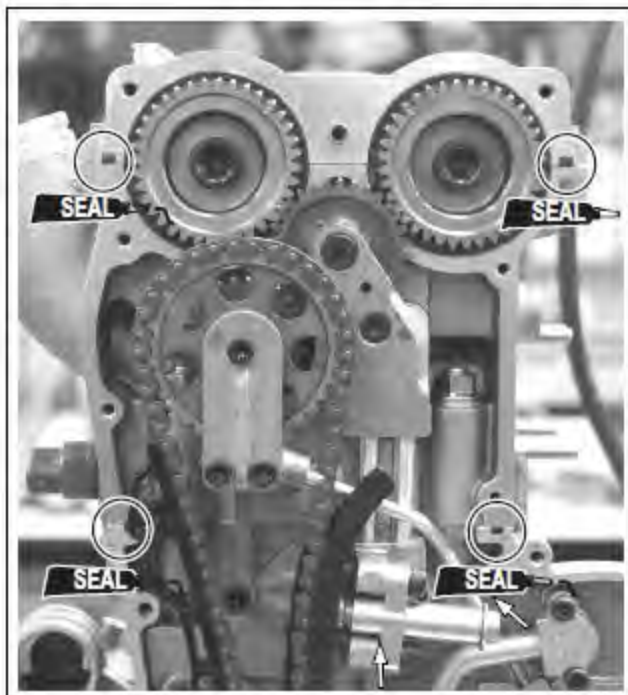
4. Remove crankcase cover bolts (see photo below).



1. Remove the clutch cover.
2. Remove the starter (page 175).
3. Remove the shift lever.

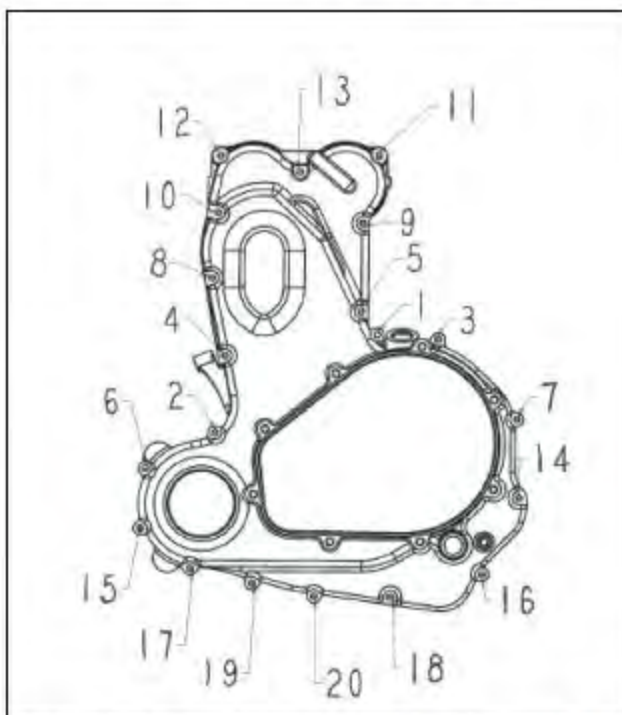
5. Remove the cover.
6. To install, make sure the case and cover mating surfaces are clean and free of contaminants (e.g., remove any grease, oil, dirt, old gasket material).
7. Lay the cover onto a surface plate or other flat surface to inspect for any warpage. Also, inspect the cover for cracks or other damage. Replace if necessary.

8. Apply a small amount of silicone sealant to the seal ends of the camshaft cover and the cylinder head seal. Only use a small amount of gasket sealer at a few other points to hold the gasket in place if necessary.



9. Install a new crankcase cover gasket onto the case.
10. Inspect the shift shaft bushing in the cover for signs of excessive wear or damage. Replace if necessary. While you are inspecting the seal, inspect the shift lever transmission oil seal - also in the cover. If it is in good condition, apply some clean transmission oil to the seal lips. If the seal appears damaged, replace it with a new one. Apply a light coat of O-ring lubricant to the engine oil filter housing the O-ring.

11. Carefully, install crankcase cover onto the case. Tighten the bolts evenly to the specified torque and in the order that is illustrated.



This illustration shows the recommended tightening pattern for the cover bolts. Bolts 13, 15 and 16 are 25mm long, the rest of the bolts are 20mm.

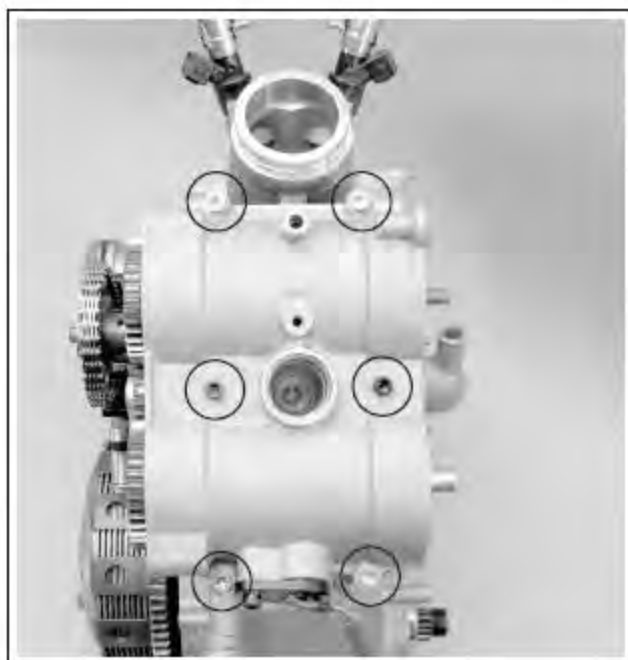


**Crankcase cover bolts**  
3.3 lbf·ft (4.5 N·m)

**Clutch cover bolts**  
3.3 lbf·ft (4.5 N·m)

## CYLINDER HEAD / CAMSHAFT COVER, REMOVE

1. Remove crankcase cover (page 21).
2. Position the crankshaft to TDC (page 48). This step may be omitted if you will not be servicing the camshafts (e.g. replacing seals or cover).
3. Remove the coolant pump cover (page 26).
4. Remove the ignition coil (page 175).
5. Remove the bolts and cover.



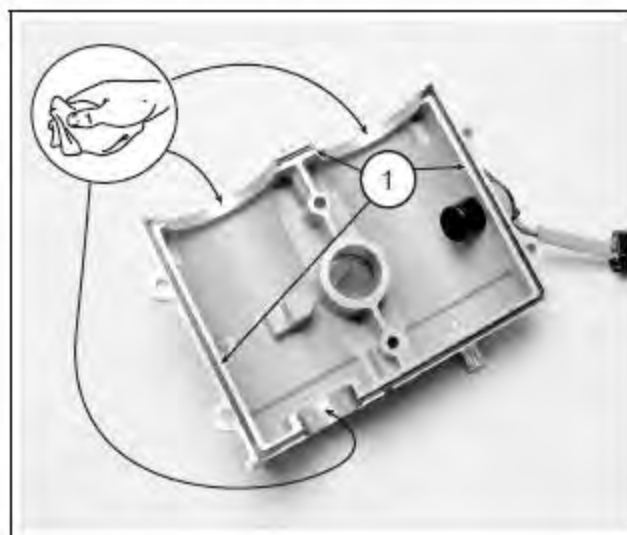
## CYLINDER HEAD / CAMSHAFT COVER, INSTALL

### CAUTION

Misalignment of the camshaft cover can contribute to fluid leaks (oil and coolant). Make sure you read and follow the techniques for installing the cover.

Never re-use a seal. Install new ones. Pay particular attention to the oil and coolant seals on the intake camshaft. If these seals have any cover marks or impressions - replace with new ones. Also examine the large camshaft seals for any damage or impressions that can contribute to leakage.

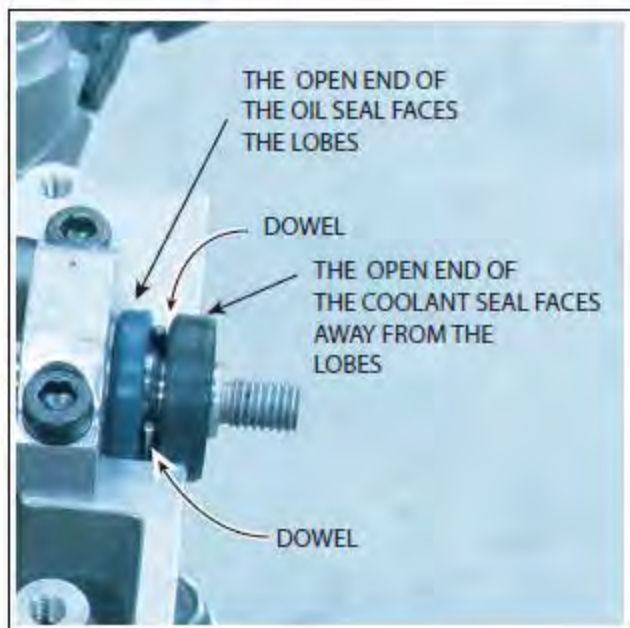
1. Use a clean shop towel to remove any oils or assembly lube from the cover seal mating surfaces and seals. All seals must be "dry" and positioned correctly before the cover is tightened.



1. Seals

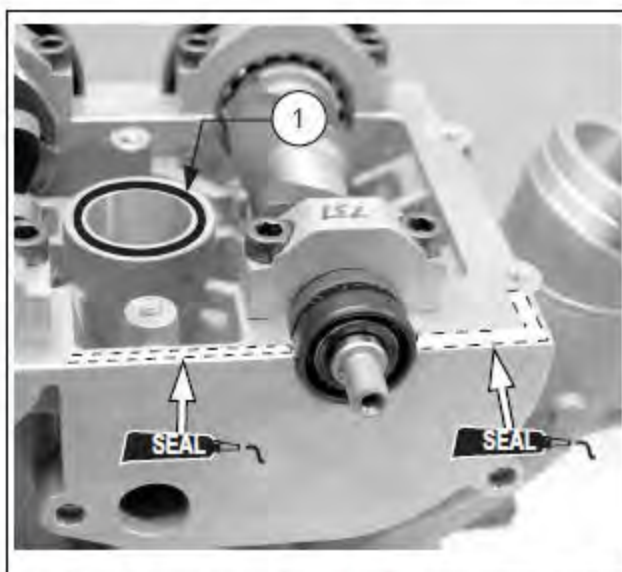


2. Make sure the intake camshaft oil and coolant seals are positioned correctly with the dowel pins between them. When the cover is tightened later, make sure the coolant seal is seated against the dowels.



3. Apply the O-ring assembly aid to the O-ring and install the ignition coil hole O-ring (1).

4. Apply a small amount of liquid silicone gasket around the intake cam seals as indicated in the photo; apply up to the seals but NOT on them.



The dotted lines indicate where the silicone sealant should be placed.

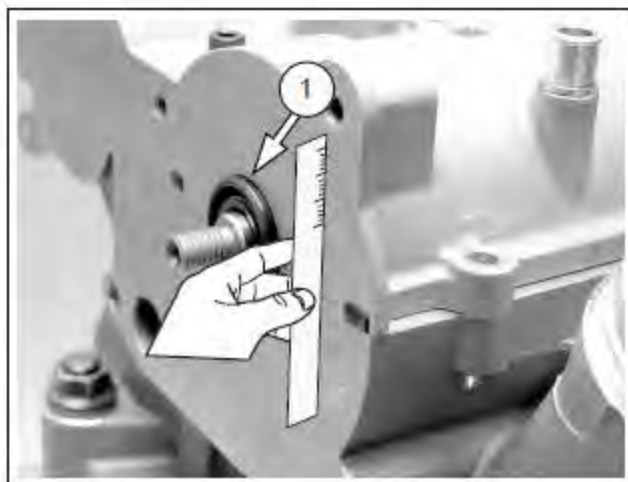
1. O-ring

5. Place the cover onto the cylinder head, and install the bolts loosely.
6. Use a straight edge to ensure the cover is positioned correctly.

#### NOTE :

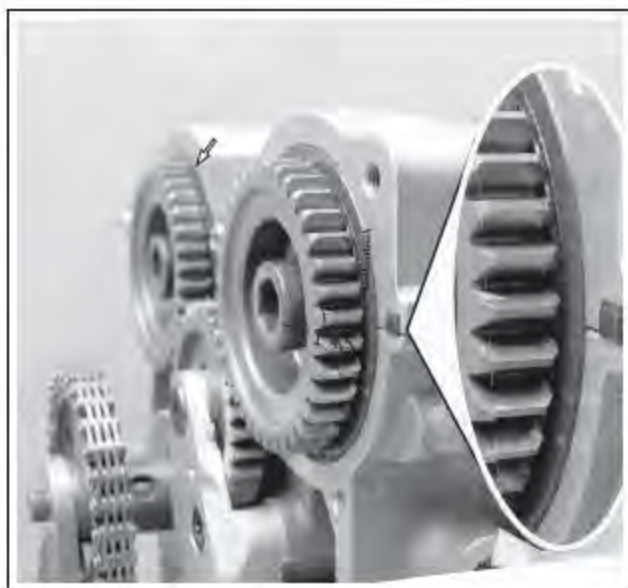
*The coolant pump cover (without the impeller installed) can be installed temporarily to aid in the alignment of the camshaft cover and cylinder head.*

7. Check the alignment at several points. If the cover is positioned incorrectly, coolant leakage will result.

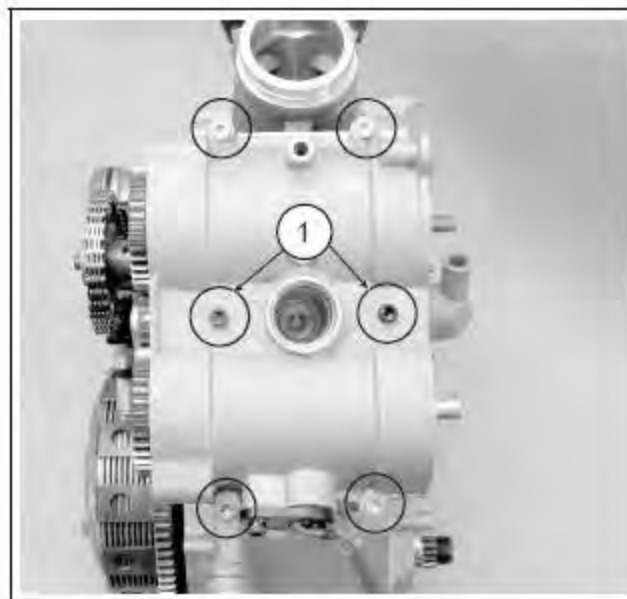


1. Coolant seal (open end facing out)

8. Examine the camshaft oil seals; make sure they are installed correctly. They should be flush with the cover edges.



9. Carefully hand-tighten the inner bolts. Then, tighten the outer bolts. Then, tighten all the bolts uniformly to the specified torque.



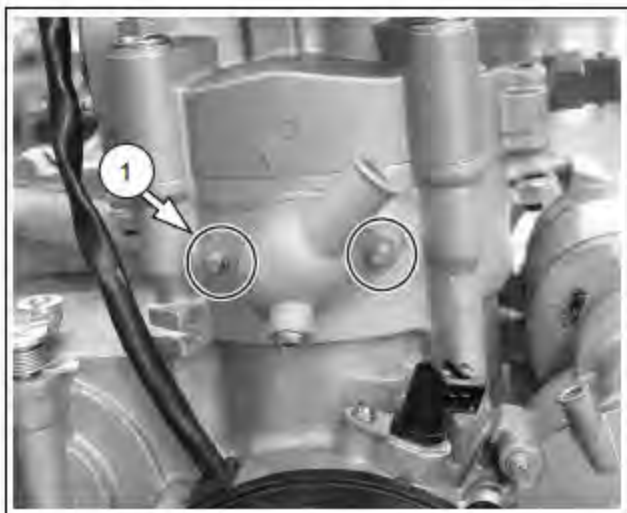
1. Inner bolts



Cylinder head/ camshaft cover  
bolts  
3.3 lbf·ft (4.5 N·m)

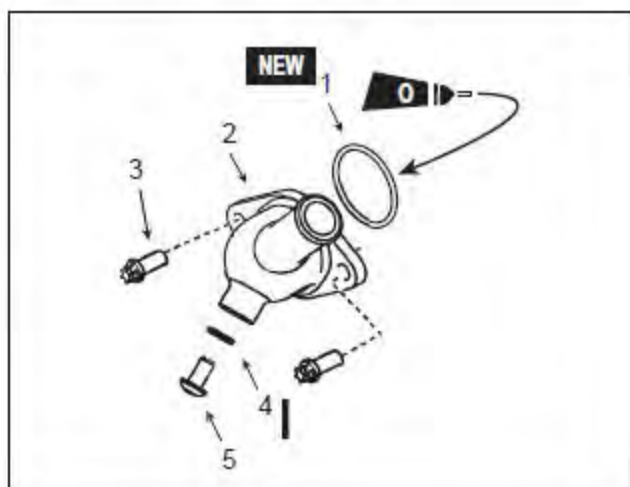
## COOLANT OUTLET COVER, REMOVE - INSTALL

1. Remove the bolts (1) and remove the cover and O-ring.



1. Bolts

2. To install, apply some O-ring lubricant to the O-ring, and install it onto the cover.



1. O-ring
2. Coolant outlet cover
3. Bolts
4. Sealing washer
5. Coolant drain

3. Install the bolts and tighten to the specified torque.



Coolant outlet cover bolts and  
drain  
3.3 lbf·ft (4.5 N·m)

4. Install the sealing washer and drain bolt. Tighten drain bolt securely.



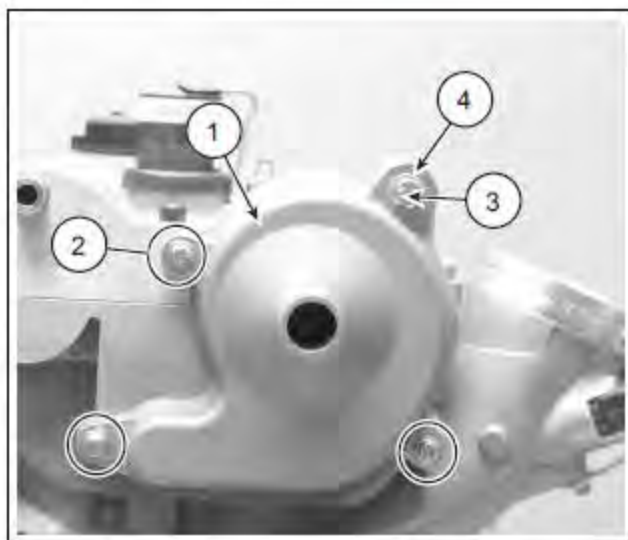
## COOLANT PUMP & COVER, REMOVE

### NOTE :

*Note the location of the coolant bleed bolt and sealing washer on the cover before removing.*

*Note the two lower cover bolts. The dowels can stick in the cover when removing it. Return them when reinstalling.*

1. Remove the cover bolts, bleed bolt, and the sealing washer.
2. Remove the cover and seal.

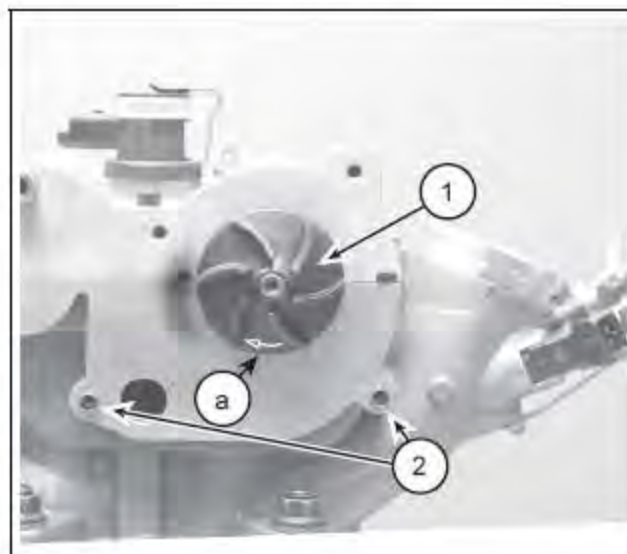


1. Cover
2. Bolts
3. Coolant bleed bolt
4. Sealing washer

### NOTE :

*The pump impeller is a reverse thread.*

3. Remove the pump impeller and stainless steel washer from the camshaft end.



1. Pump impeller
2. Dowels
- a. Loosening direction

## COOLANT PUMP & COVER, INSTALL

### CAUTION

Apply silicone gasket material only as directed. Mis-application, especially to the area of the bleed bolt, will result in passage blockage and the inability to properly bleed the coolant system.

An improperly bled coolant system can result in severe engine damage due to over-heating.

### NOTE :

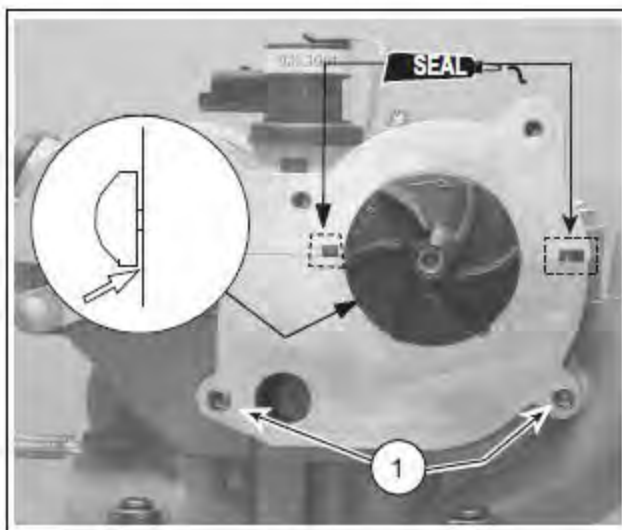
*When reinstalling the pump and pump cover, be sure to install the stainless steel washer onto the camshaft end first, then install the impeller hand tight.*

*Make sure there is adequate clearance between the impeller and head/cover surfaces.*

*Be sure to reinstall the bleed bolt sealing washer.*

1. Make sure the cylinder head / camshaft cover is installed correctly (page23).

2. Make sure the dowels for the lower cover bolts are installed into the cylinder head.



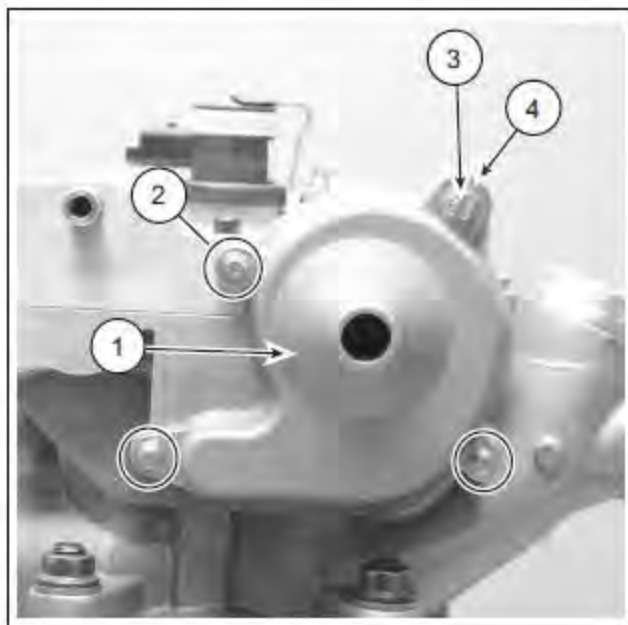
1. Hollow dowels

### NOTE :

*Apply a high quality silicone gasket material to the areas indicated in the photo.*

*Do not apply outside the areas indicated by the dotted line.*

3. Install the seal into the cover, and install the cover. Tighten the bolts evenly to the specified torque.



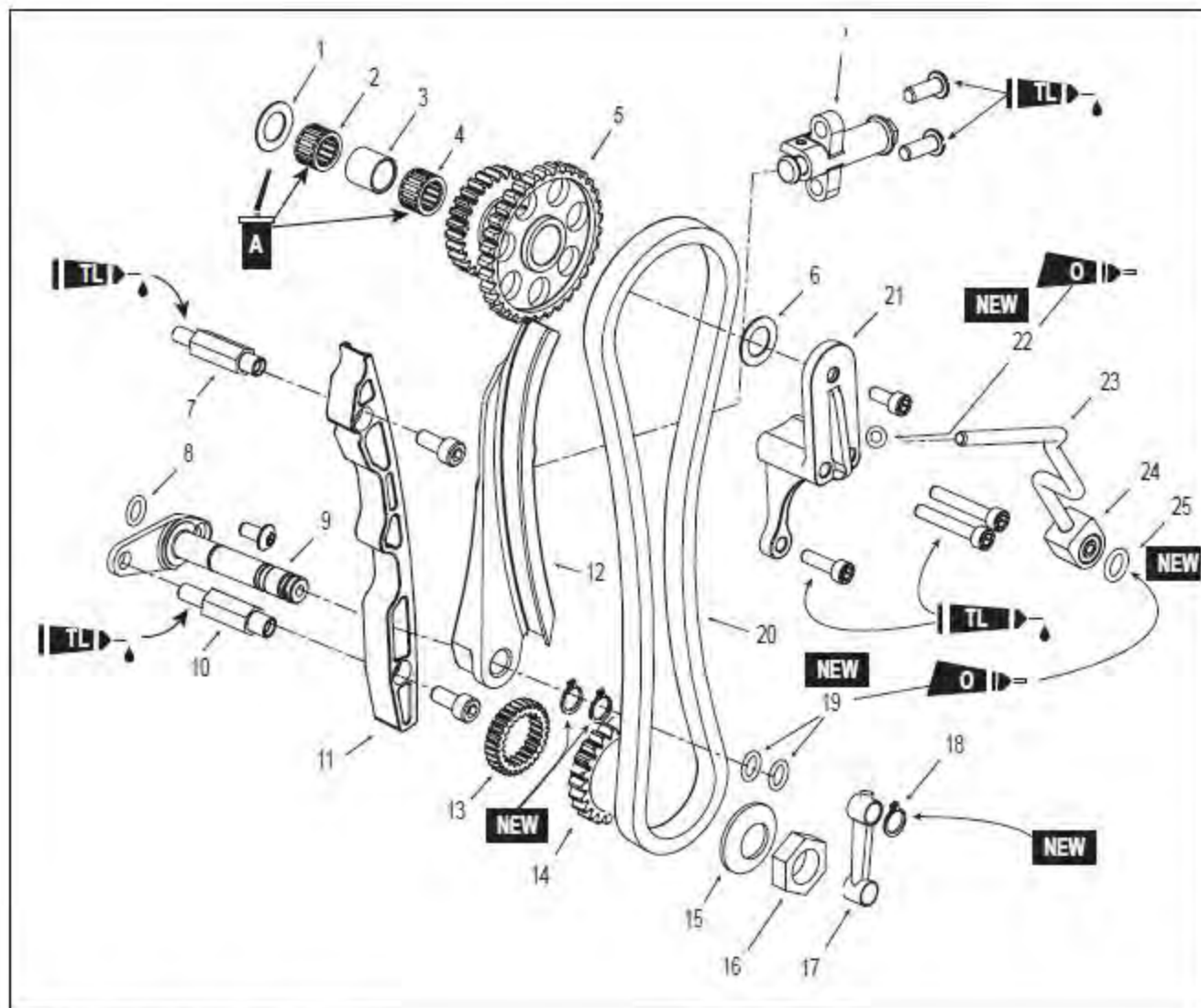
1. Cover
2. Bolts
3. Sealing washer
4. Bleed bolt



Coolant, pump cover bolts  
3.3 lbf·ft (4.5 N·m)

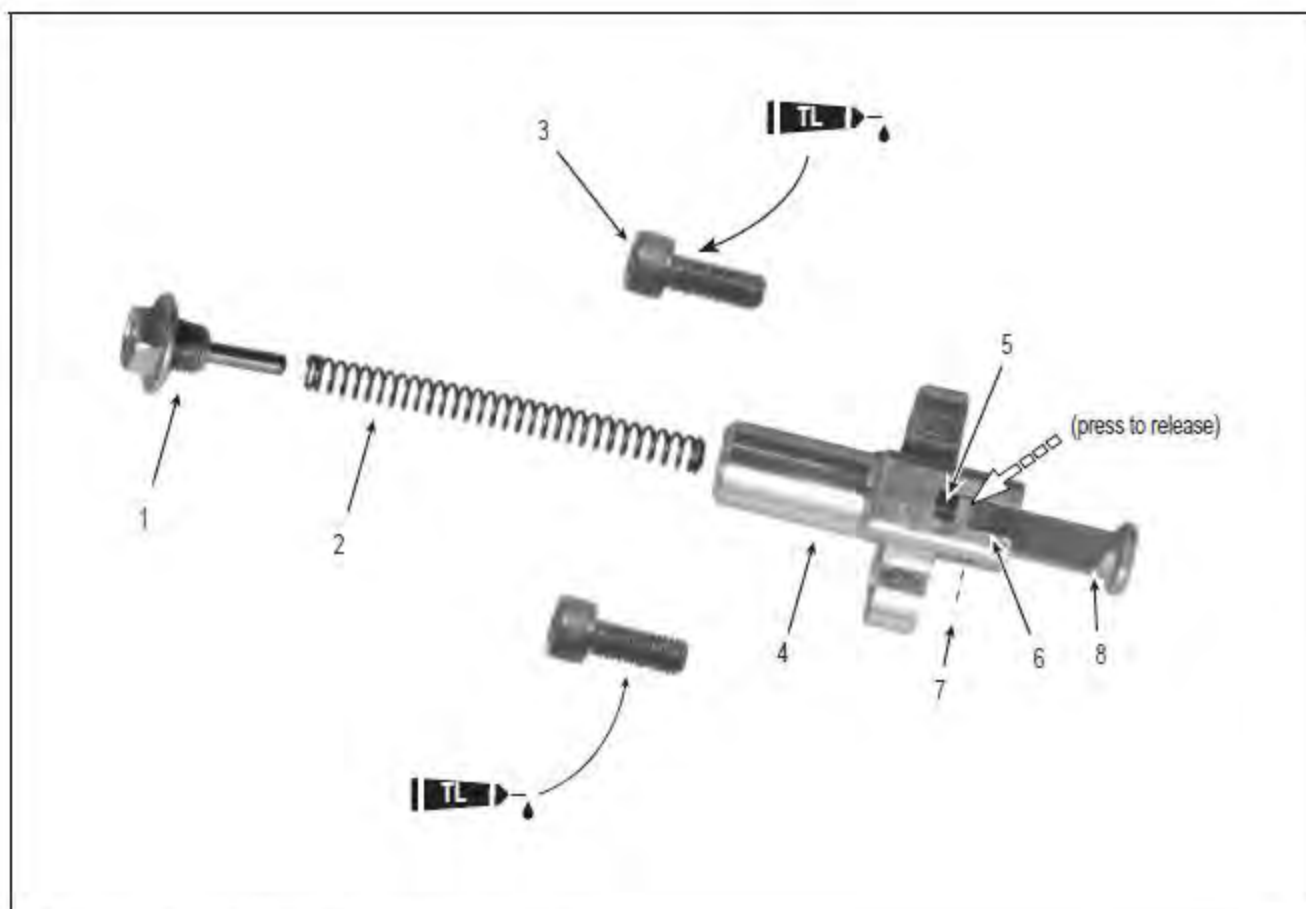


# Timing chain



**ASSEMBLY VIEW : Timing chain**

- |                       |                                    |                                  |
|-----------------------|------------------------------------|----------------------------------|
| 1. Washer             | 11. Front chain guide              | 21. Camshaft drive gear bracket  |
| 2. Bearing            | 12. Rear timing chain guide        | 22. O-ring                       |
| 3. Spacer             | 13. Oil pump drive gear            | 23. Timing chain oil supply tube |
| 4. Bearing            | 14. Timing chain drive gear        | 24. Adapter block                |
| 5. Drive gear         | 15. Bevel washer (convex side out) | 25. O-ring                       |
| 6. Washer             | 16. Crankshaft nut                 |                                  |
| 7. Guide adapter      | 17. Oil supply bridge              |                                  |
| 8. O-ring             | 18. Circlip                        |                                  |
| 9. Pivot shoe bracket | 19. O-ring                         |                                  |
| 10. Guide adapter     | 20. Chain                          |                                  |



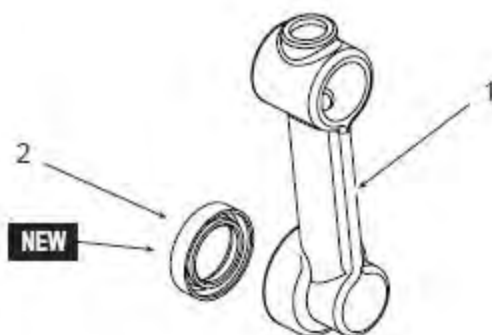
**ASSEMBLY VIEW : Timing chain tensioner**

**NOTE :**

*Always install the assembly with the ratchet paw facing toward the transmission oil transfer tube.*

*The ratchet paw side is facing you in the illustration above. It has been presented this way to show the ratchet.*

1. Cap bolt
2. Spring
3. Bolts
4. Housing
5. Ratchet spring
6. Ratchet pawl
7. Pin
8. Ratchet shaft



**ASSEMBLY VIEW : Engine oil supply bridge**

- 1. Bridge
- 2. Seal

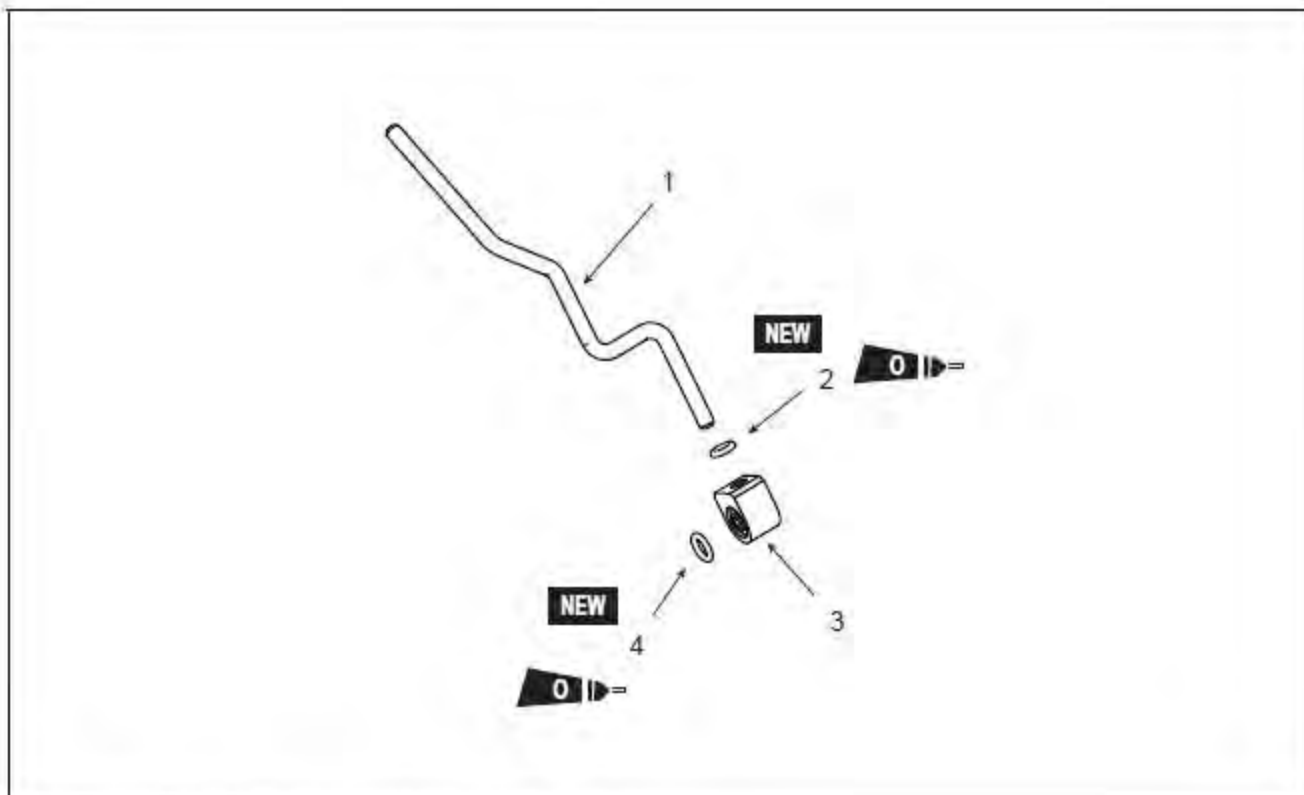
**NOTE :**

*The open end of the seal faces into the bridge body.*

*Lubricate the seal lips with clean engine oil when reinstalling.*

*And, make sure the O-rings on the timing chain tensioner shoe pivot are in good condition and lubricated.*

*Clean the bridge with compressed air before installing.*



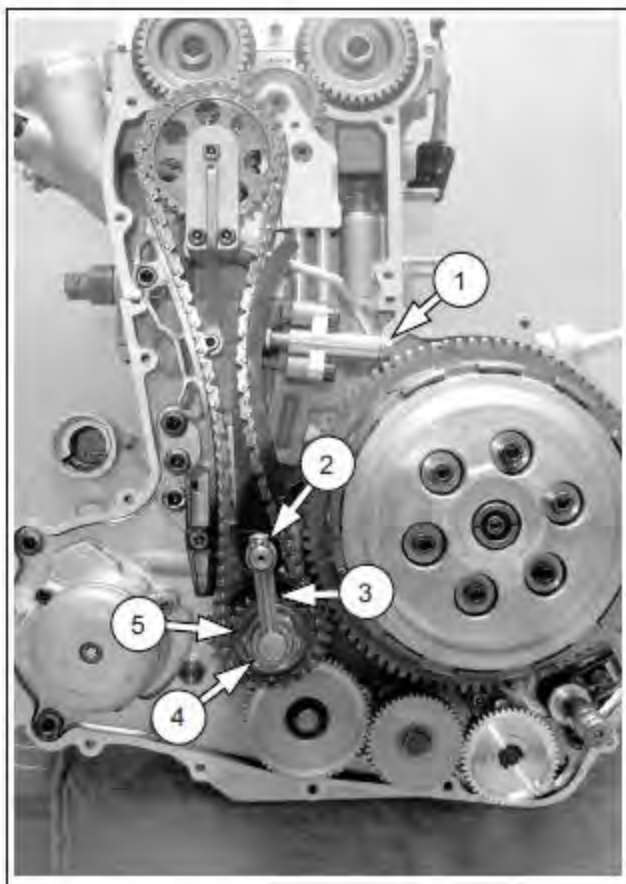
**ASSEMBLY VIEW : Timing chain oil transfer tube**

- 1. Oil supply tube
- 2. O-ring
- 3. Block
- 4. O-ring



## TIMING CHAIN, REMOVE

1. Remove the crankcase cover (page 21).
2. Remove tensioner bolt (1) and spring.
3. Remove the circlip (2) and oil supply bridge (3).

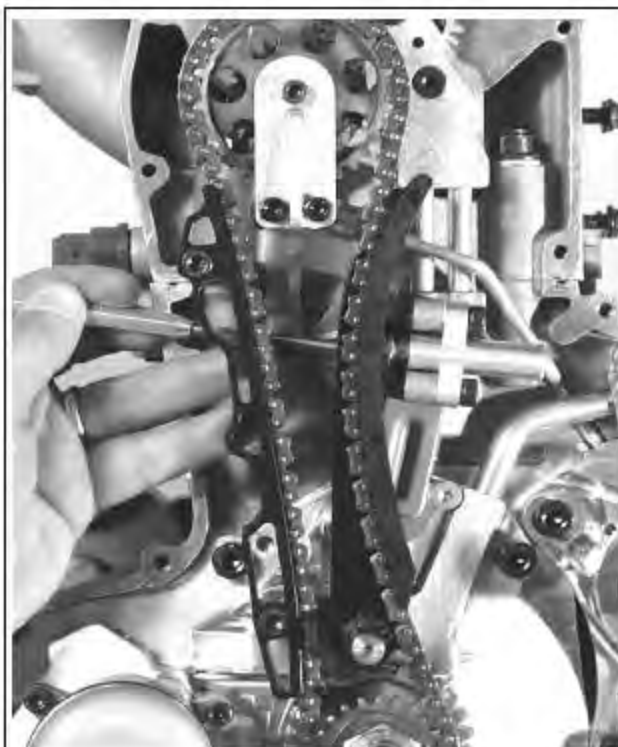


1. Tensioner spring bolt
2. Circlip
3. Oil supply bridge
4. Crankshaft nut
5. Washer

4. Using a thin blade screwdriver or a blunt pick, press in on the tensioner ratchet release.

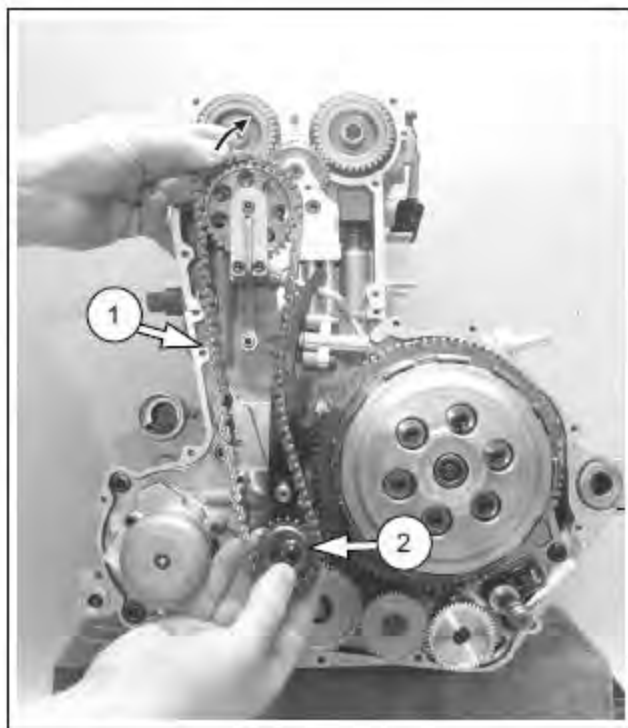
### NOTE:

*Grabbing the rear guide and squeezing the chain to take the pressure off the tensioner will make it easier to perform this procedure.*



1. Tensioner ratchet release

5. Remove the left timing chain guide mounting bolts and front guide.
6. Remove the crankshaft nut and washer.
7. Lift the timing chain (1) off the camshaft drive gear and remove the chain and (lower) drive gear (2) together.



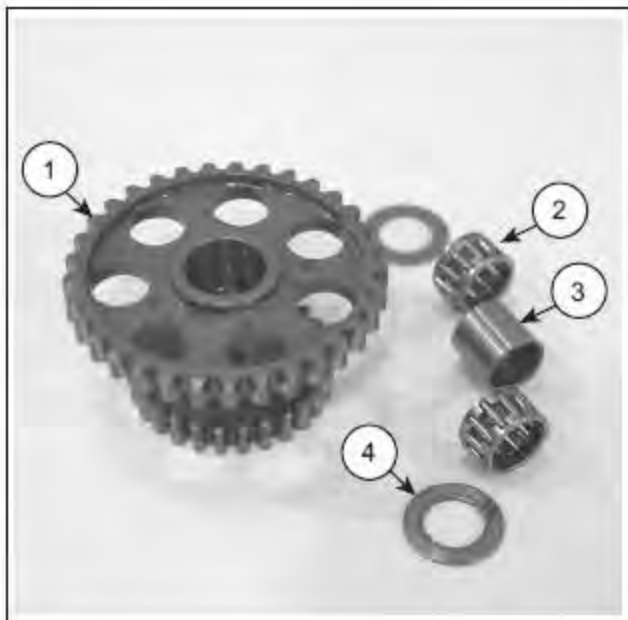
1. Chain
2. Drive gear

## TIMING CHAIN, INSPECT

1. Remove the timing chain (page 34).
2. Remove camshaft drive gear bracket from the cylinder head. Refer to "Cylinder head, disassemble" starting on page 60. Clean the oil passage with compressed air. Make sure the passage is unobstructed.
3. Inspect the camshaft drive gear bracket for bending or damage.  
  
Inspect the oil transfer tube O-ring within the bracket for damage
4. Inspect the camshaft drive gear teeth for wear or damage. Be certain the bearings are undamaged and turn freely.

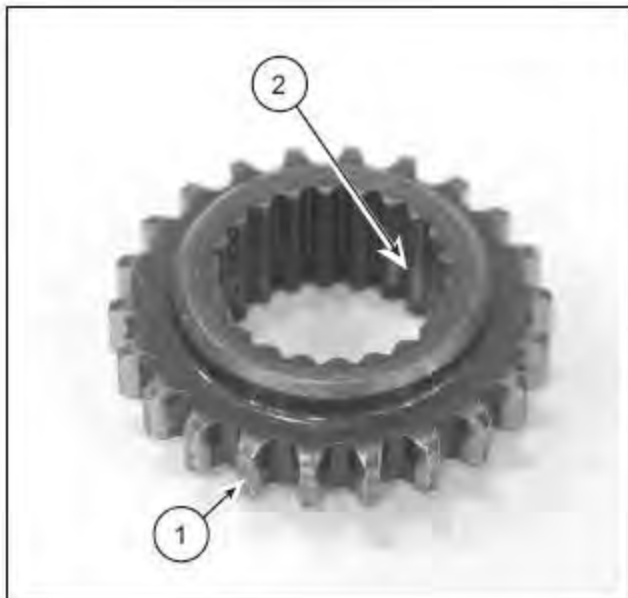


1. Bracket
2. Transmission oil transfer tube O-ring



1. Gear
2. Bearing (2)
3. Spacer (1)
4. Thrust washers (2)

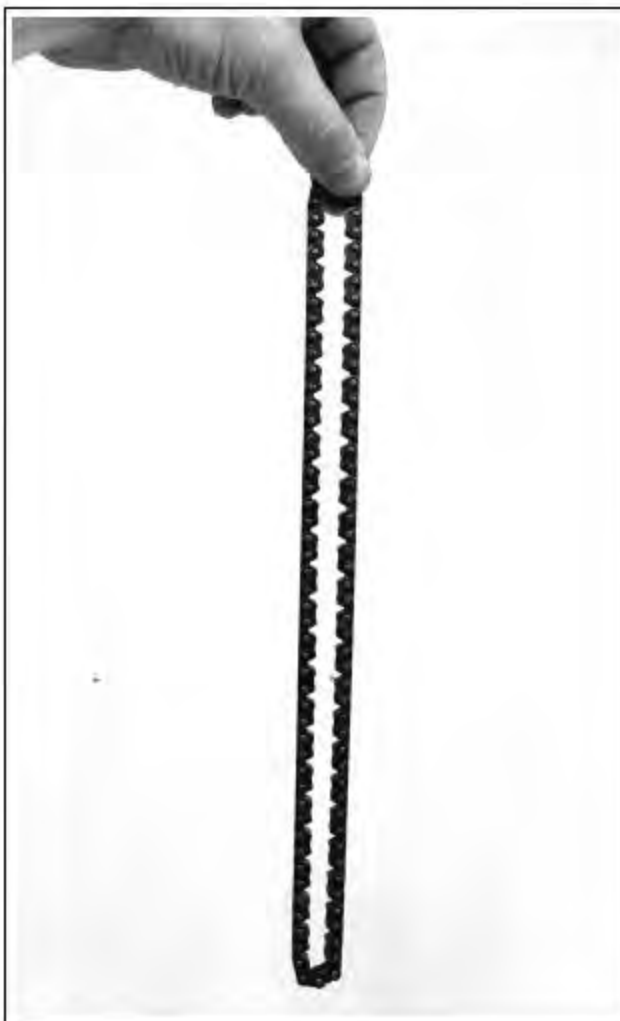
5. Inspect the timing chain drive gear (lower) teeth and splines for excessive wear or damage.



1. Teeth
2. Splines

6. Clean and oil the chain with the specified transmission oil.

Hold the chain as indicated, inspect the timing chain for any stiffness between the links. It should hang freely. If there are cracks or stiffness, replace the chain.



7. Inspect the front and rear timing chain guides for excessive damage or wear.



## TIMING CHAIN, INSTALL

### CAUTION

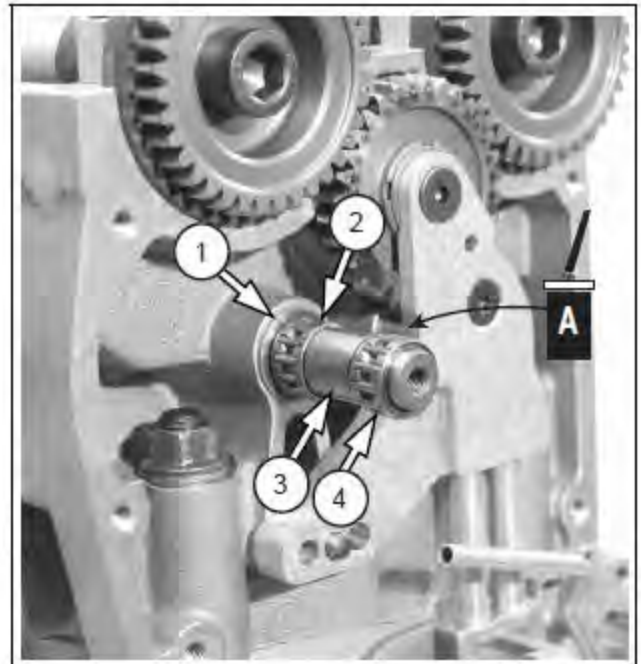
The timing chain tensioner maintains proper chain tension when installed correctly. Do not draw timing chain guides together manually after installing tensioner spring. Severe damage to the timing assembly and engine will occur.

It is recommended to check the camshaft timing following this procedure (page e55).

It is recommended to check the camshaft timing after completing the chain installation (page 55).

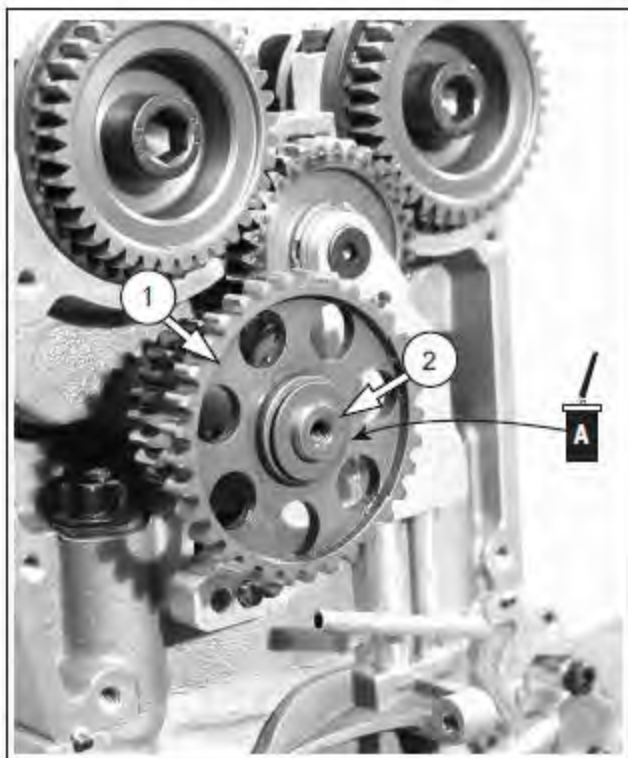
1. Position crankshaft to top-dead-center (TDC) (page 48).
2. Make sure camshafts on the cylinder head are aligned to the TDC position. Refer to "Top Dead Center (TDC), gear alignment, (camshaft, camshaft idler, and timing idler)" starting on page 48.

3. Apply assembly lube to cam drive gear shaft, and install the thrust washer (1), needle bearing (2), spacer (3), needle bearing (4).



1. Washer
2. Bearing
3. Spacer
4. Bearing

4. Apply assembly lube on the bearings. Install camshaft drive gear (1) and thrust washer (2) onto the shaft.



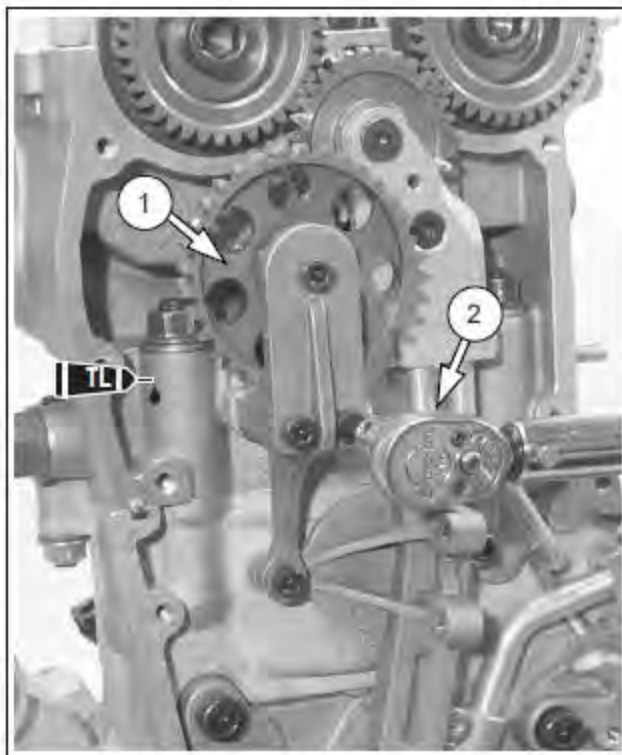
1. Camshaft drive gear
2. Thrust washer

5. Inspect the condition of the oil tube O-ring in the camshaft drive gear bracket. Apply some O-ring lubricant to the O-ring, and install the bracket onto the oil transfer tube. Then install the bracket onto the shaft.

Apply Loctite #242 to the mounting bolts, and tighten evenly to the specified torque.



**Camshaft drive gear bracket bolts**  
3.3 lbf·ft (4.5 N·m)



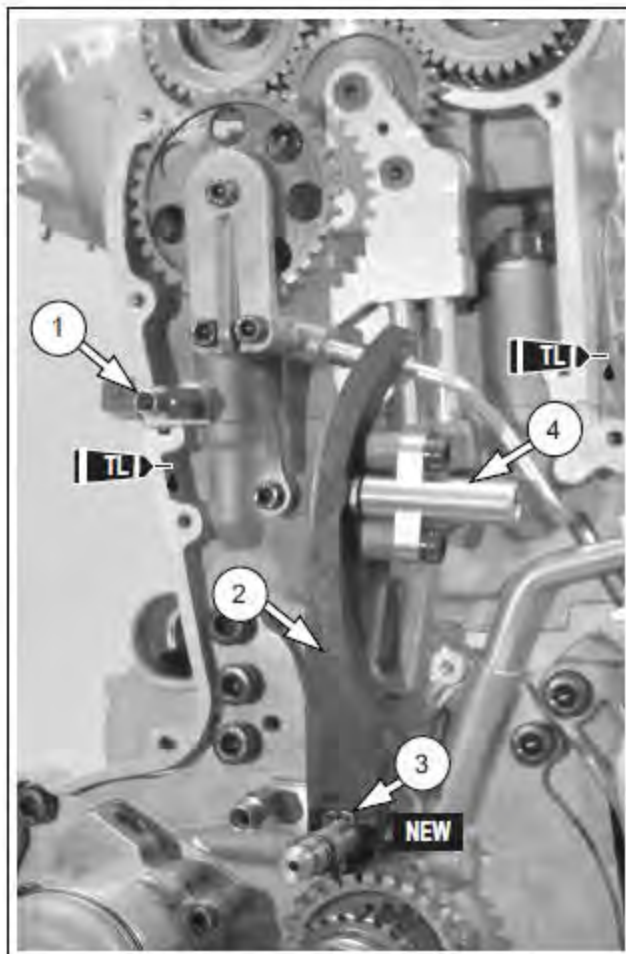
1. Cam shaft drive gear bracket
2. Oil tube (hidden behind torque wrench)

6. Apply Loctite #242 to the threads, and install the front timing chain guide mount. Tighten to the specified torque.

Apply a light coat of transmission oil to the o-rings, and install rear timing chain guide (tensioner side) onto the pivot then install the circlip.

7. Make sure the ratchet pawl is fully retracted.

Apply Loctite #242 to the bolt threads and install the tensioner housing onto the piston pin access cover. Tighten to the specified torque.



1. Left guide mount
2. Rear guide
3. Circlip
4. Tensioner housing

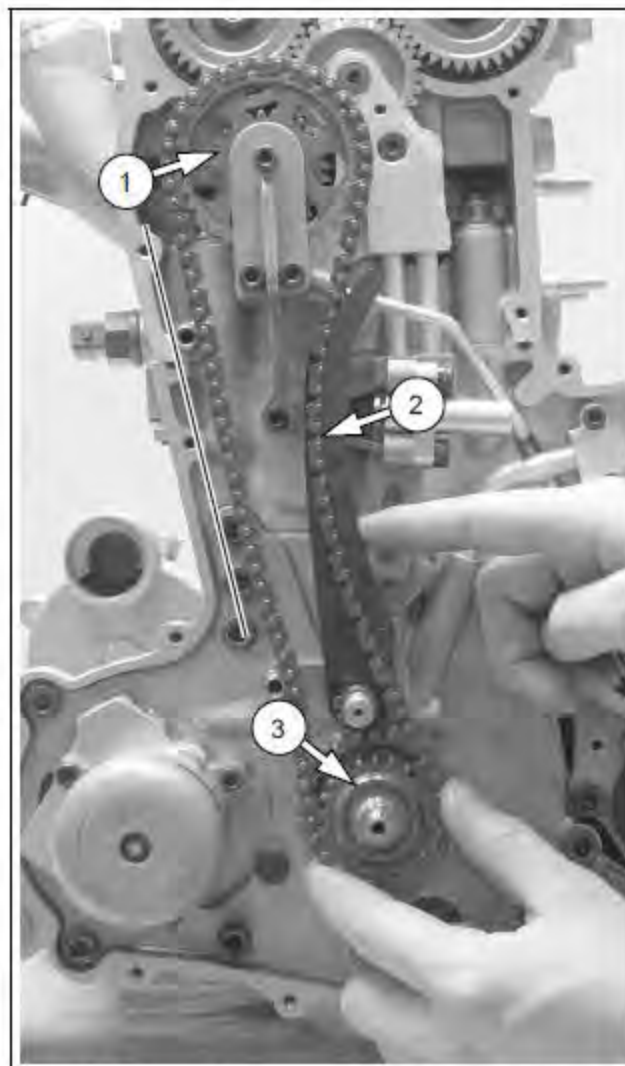


**Left timing chain guide mount upper**  
3.3 lbf·ft (4.5 N·m)

**Timing chain tensioner housing bolts (6 mm)**  
3.3 lbf·ft (4.5 N·m)

8. Position the lower timing chain drive gear onto the timing chain.

Install the upper portion of the chain onto the camshaft drive gear, and install the drive gear (3) onto the crankshaft end.



Keep the left side of the chain taut as you move the drive gear onto the crankshaft splines.

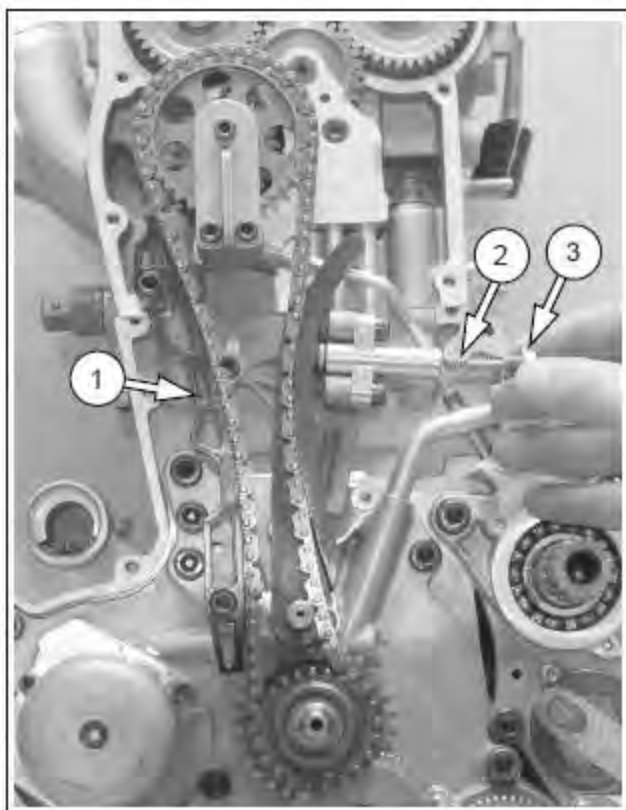
1. Camshaft drive gear
2. Timing chain
3. Timing chain drive gear

#### CAUTION

When installing the left timing chain guide, make sure the recess for the bolt heads face out. If the guide is installed backwards (upside down), the timing chain assembly will be damaged.



9. Apply Loctite #252 (red) to the bolt threads and install the front timing chain guide (1). Tighten the bolts to the specified torque. Install the timing chain tensioner spring (2) and bolt (3).



- 1. Left guide
- 2. Tensioner spring
- 3. Bolt

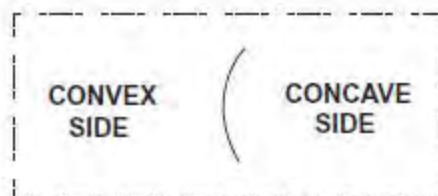


**Left timing chain guide mounting bolts**  
3.3 lbf·ft (4.5 N·m)

**Timing chain tensioner spring bolt**  
3.3 lbf·ft (4.5 N·m)

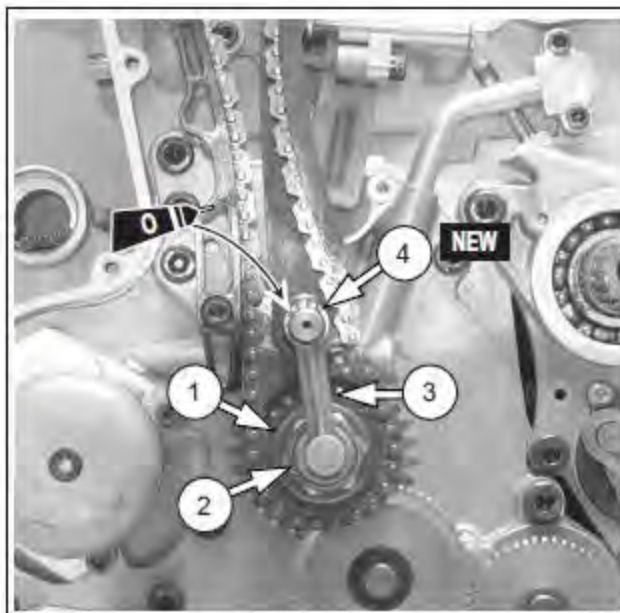
**Crankshaft nut**  
51.6 lbf·ft (70.0 N·m)

10. Check the condition of the crankshaft washer. It can be re-used but only if it is in good condition and undamaged. On rare occasions the washer may flatten - damage.



11. Install the washer with the convex side facing out (toward the nut) and install the crankshaft nut. Tighten the nut to the specified torque.

12. Check and lubricate the two pivot shaft O-rings. Then, Lubricate the oil supply bridge oil seal lips and install it onto the crankshaft end and pivot shaft. Install a new circlip.

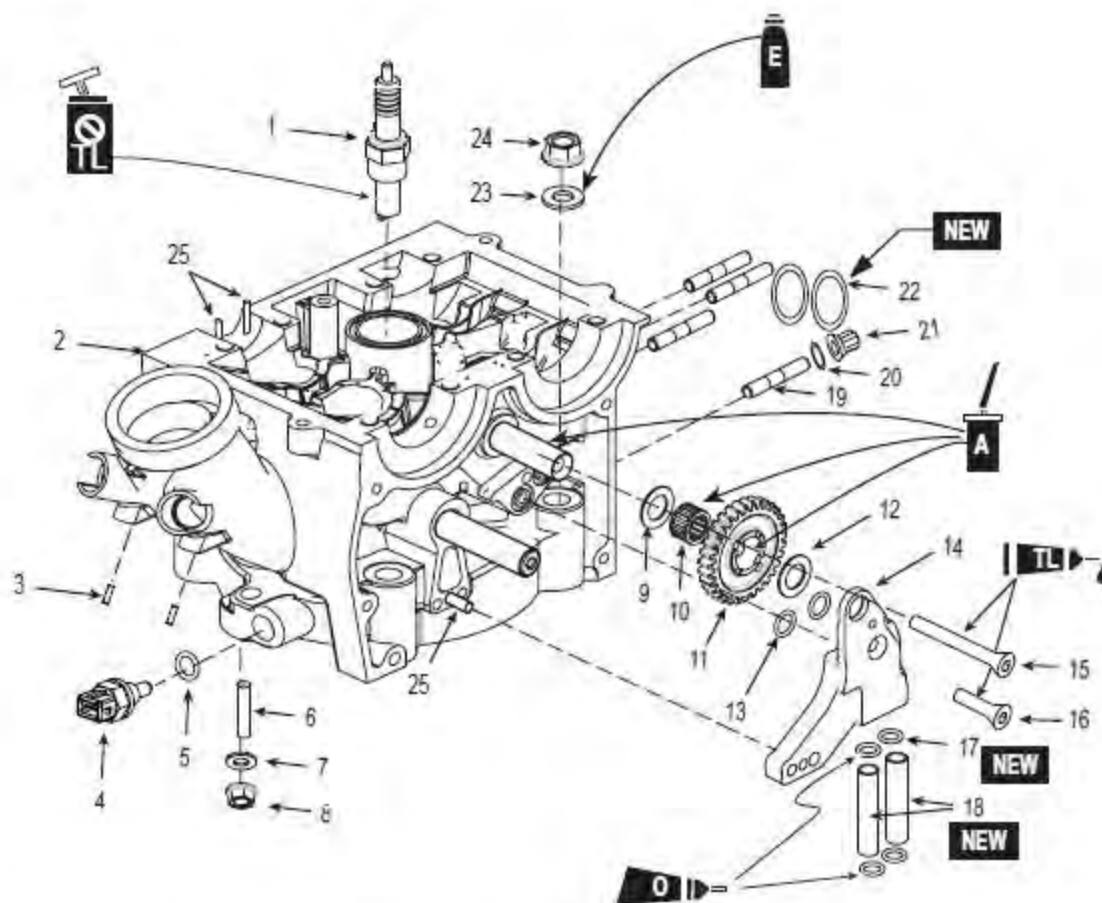


- 1. Washer (convex side out)
- 2. Crankshaft nut
- 3. Oil supply bridge
- 4. Circlip

# Cylinder head/ camshafts/valves

Unit: mm (in)

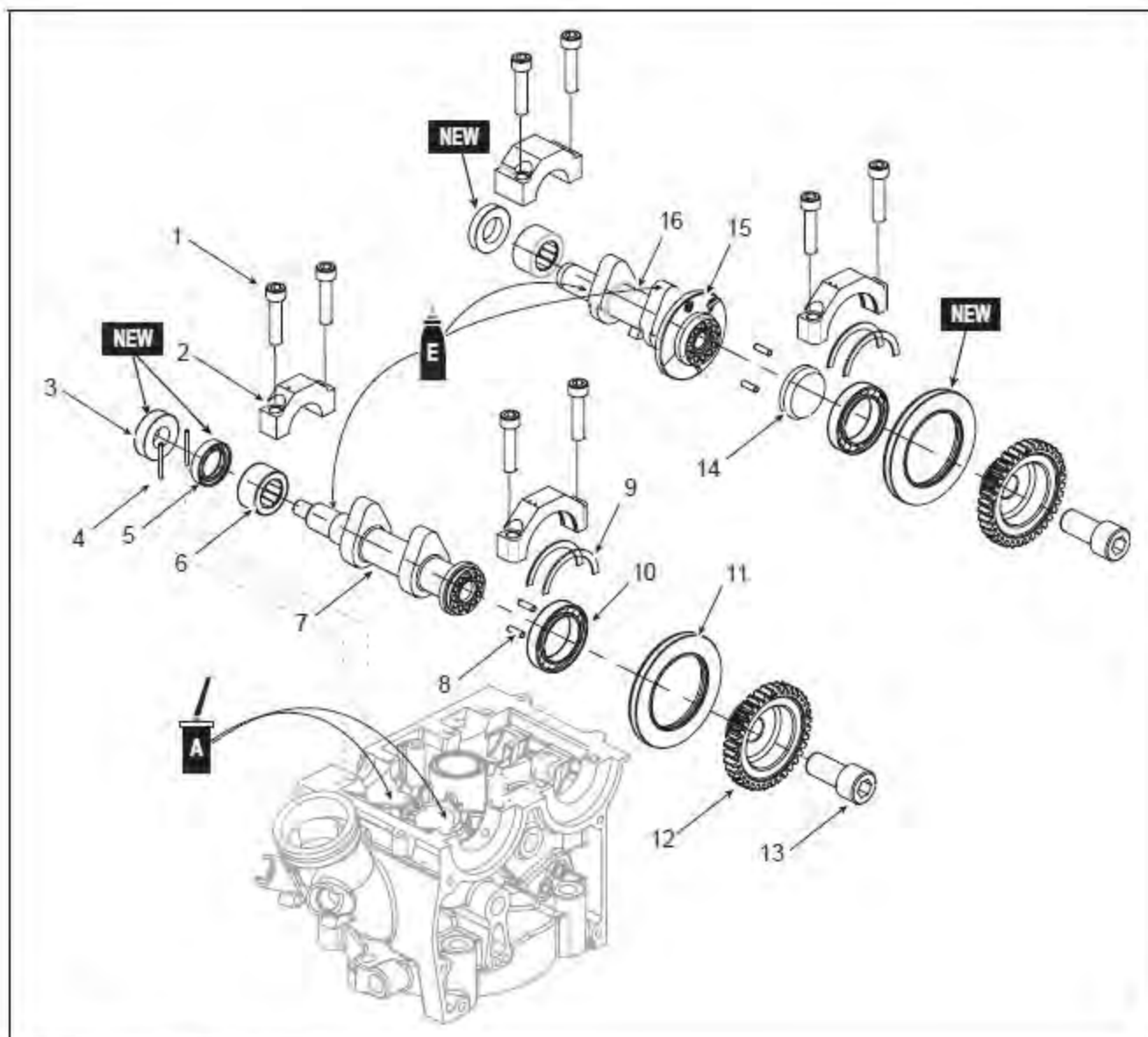
ITEM			STANDARD	SERVICE LIMIT
Cylinder compression			70 - 100PSI (482.633 - 689.4757 kPa, 4.9214 - 7.0308 kg/cm <sup>2</sup> )	
Cylinder head warpage			-	0.002 - 0.05 (0.00007873 - 0.001968)
Camshafts	lobe height	IN	37.850 - 38.000 (1.4901 - 1.4960)	37.500 (1.476)
		EX	36.450 - 36.600 (1.4350 - 1.4409)	36.000 (1.417)
	timing	IN	106° ± 2°	-
		EX	106° ± 2°	-
Valves	clearance	IN	0.18 - 0.23 (0.007 - 0.009)	-
		EX	0.36 - 0.41 (0.014 - 0.016)	-
	stem O.D.	IN	5.474 - 5.489	-
		EX	5.462 - 5.477	-
	head margin	IN/EX	0.87 - 1.13	0.70
	stem runout	IN/EX	-	0.05 (0.00196)
	head radial runout	IN/EX	-	0.03 (0.00118)
	spring free length	Inner	39.0 - 41.0 (1.535 - 1.614)	37.0 (1.456)
		Outer	41.5 - 43.5 (1.633 - 1.712)	39.5 (1.555)
	spring compressed force installed	Inner	84 N (8.566 kgf, 18.888 lbf) at length 32.5 (1.28)	-
		Outer	175 N (17.845 kgf, 39.341 lbf) at length 36.0 (1.417)	-
	spring tilt		-	2.0 (0.078)
	guide I.D.	IN/EX	5.500 - 5.512 (0.216 - 0.217)	-
	Stem-to-guide clearance	IN	0.011 - 0.038 (0.000433 - 0.00196)	0.10 (0.00393)
		EX	0.023 - 0.050 (0.0009 - 0.00196)	0.12 (0.00472)
	seat width	IN	0.9 - 1.1 (0.0354 - 0.0433)	-
		EX	1.0 - 1.2 (0.0393 - 0.0472)	-
Bucket	O.D.		27.985 - 27.980 (1.100 - 1.1015)	-
	Bore		27.995 - 28.010 (1.1021 - 1.1028)	-
	Clearance		0.015 - 0.045 (0.00059 - 0.00177)	0.070 (0.00275)



**ASSEMBLY VIEW : Cylinder head (camshafts removed)**

- |                           |                               |   |
|---------------------------|-------------------------------|---|
| 1. Spark plug             | 11. Idler gear                | 21. Exhaust nuts (4)                      |
| 2. Cylinder head          | 12. Washer                    | 22. Exhaust gaskets (2)                   |
| 3. Injector bracket studs | 13. O-rings (2)               | 23. Washers (4)                           |
| 4. Coolant sensor         | 14. Cam idler gear bracket    | 24. Stud nuts (4)                         |
| 5. O-ring                 | 15. Bolt, 8x45mm              | 25. Dowel                                 |
| 6. Helper studs (2)       | 16. Bolt, 5x25mm              | 26. Intake camshaft seal separator dowels |
| 7. Washer (2)             | 17. Bracket O-rings (4)       |   |
| 8. Helper nut (2)         | 18. Engine oil transfer tubes |   |
| 9. Washer                 | 19. Exhaust studs (4)         |   |
| 10. Bearing               | 20. Exhaust stud lock washers |   |

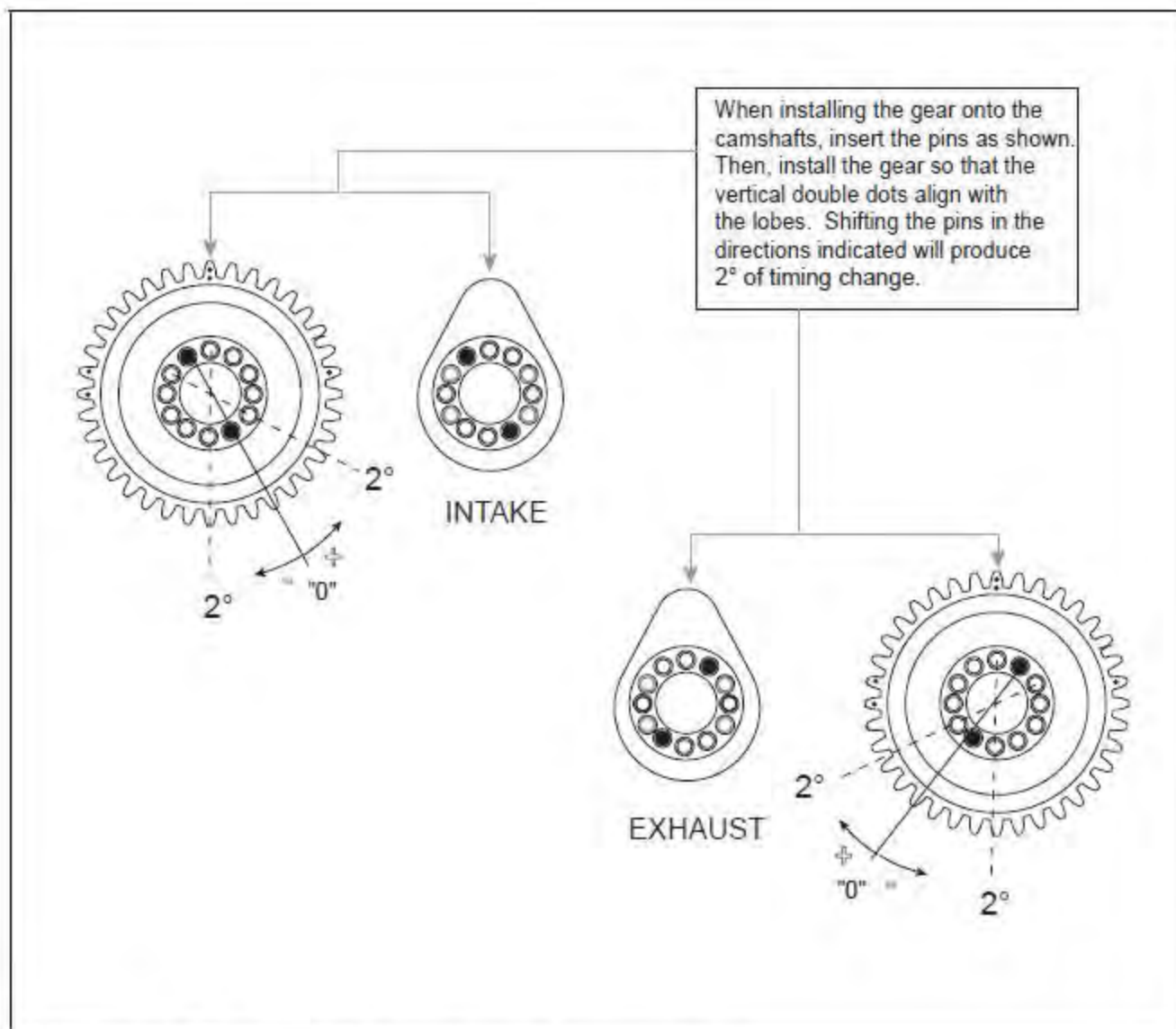




### ASSEMBLY VIEW : Camshafts

- |                          |                          |                                  |
|--------------------------|--------------------------|----------------------------------|
| 1. Bearing cap bolts (8) | 7. Intake cam            | 13. Gear bolt                    |
| 2. Bearing caps (4)      | 8. Pins (4)              | 14. Bearing sleeve               |
| 3. Coolant seal          | 9. Bearing retainers (4) | 15. Compression release assembly |
| 4. Dowel (2)             | 10. Bearings (2)         | 16. Exhaust cam                  |
| 5. Oil seal              | 11. Seal (2)             |                                  |
| 6. Bearing (2)           | 12. Gear (2)             |                                  |



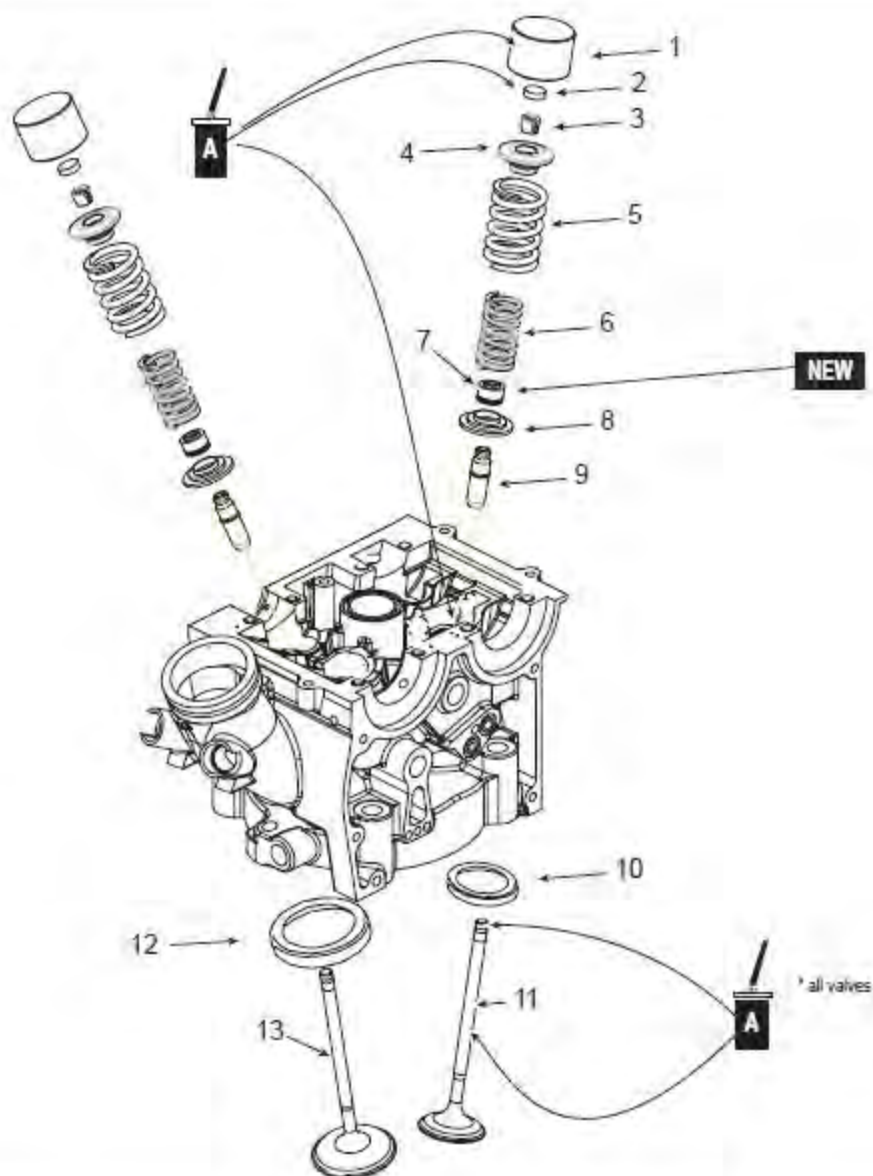


**ASSEMBLY VIEW : Camshafts (gear-to-pin timing positions)**

**NOTE :**

*Always insert the pins in the camshaft then reinstall the gear with the lobe and two vertical dots on the gear aligned.*

*Pin movement to the right/left of the factory installed position "0" will change 2° -/+ as indicated in the illustration.*

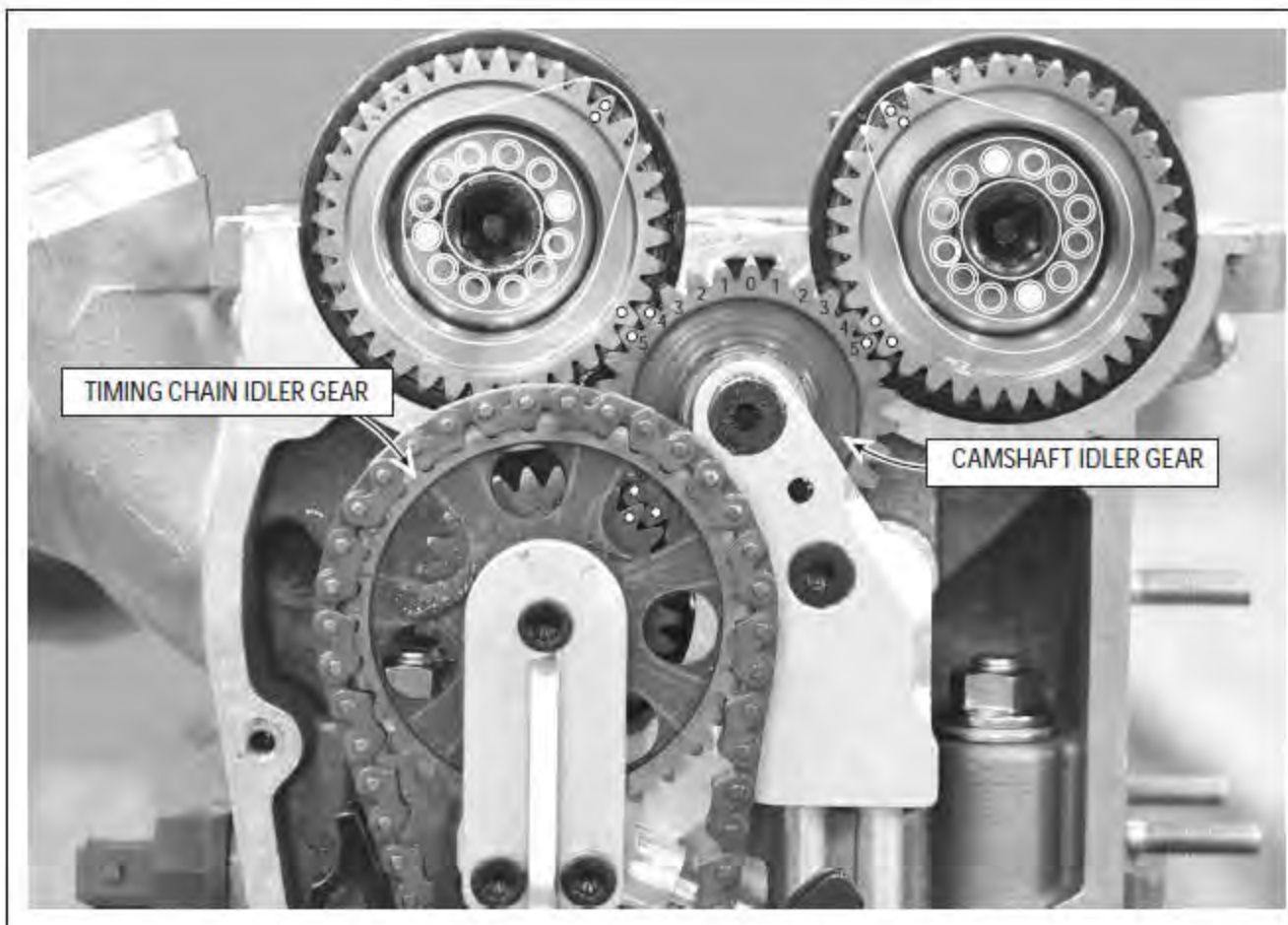


### ASSEMBLY VIEW : Valves

- |                          |                       |                      |
|--------------------------|-----------------------|----------------------|
| 1. Bucket (4)            | 7. Seal (4)           | 13. Intake valve (2) |
| 2. Shim (4)              | 8. Spring seat (4)    |                      |
| 3. Keepers (2 per valve) | 9. Guide (4)          |                      |
| 4. Retainer (4)          | 10. Exhaust seat (2)  |                      |
| 5. Outer spring (4)      | 11. Exhaust valve (2) |                      |
| 6. Inner spring (4)      | 12. Intake seat (2)   |                      |



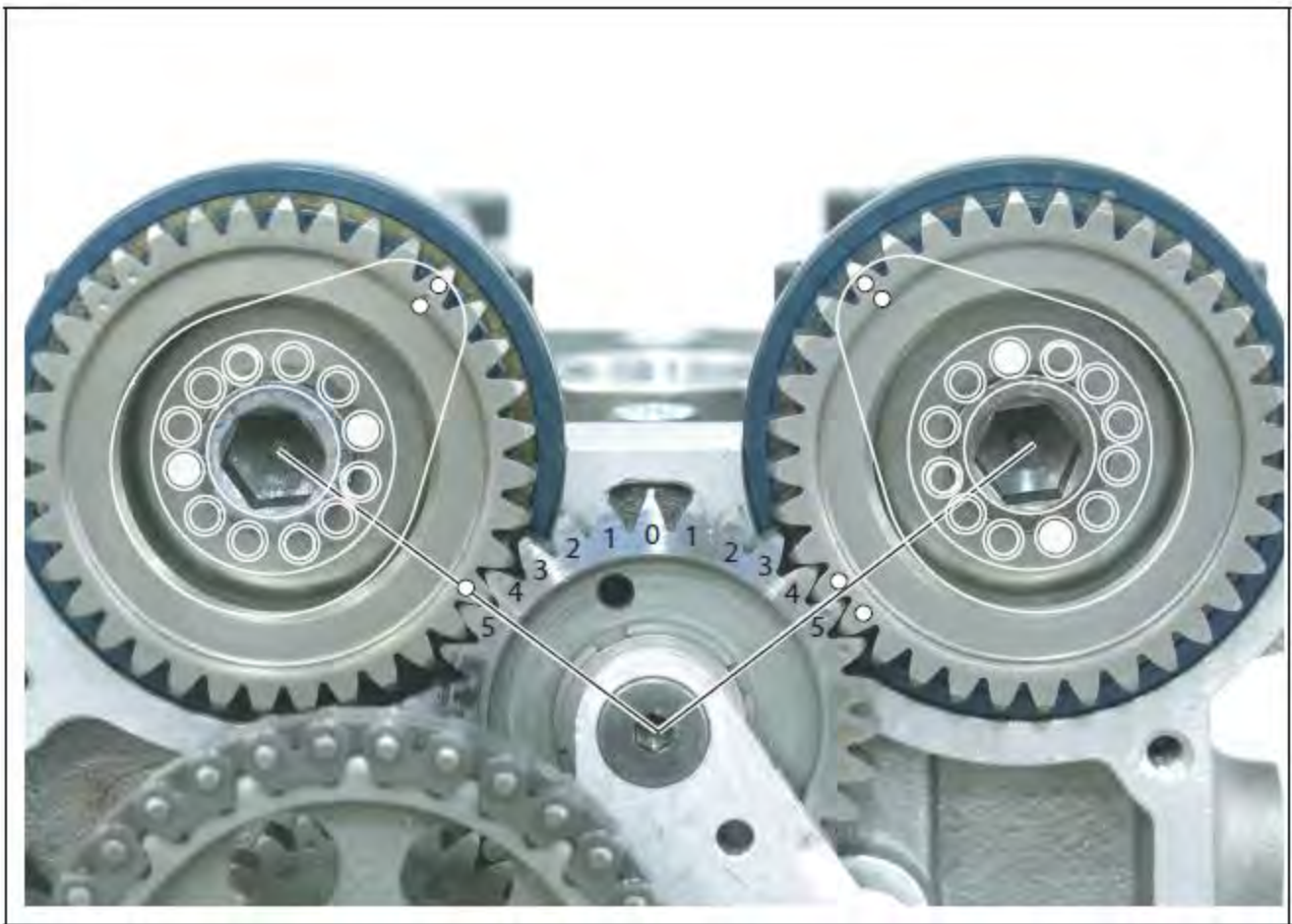




**ASSEMBLY VIEW : Top Dead Center (TDC), gear alignment, (camshaft, camshaft idler, and timing idler)**

**NOTE :**

*Notice the alignment of timing marks for all gears - when rebuilding the engine (reinstalling the cylinder head) Although this alignment can be achieved by continually rotating the crankshaft until the markings align as shown, see the next illustration for an alternative alignment of only the cylinder head idler gear and the camshaft gears.*



**ASSEMBLY VIEW : Top Dead Center (TDC), gear alignment, (camshafts and camshaft idler)**

**NOTE :**

*This photo illustrates the correct alignment of the timing marks with the TDC bolt installed. This alignment view is possible when it is not desirable to disassemble the entire timing chain drive system. Here markings of the idler gear are not considered - only the camshaft gear markings.*



## CRANKSHAFT TOP-DEAD-CENTER (TDC), SETTING

The following procedure is a common "first step" in many other procedures in this manual.

### CAUTION

After performing any service procedure that requires the use of the TDC bolt to position the crankshaft, replace the spacer on the TDC bolt and tighten to it's specified torque.



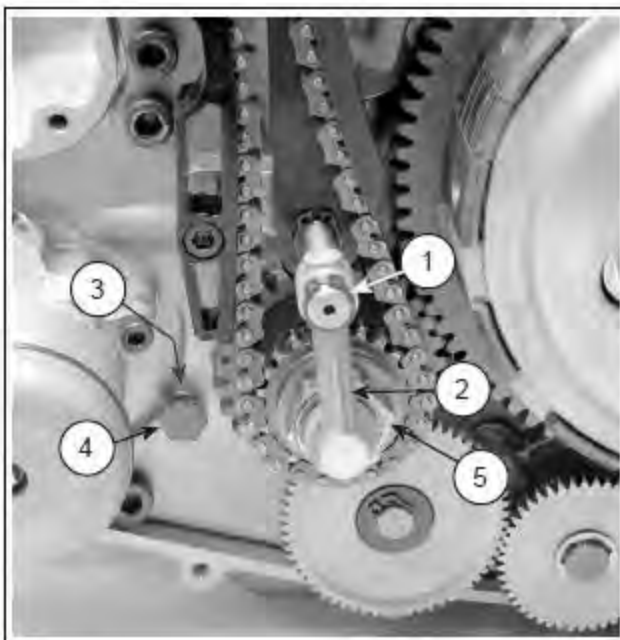
**TDC bolt (Top Dead Center bolt)**  
8.1 lbf·ft (10.8 N·m)

### NOTE :

*Remove spark plug to reduce compression resistance.*

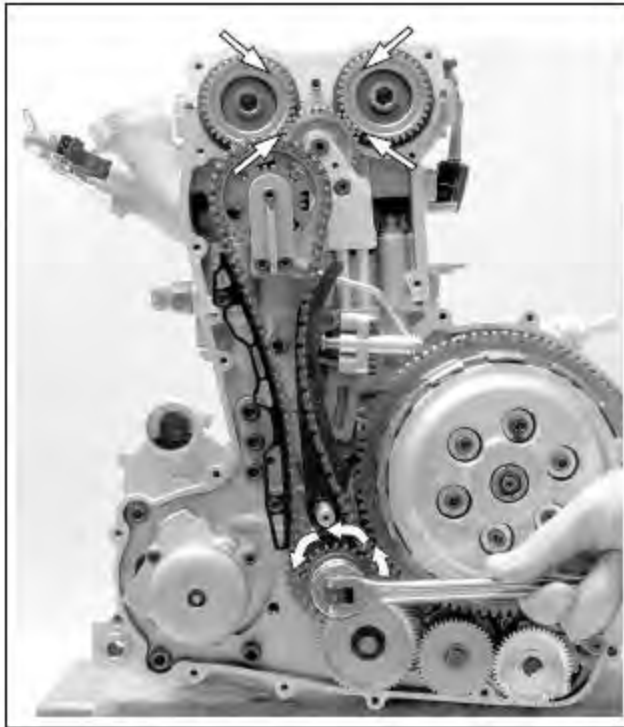
1. Remove the spark plug.
2. Remove the crankcase cover (page 21).

3. Remove the circlip (1) and oil supply bridge (2). Remove the TDC bolt (4) and spacer (3).



1. Circlip
2. Oil supply bridge
3. TDC washer (spacer)
4. TDC bolt
5. Crankshaft nut

4. Use a socket and wrench on the crankshaft nut to slowly turn the crankshaft counterclockwise until timing marks on cam gears appear as illustrated.



5. Refer to "Top Dead Center (TDC), gear alignment, (camshaft, camshaft idler, and timing idler)" starting on page 48.

- Or -

6. Refer to "Top Dead Center (TDC), gear alignment, (camshafts and camshaft idler)" starting on page 49.

#### CAUTION

When installing the TDC bolt, make sure the tip of the bolt locates in the hole (1) in the crankshaft counter weight.

In order for the tip of the TDC bolt to locate properly in the counterweight, the head of the bolt must contact the plate surface.



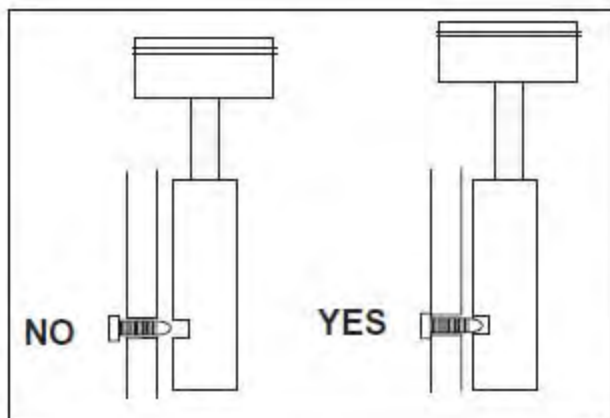
1. Crankshaft TDC bolt relief hole (crankshaft is shown removed for clarity)

1. Use the crankshaft nut to shift the crankshaft back and forth slightly. Watch for the crankshaft hole as it moves past the hole in the crankshaft cartridge plate.

Install the TDC bolt (without the washer (spacer)) finger tight. Make sure the head of the bolt contacts the plate surface.

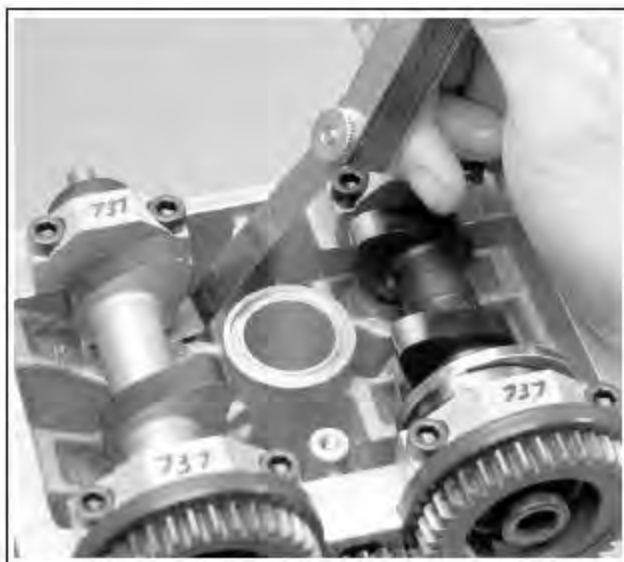


Use the crankshaft nut, to rock the crankshaft so that you can see crankshaft hole moving past the hole in the crankshaft cartridge plate.



## VALVE CLEARANCE, INSPECT

1. Position the crankshaft to top dead center (TDC) (page 48).
2. Remove the cylinder head / camshaft cover (page 23).
3. Measure valve clearance at each lobe on the intake and exhaust camshafts using a feeler gauge.



**Valve, intake clearance**  
0.007 - 0.009 in (0.18 - 0.23mm)

**Valve, exhaust, clearance**  
0.014 - 0.016 in (0.36 - 0.41mm)

4. If the clearance is out of specification, you will have to replace the installed shims with a different shim.

### NOTE :

*Following any shim change, be sure to rotate crankshaft one cycle and reinstall the TDC bolt. Then, recheck the clearance on each lobe.*



## CAMSHAFTS, INSTALL

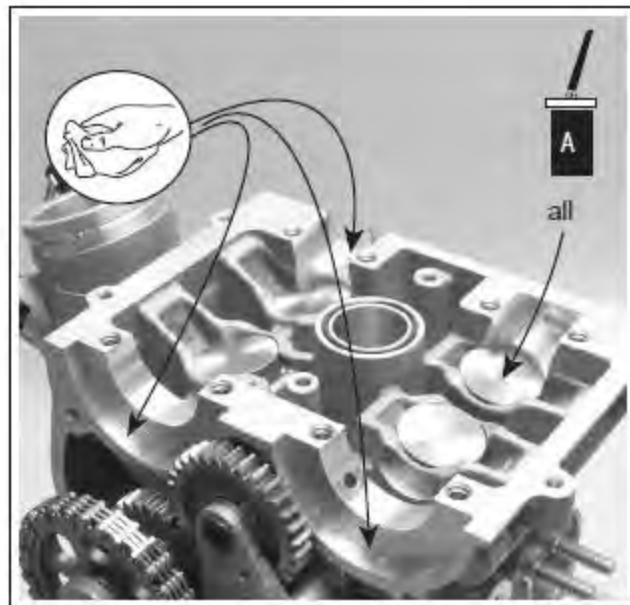
### CAUTION

Avoid mis-application of assembly lube especially in the areas near to coolant or oil seals. Make sure the seals and contact surfaces are clean and dry before positioning the seals.

Restrict application of assembly lube to bearings, bucket tops, and cam lobes.

Return all bearing caps to their original location.

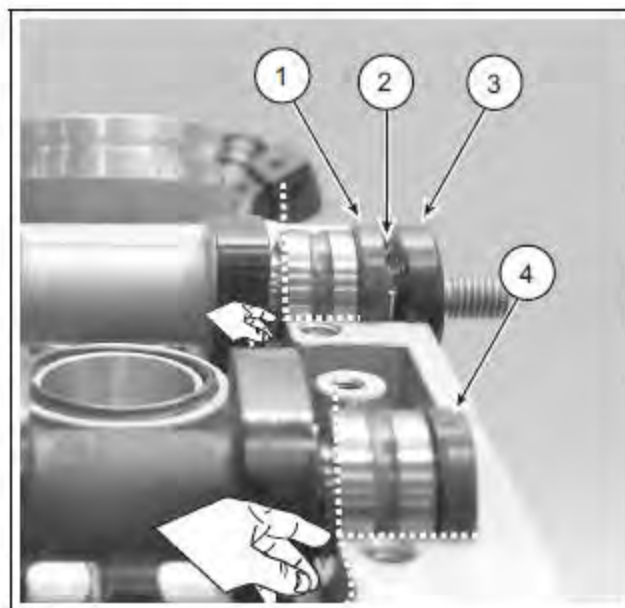
1. Position crankshaft to TDC, and install the TDC bolt (page 48).
2. Make sure the areas indicated in the photo are clean and dry.
3. Apply assembly lube to the tops of the valve buckets.



4. Install the camshaft assemblies onto the cylinder head.

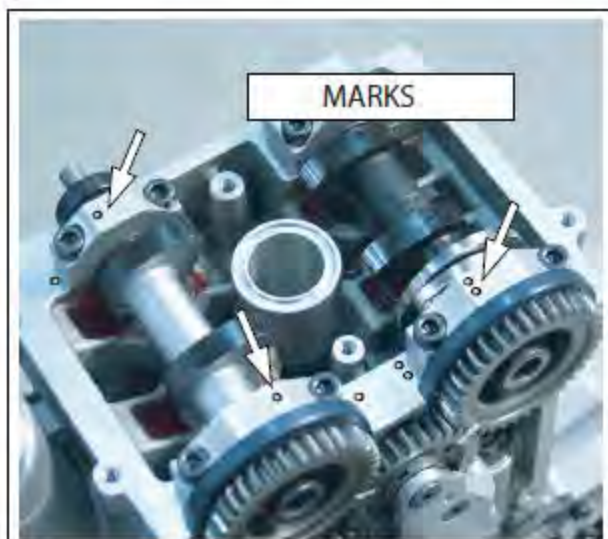
While installing the intake cam, position the oil and coolant seal as illustrated.

For both camshafts, make sure the right cam bearings align with the inner edge of the cylinder head. See the photo below. Also, make sure each bearing is returned as removed and the bearing markings face the lobes.



1. Intake camshaft oil seal (open end faces lobes)
2. Locating dowels
3. Intake camshaft coolant seal (open end faces pump impeller)
4. Exhaust camshaft oil seal (open end faces away from lobes)

5. Install the camshaft bearing caps. The camshaft caps are a machined "match" and must be returned to their original location. Use the punch marks to locate each cap properly.



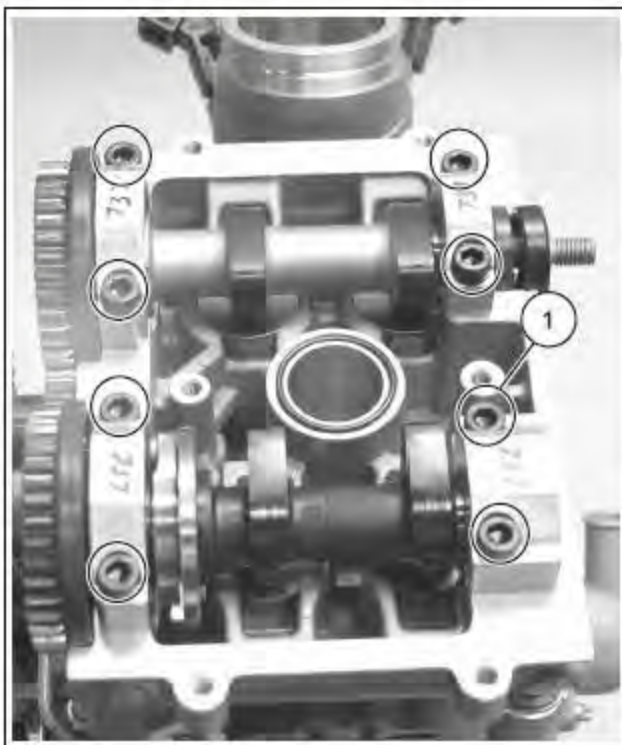
**NOTE :**

*Before you tighten the cap bolts make sure the large seal on each camshaft is positioned properly.*

6. Tighten the cap bolts evenly to the specified torque.



**Camshaft bearing cap bolts  
10.0 lbf·ft (14.0 N·m)**



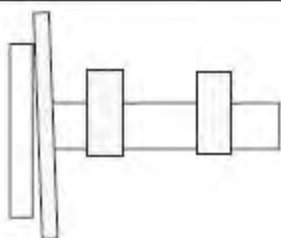
1. Bolts)

**NOTE :**

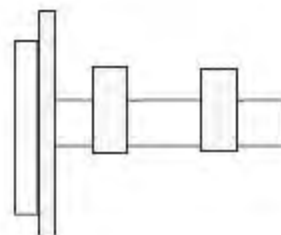
*Following installation of the camshafts, it is recommended that the camshaft timing be inspected (page 55).*

*It is also recommended that the valve clearance be inspected (page 58).*

**NO**




**YES**





## CAMSHAFT TIMING, INSPECT

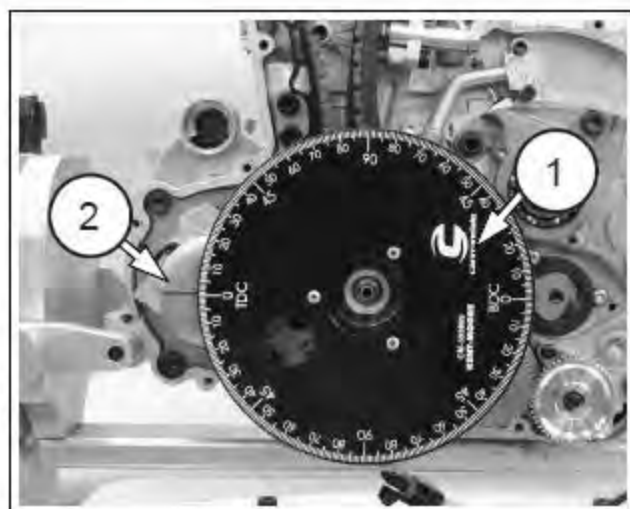
The following procedure applies to both camshafts.

	<p><b>Camshaft, intake, timing</b>  <math>106^{\circ} \pm 2^{\circ}</math></p> <p><b>Camshaft, exhaust, timing</b>  <math>106^{\circ} \pm 2^{\circ}</math></p>
---	--

1. Position crankshaft to top-dead-center (TDC) (page 48).
2. Remove the cylinder head / camshaft cover (page 23).
3. With the TDC bolt properly installed, apply the special tool (1) onto the crankshaft end. Next, install the crankshaft washer and nut. Then, roughly locate the "0" mark of the tool over the center of the oil filter housing cap. Tightening the crankshaft nut securely.

**TOOL : CM-503869,  
 Degree wheel**

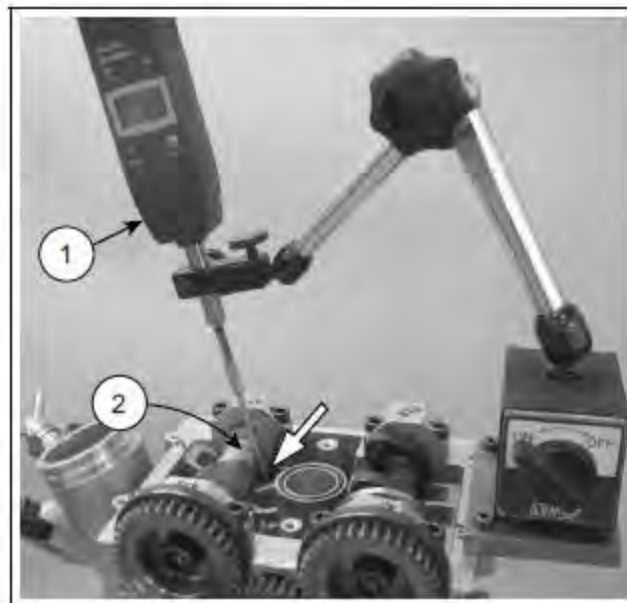
4. With the crankshaft nut tightened securely, make a temporary reference mark (2) on the housing cover.



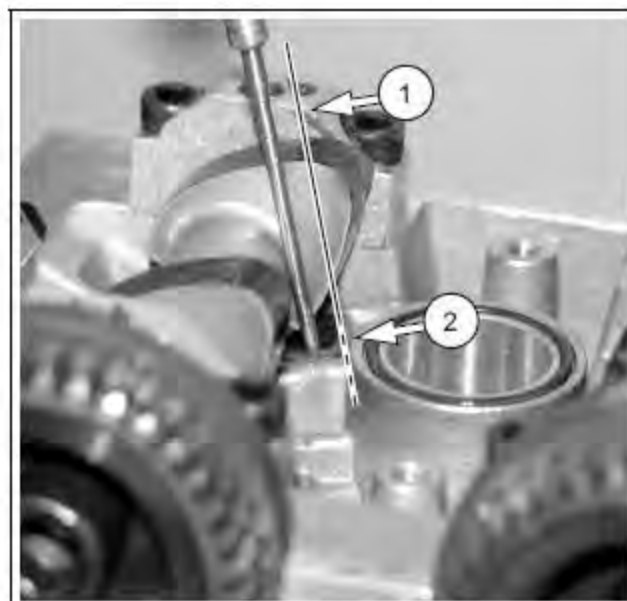
1. Special tool
2. Reference mark

5. Position a dial indicator onto the cylinder head. Use the camshaft cover bolts to retain the dial mounting plate.

Then, position the probe as indicated in the photo below. Make sure the probe shaft is aligned with the valve bucket sides.



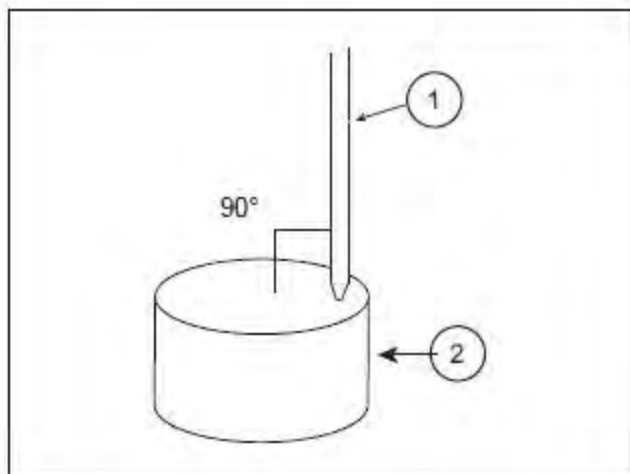
1. Dial indicator tool
2. Intake camshaft



This photo shows the proper positioning of the probe shaft to obtain an accurate reading. Notice that it is at a 90 degree angle with the top of the bucket.

1. Probe tip
2. Bucket





1. Probe tip
2. Valve bucket

6. Remove the TDC bolt and "zero-out" the dial indicator tool.

**NOTE :**

*In the next step, the probe will be traveling in the negative direction (downward) as you turn the crankshaft.*

7. Slowly turn the crankshaft counterclockwise until dial indicator reads -1.00mm; hold and have an assistant record the degree wheel reading at the reference mark. This is wheel reading "A."
8. Continue turning the crankshaft counterclockwise until the dial indicator reads -1.00mm again; have your assistant record the reading. This is wheel reading "B."
9. Add wheel readings "A" and "B". Next, add 180 and divide by 2.
10. Subtract the smaller of the two wheel readings "A" or "B" from the result. This will give you the current camshaft timing in degrees.

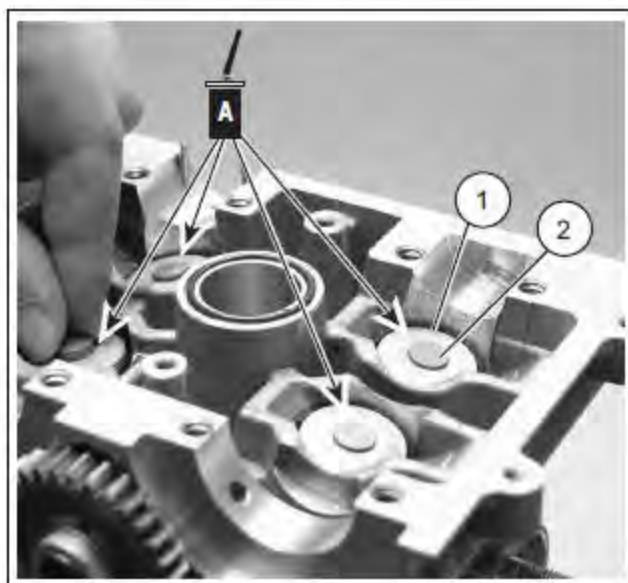
If the timing is not within the specified limits, you have to relocate the pins in camshaft. Refer to "Camshafts (gear-to-cam pin timing positions)" starting on page 45.

## VALVE CLEARANCE, ADJUST

### CAUTION

Be sure to record shim numbers and bucket positions as they are removed.

1. Remove the camshafts (page 61).
2. Use a valve lapping tool to remove the valve buckets.
3. Remove the current shim from the spring retainer and measure it - record the measurement.
4. Consult the shim tables and select a new shim for each valve to achieve specified clearance. Refer to "Valve Clearance Shim Tables" starting on page 183.
5. Apply some assembly lube to the top of the valve retainer, and install the new shim with the markings facing up into the retainer.

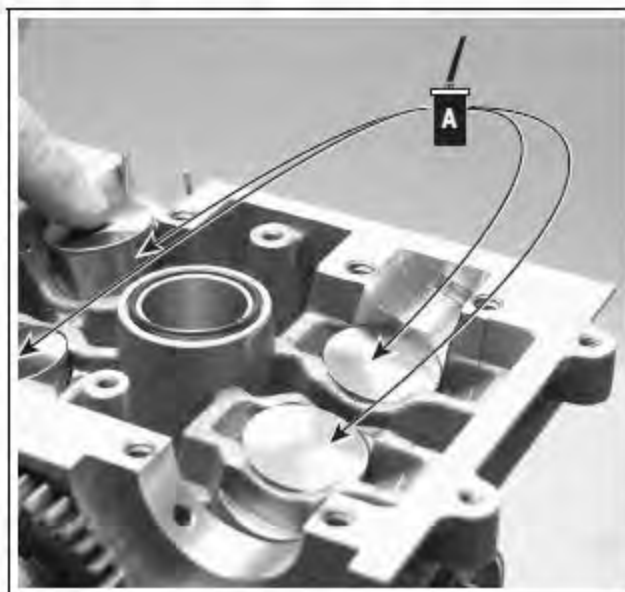


1. Retainer
2. Shim

### CAUTION

When re-installing the buckets, they should "slip fit" into the cylinder head. And, should be able to be rotated when installed. If they are hard to install and are not free to rotate, they are damaged and must be replaced.

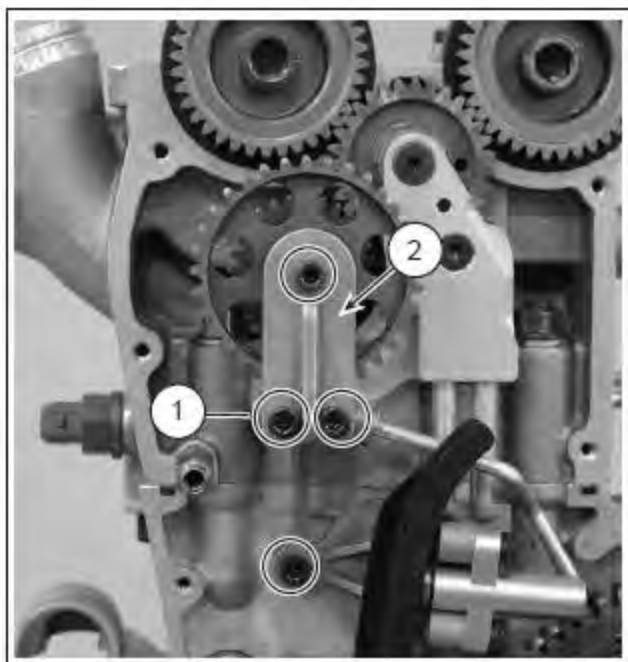
6. Apply assembly lube to the bucket tops, then install them into their original locations.



7. Reinstall the camshafts to the correct TDC alignment. Refer to "Top Dead Center (TDC), gear alignment, (camshaft, camshaft idler, and timing idler)" starting on page 48.
8. Remove the TDC bolt and rotate crankshaft one full revolution counterclockwise.
9. Re-position crankshaft back to TDC and install the TDC bolt - without the spacer.
10. Reinspect valve clearance and adjust if necessary.

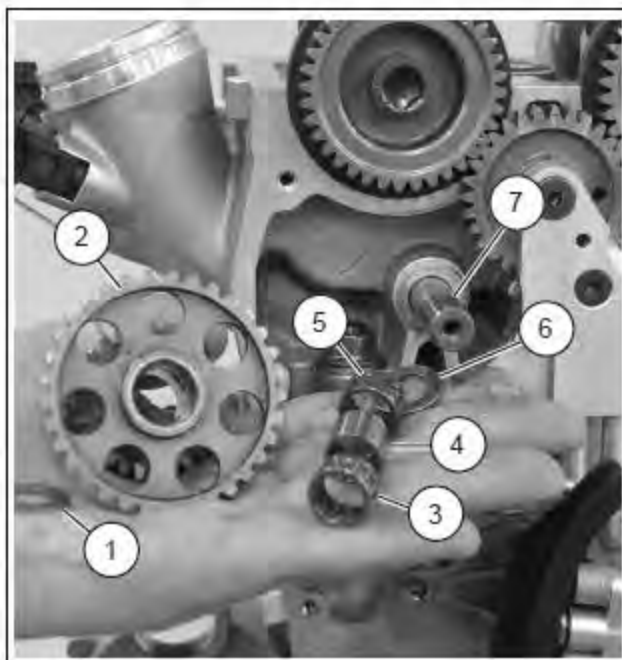
## CYLINDER HEAD, REMOVE

1. Remove the crankcase cover (page 21).
2. Remove the coolant pump housing (page 27).
3. Remove the cylinder head/camshaft cover (page 23).
4. Position crankshaft to top dead center (TDC) and install the TDC bolt (page 48).
5. Remove the timing chain assembly (page 34).
6. Remove the bolts (1) and remove the camshaft drive gear bracket (2).



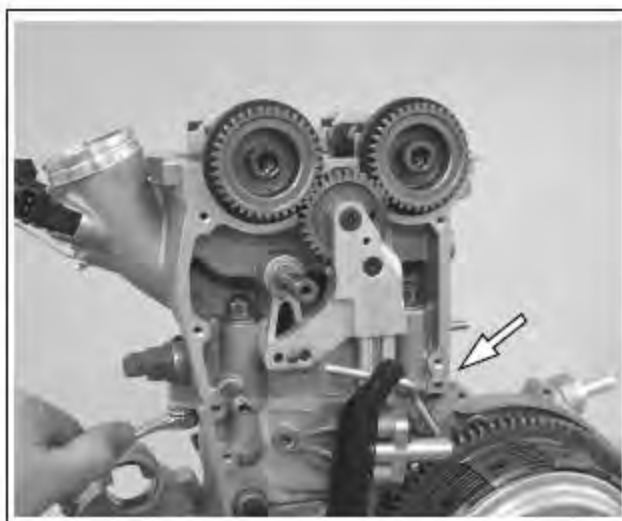
1. Bolts
2. Camshaft drive gear bracket

7. Remove the thrust washer (1), camshaft drive gear (2), bearing (3), spacer (4), bearing (5), and thrust washer (6) from the shaft (7).



1. Thrust washer
2. Camshaft drive gear
3. Bearing
4. Spacer
5. Bearing
6. Thrust washer
7. Shaft

8. Remove the two lower helper stud nuts and washers.

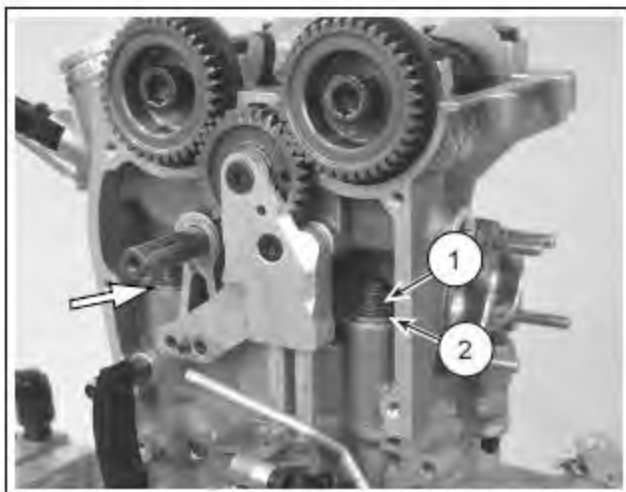




## CAUTION

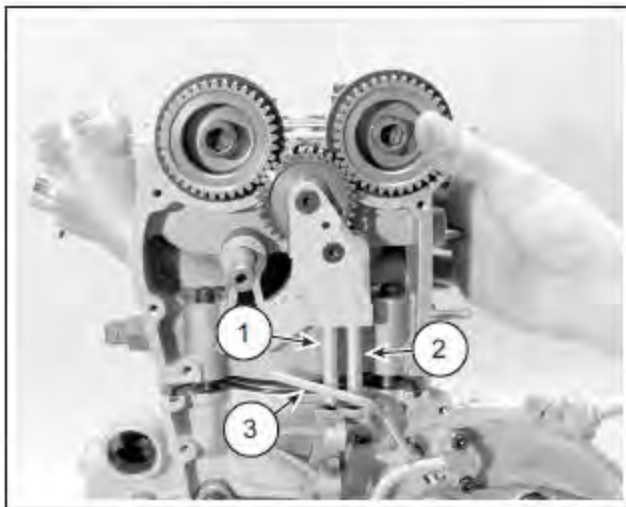
Loosen each of the four cylinder head stud nuts 1/4 turn and in a criss-cross pattern. This technique helps avoid head distortion.

9. Remove the four cylinder head stud nuts and washers.



1. Nut
2. Washer

10. Lift the cylinder head assembly off of the crankcase taking care not to damage the oil supply tubes.



1. Supply tube (engine oil)
2. Scavenge tube (engine oil)
3. Transfer tube (transmission oil)

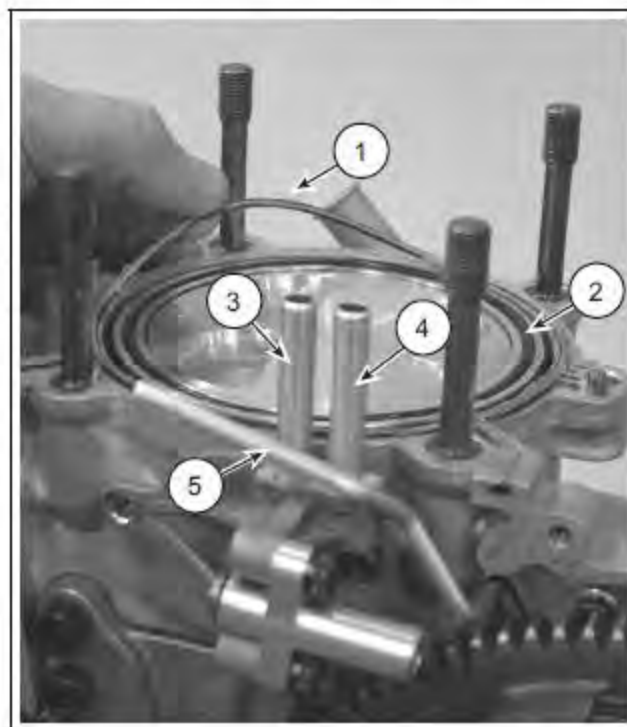
## NOTE :

*The oil transfer tubes may be left in place if steps are taken to protect the tubes from damage or contaminants entering the system.*

*If you remove the oil tubes, cover the holes with a piece of masking tape so that no debris will enter the system.*

11. Remove the cylinder head seal (1) and sleeve o-ring (2) and discard them.

Be certain to clean off any remaining silicon sealant from the crankcase mating surface.



1. Head seal
2. Sleeve O-ring
3. Engine oil supply to cylinder head
4. Engine oil supply to scavenge pump
5. Transmission oil transfer tube.



## CYLINDER HEAD, DISASSEMBLE

### CAUTION

When handling the cylinder head with the intake camshaft bearing caps removed, avoid damaging the two seal locating dowel pins on the right side of the head.

Be sure to record the location of removed components.

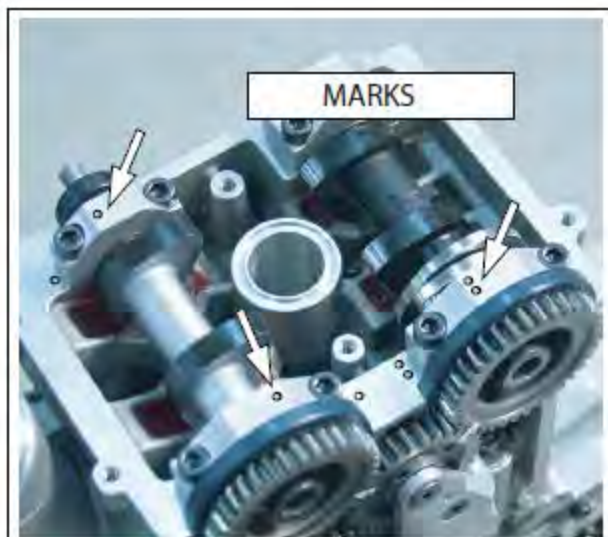
Do not reuse any seals. Discard them and replace new.

The camshaft bearing caps are marked - be sure to return them as removed.

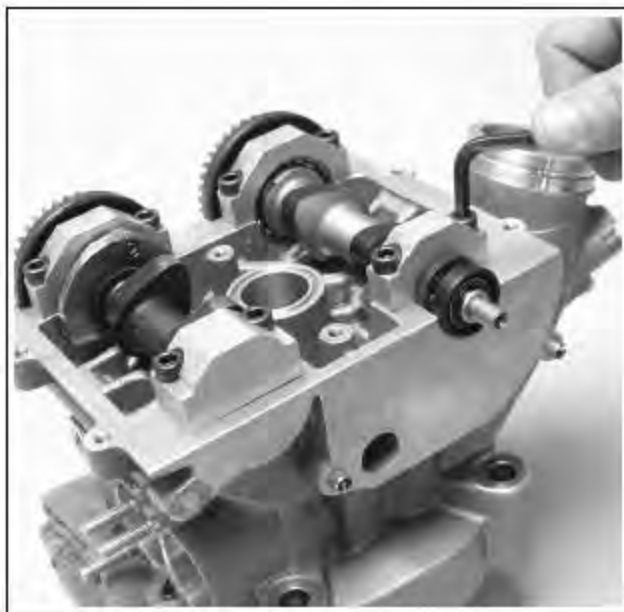
1. Remove the cylinder head (page 58).

### CAUTION

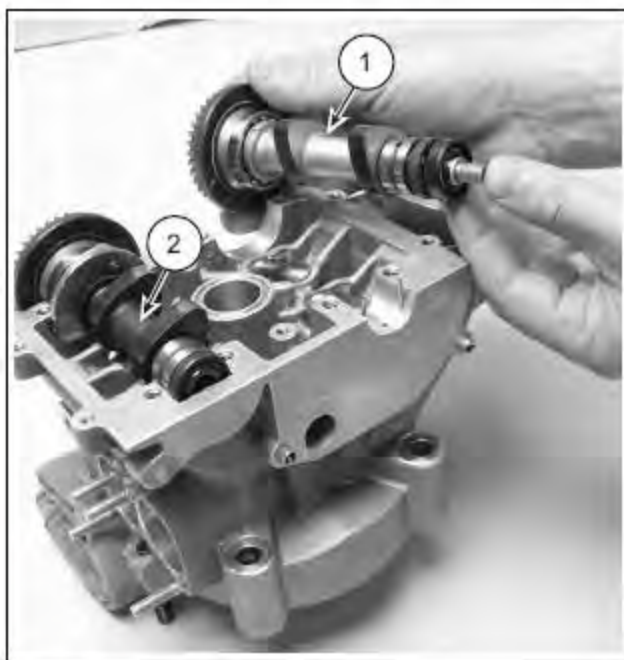
The camshaft bearings must be returned as removed. Notice the alignment marks on the caps and cylinder head. Use these marking to reposition the caps when reinstalling.



2. Remove the cap bolts and remove the camshaft bearing caps.



3. Lift out the camshaft.
4. Lift out the camshaft assemblies.



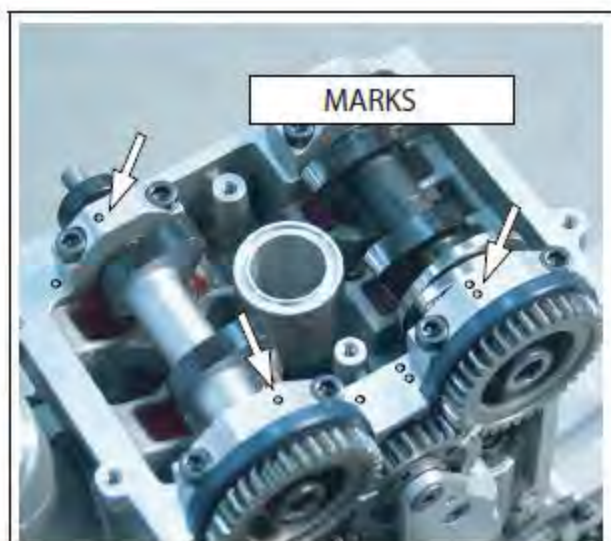
1. Intake camshaft assembly
2. Exhaust camshaft assembly

## CAMSHAFTS, REMOVE

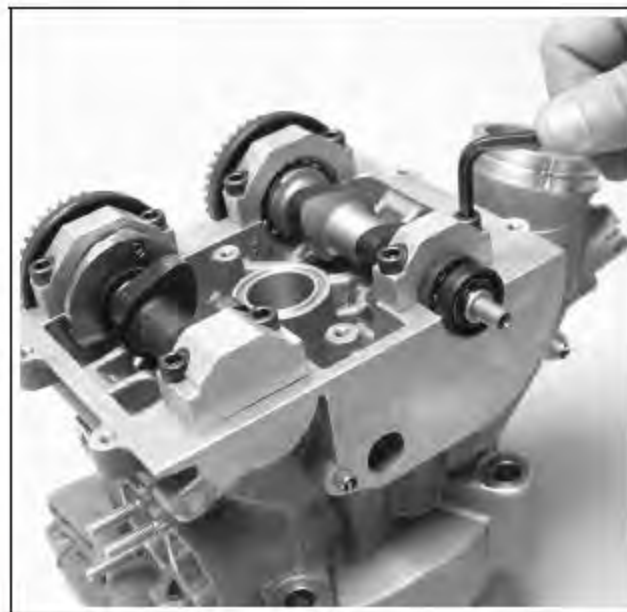
1. Position crankshaft to top dead center (TDC), and install the TDC bolt (page 48).
2. Remove cylinder head/camshaft cover (page 23).

### CAUTION

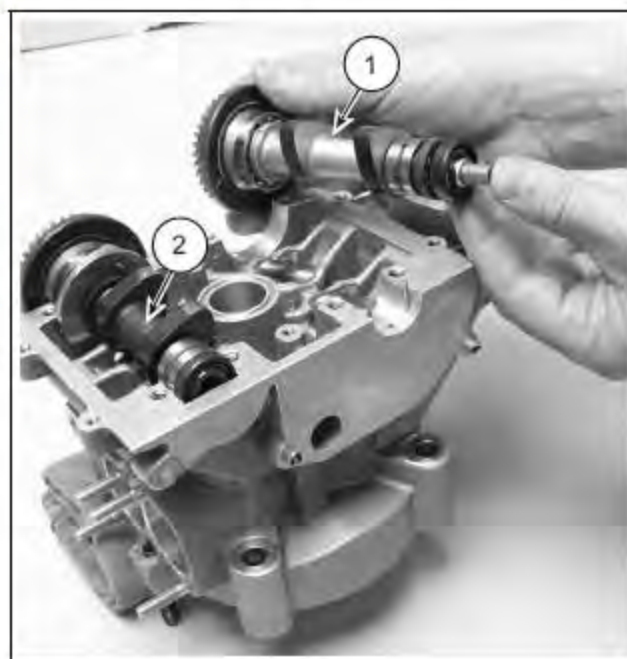
Notice the markings "dots" on the caps and cylinder head itself. Use these marking to reposition the caps when reinstalling later.



3. Remove the cap bolts and remove the camshaft bearing caps.



4. Lift out the camshaft assemblies.



1. Intake camshaft assembly
2. Exhaust camshaft assembly

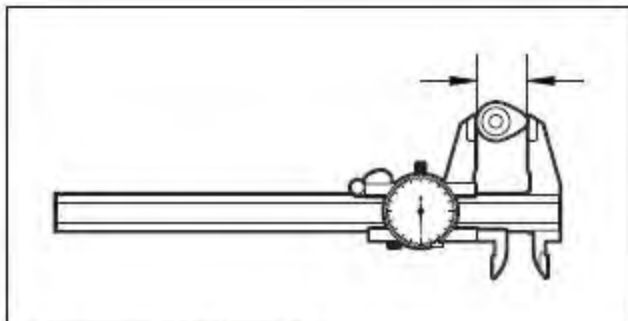


## CAMSHAFTS, INSPECT

### CAUTION

Do not attempt to remove (or disassemble) the automatic decompression assembly of the exhaust camshaft. It is not serviceable.

1. Disassemble the camshafts.
2. Check the cam gear teeth for wear or damage.
3. Turn the outer race of both the larger and smaller bearing of each camshaft. The bearings should turn smoothly and quietly.
4. Check larger seals for tears, cracks, and other uncharacteristic wear.
5. Measure lobe height of each lobe on both camshafts. Replace new if out of specification.



Measuring camshaft lobe height.

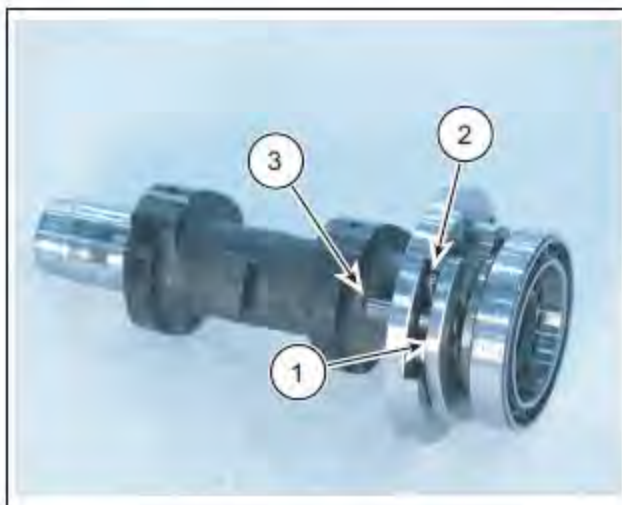
6. Measure the lobe width of each lobe on both camshafts. Replace new if out of specification.



**Intake lobe height**  
standard - 1.4901 - 1.4960 in  
(37.85 - 38.0mm)  
limit - 1.476 in (37.5mm)

**Exhaust lobe height**  
standard - 1.435 - 1.4409 in  
(36.45 - 36.6mm)  
limit - 1.417 in (36.0mm)

7. On the exhaust camshaft, move the automatic decompression assembly weight with your fingers. It should move smoothly without binding or drag. If it does not operate smoothly, replace the exhaust camshaft. Be sure to examine the pin of the decompression assembly for any bending and the cylinder for signs of excessive wear or damage.



1. Weight
2. Pin
3. Cylinder

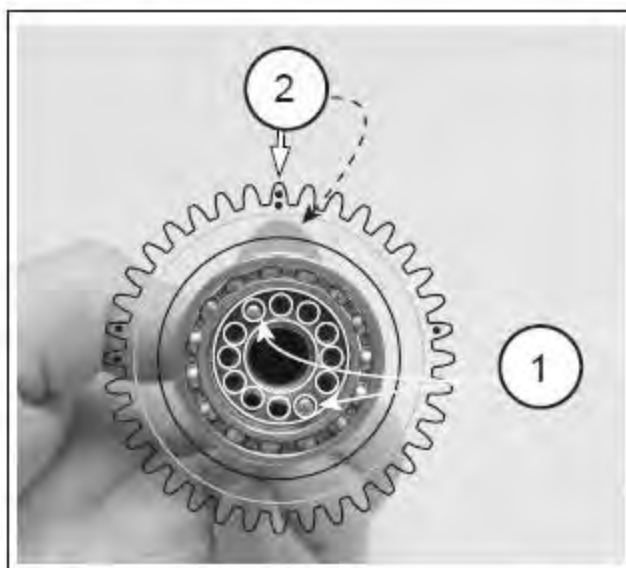
8. Inspect the large bearing. It should rotate freely. If it is damaged, the camshaft must be replaced.
9. Inspect the smaller bearing. It should rotate freely.

## CAMSHAFT, INTAKE, ASSEMBLE

1. Install the larger bearing onto the camshaft.



2. Hold the intake camshaft with lobes pointing straight up (2), and install dowel pins at 11 and 5 o'clock (1). See the photo.
3. Install the cam gear onto the camshaft so that the two vertical dots on the gear point straight up (aligned with the lobe) as illustrated. Refer to "Camshafts (gear-to-cam pin timing positions)" starting on page45..



1. Pins (camshaft)
2. Camshaft lobes aligned with double vertical dots in gear.

4. Apply Loctite #242 and install the cam gear bolt. Tighten the bolt to the specified torque.

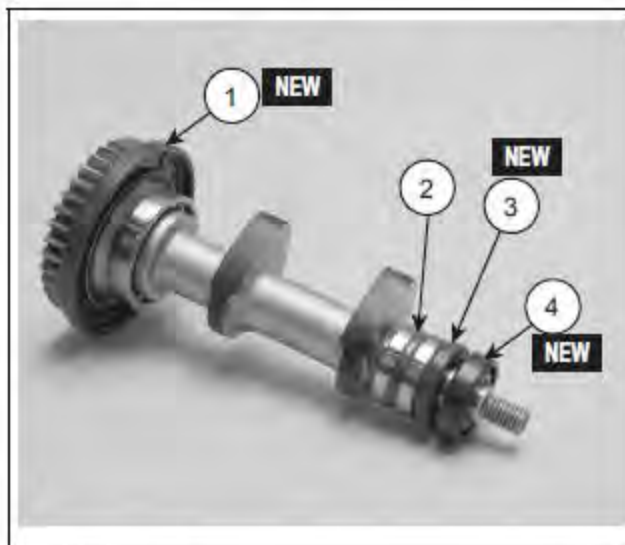


Camshaft(s), gear bolt  
59.0 lbf•ft (80.0 N•m)

5. Apply some clean engine oil to the seal lips and install the large oil seal (1) with the spring side facing the lobes onto the cam gear.

Apply some clean engine oil to the camshaft, and install the smaller bearing (2) with the marking facing the lobes, and small oil seal (3) with the spring side of the seal facing the lobes.

Then, wipe the tip of the camshaft with a clean shop towel to remove any traces of oil, and install the coolant seal (4) with the spring side facing away from the lobes.



1. Large oil seal
2. Bearing
3. Small oil seal
4. Coolant seal

### NOTE :

Later, when the camshaft is installed onto the cylinder head, the dowels will separate the smaller oil seal and coolant seal.



## VALVES, REMOVE

### CAUTION

Do not pry at the bucket with any sharp instrument to remove them. You can damage the bucket itself or the cylinder head.

### NOTE :

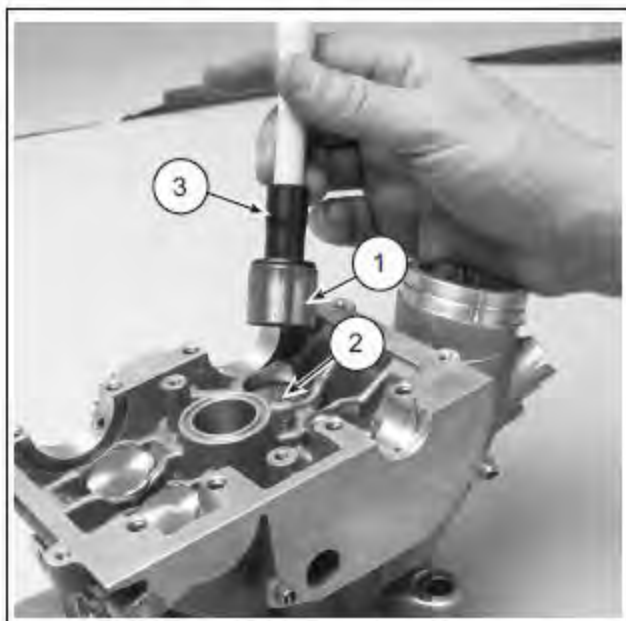
Use a valve lapping tool to remove the valve buckets.

1. Remove the cylinder head (page 58).
1. Remove the camshafts (page 61).
2. Use a valve lapping tool to remove the valve buckets (1) and shims (2) from the top of each spring.  
Mark the position of each valve bucket and shim as you remove them. If not replacing each original valve bucket and shim, they must be returned to the correct position.

### NOTE :

Align the removed components on a clean piece of marked paper - out of the work area.

When removing valves and springs from cylinder head, be sure to identify each as they are removed so that they can be returned to their correct location.

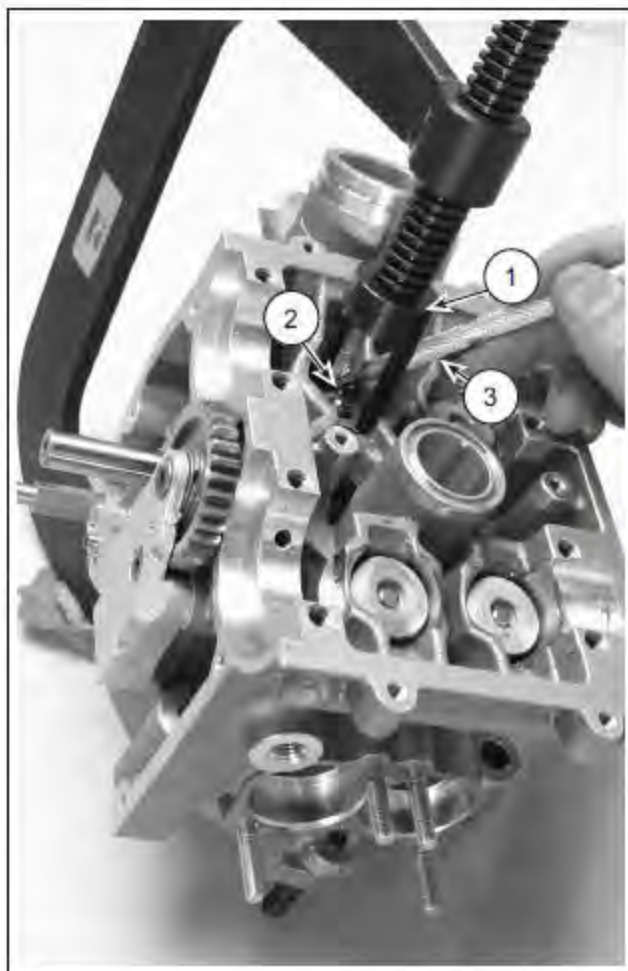


1. Valve bucket
2. Shim (may adhere inside bucket)
3. Valve lapping tool

### CAUTION

Compress the valve springs only enough to remove the retainer locks.

3. Position the special tool (1) onto the valve head and spring retainer, and compress the spring enough to free the retainers (2). Use a magnetic hand (3) to remove the retainer halves.



1. Spring compressor
2. Retainer locks (2)
3. Magnetic hand

**TOOL : CM-504828**  
**Valve spring compressor**

4. Remove the special tool from the cylinder head.
5. Remove the spring retainers and the inner and outer springs from each valve.

6. Use the seal installer/remover to remove oil seals. Discard the seals after removal. Then, remove the spring seats.



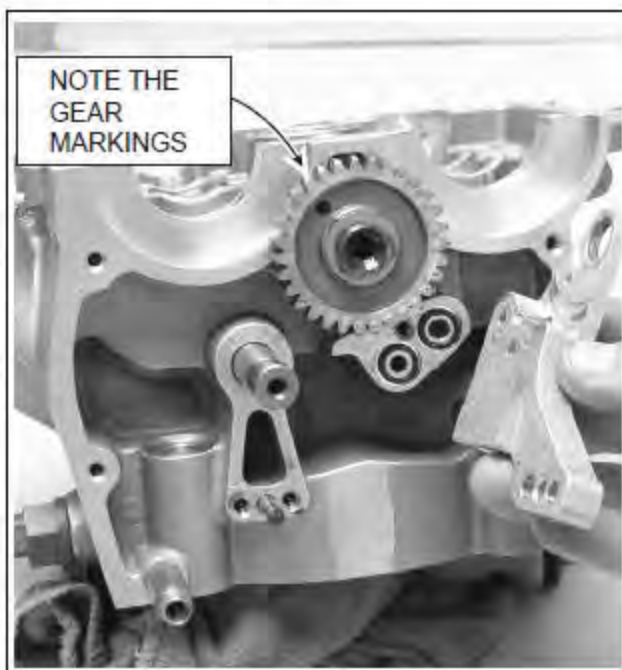
**TOOL : Commercially available**  
**Stem seal installer / remover**

7. Remove the valves and make a temporary reference on each valve so that you can return them as removed.

8. Remove camshaft idler shaft support bracket bolts.

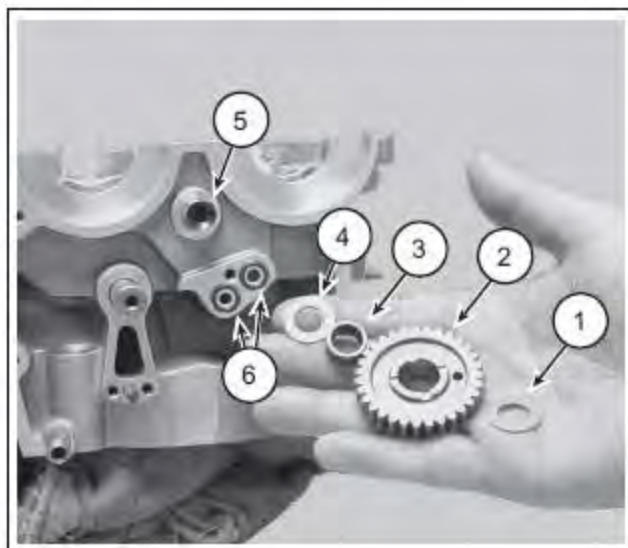


9. Work the bracket off the cylinder head uniformly and carefully. Do not pry at the bracket, it will come off easily with patience.



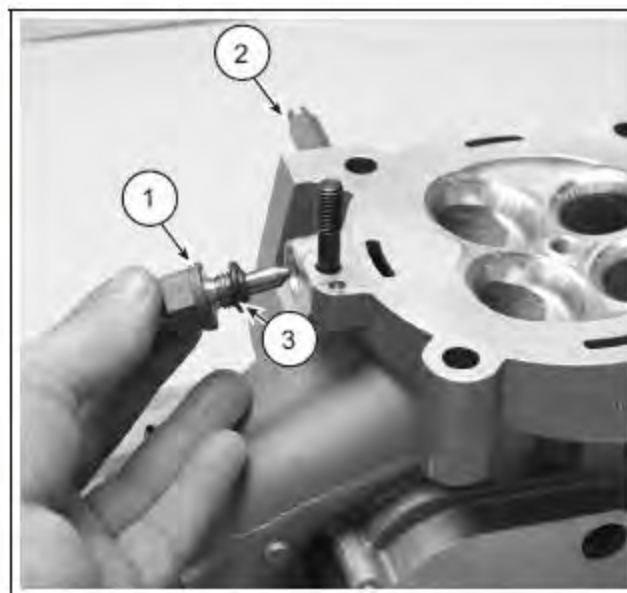


10. Remove the thrust washer (1), idler gear (2), bearing (3), thrust washer (4), from the shaft (5). Then, remove the o-rings (6).



- 1. Thrust washer
- 2. Idler gear
- 3. Bearing
- 4. Thrust washer
- 5. Shaft
- 6. O-rings

12. Remove coolant temperature sensor (1) and upper left timing chain guide support (2).



- 1. Sensor
- 2. Guide mount
- 3. Sensor O-ring

11. Here's a good place to note that the gear has the timing markings on one side only. Later, when reinstalling, make sure these markings face outward. You'll need them to align the crankshaft, camshafts, and timing chain drive system to TDC. Refer to "Top Dead Center (TDC), gear alignment, (camshaft, camshaft idler, and timing idler)" starting on page 48.



## VALVE GUIDE, REMOVAL

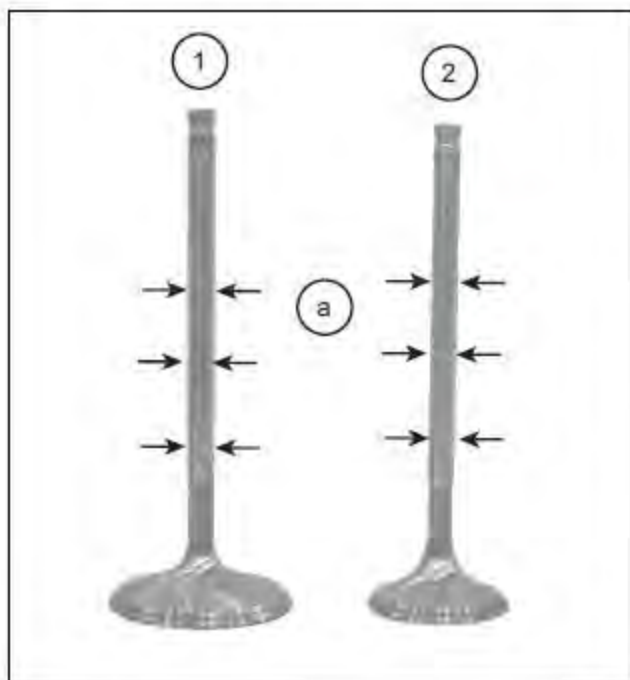
Refer to "Valve guides, replace" starting on page 72.



## VALVES, INSPECT

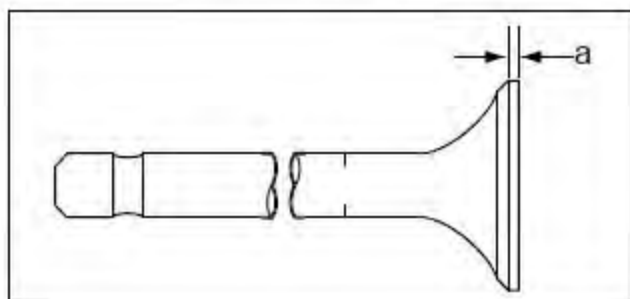
Complete the following procedures for all valves. Specifications can be found at the beginning of this section and at the end of the procedure.

1. Measure the valve stem O.D.



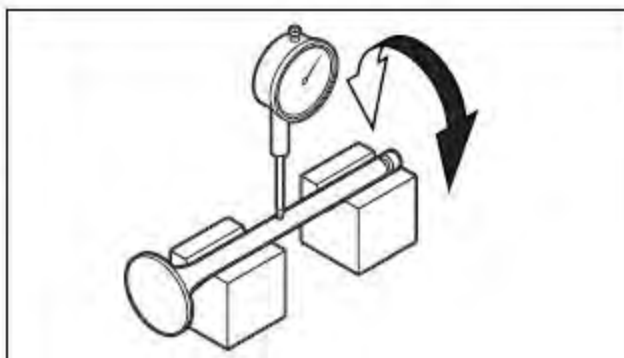
- 1. Intake valve
- 2. Exhaust valve
- a. Stem O.D.

2. Measure the valve head margin.

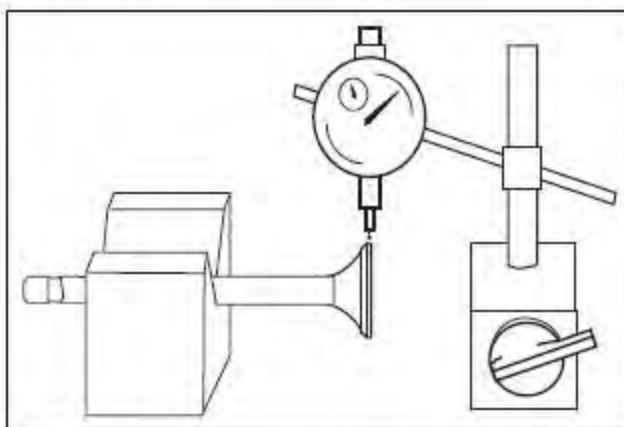


- a. Head margin

3. Measure valve stem runout.



4. Measure valve head runout.





Valve, intake, stem, O.D.  
standard - 0.2155 - 0.2161 in  
(5.474 - 5.489mm)

Valve, exhaust, stem, O.D.  
standard - 0.2150 - 0.2156 in  
(5.462 - 5.477mm)

Valve, intake, head margin  
standard - 0.03425 in  
(0.87 - 1.13mm)  
limit - 0.0 in (0.70mm)

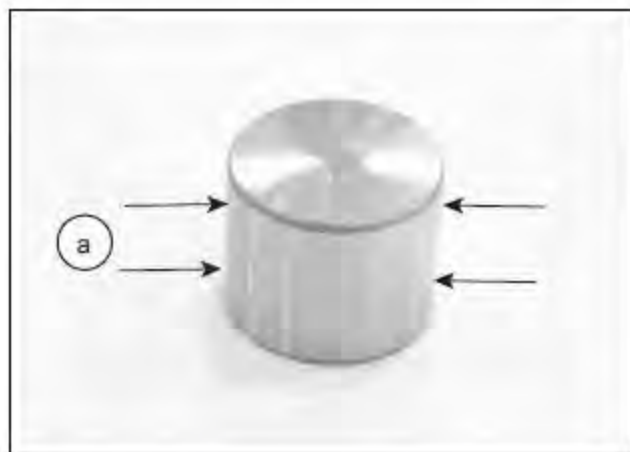
Valve, exhaust, head margin  
standard - 0.03425 in  
(0.87 - 1.13mm)  
limit - 0.0 in (0.70mm)

Valve, stem, runout  
limit - 0.00196 in (0.05mm)

Valve head radial runout limit  
0.00118 in (0.03mm)

## VALVE BUCKETS, INSPECT

Measure the valve bucket O.D. Be sure to check the bucket surfaces for cracking, pitting, scoring or any other uncharacteristic wear. Replace if damage is found.



a. Bucket O.D.

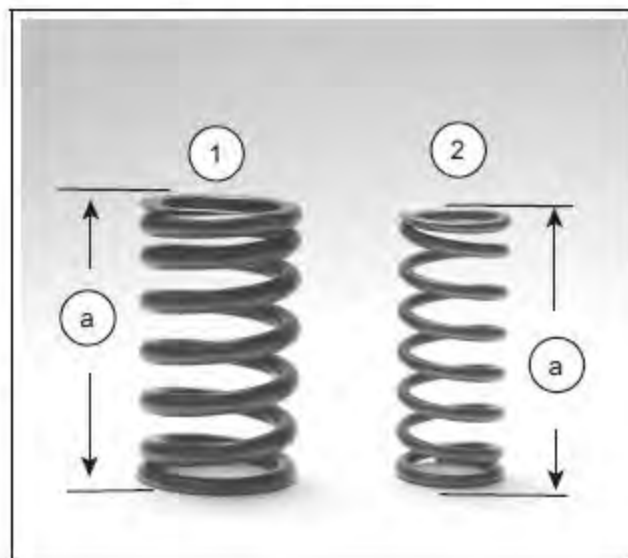


Valve bucket O.D.  
standard - 1.1 - 1.1015 in  
(27.965 - 27.98mm)

## VALVE SPRINGS, INSPECT

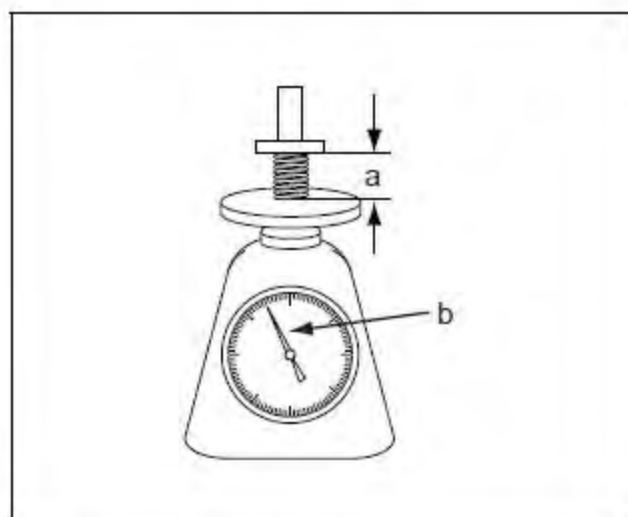
Complete the following procedures for all springs.

1. Measure the valve spring free length.



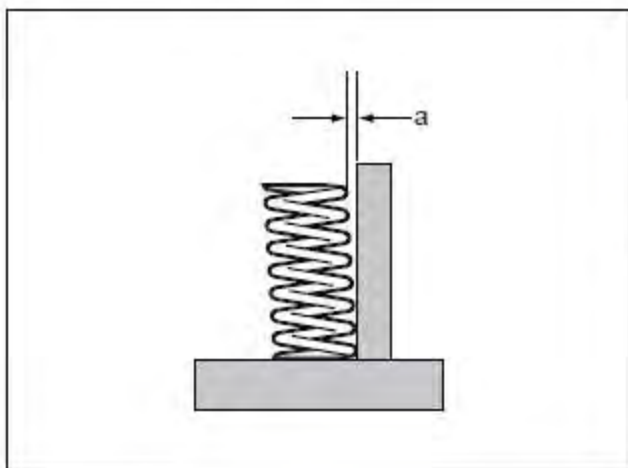
1. Outer spring
  2. Inner spring
- a. Free length

2. Measure valve spring's compressed force.



- a. Compressed height
- b. Force

3. Measure the valve spring tilt.



a. Spring tilt

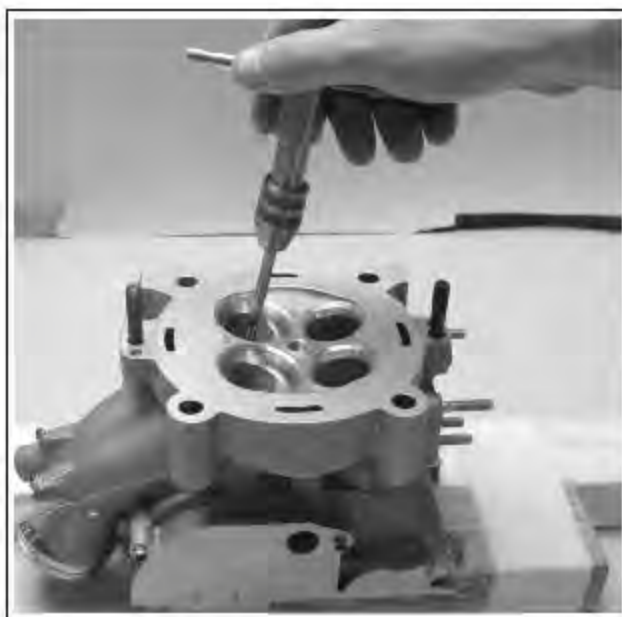
## VALVE GUIDES, INSPECT

### CAUTION

Make sure you do not tilt or lean the tool while reaming the guide.

Use cutting oil while reaming the guide.

1. Ream the valve guides to remove any carbon build up.

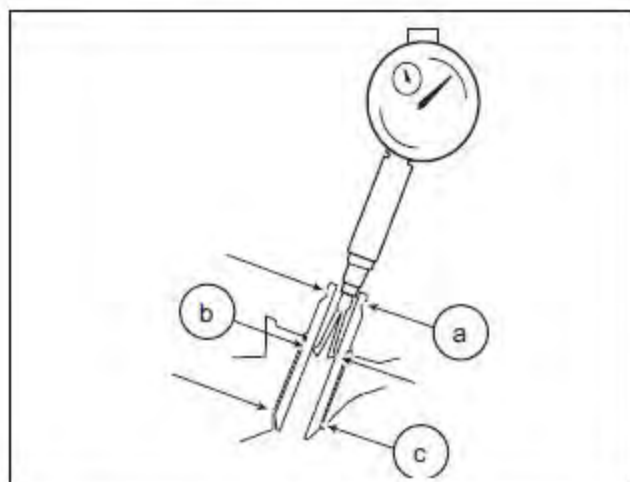


**TOOL :** CM-505054,  
Valve guide reamer, 5.50mm

2. Clean any reamed metal particles from the guides.

	<p>Valve spring, outer, free length standard - 1.633 - 1.712 in (41.5 - 43.5mm) limit - 1.555 in (39.5mm)</p>
	<p>Valve spring, inner, free length standard - 1.535 - 1.614 in (39.0 - 41.0mm) limit - 1.456 in (37.0mm)</p>
	<p>Valve spring, inner compressed force standard - 84 N, (8.566 kgf, 18.888 lbf) at length 32.5mm (1.28 in)</p>
	<p>Valve spring, outer, compressed force standard - 175 N, (17.845 kgf, 39.341 lbf) at length 36.0mm (1.417 in)</p>
	<p>Valve, spring, tilt limit - 0.078 in (2.0mm)</p>

- Use a small bore gauge to measure the I.D. of the top, middle and bottom of each valve guide, and record the measurements.



- a. Top guide I.D.
- b. Middle guide I.D.
- c. Bottom guide I.D.

- Calculate the valve stem-to-guide clearance for each guide. Refer to "Valves, inspect" starting on page 68.

#### NOTE :

*If the stem-to-guide clearance exceeds the service limit, determine if a new guide with current O.D. of the valve stem will bring the clearance back to specification. This will depend upon the wear measured on the valve stem. If the stem-to-guide clearance can not be achieved with a new guide, install a new valve and guide together.*



**Valve guide I.D.**  
standard - 0.216 - 0.217 in  
(5.5 - 5.512mm)

**Valve stem-to-guide clearance, intake -**  
standard - 0.000433 - 0.00196 in  
(0.011 - 0.038mm)  
limit - 0.00393 in (0.10mm)

**Valve stem-to-guide clearance, exhaust -**  
standard - 0.0009 - 0.00196  
(0.023 - 0.050mm)  
limit - 0.00472 in (0.12mm)

- Apply assembly lube to the valve stems and tip, and insert them into the guides. Make sure each valve moves freely in the guide with no binding or drag.



## VALVE GUIDES, REPLACE

### **⚠ WARNING**

Wear thermal protective gloves when handling heated components. Failure to follow this warning can result in serious burns.

### **CAUTION**

Damage can be done to the cylinder head if this procedure is not performed correctly. It is recommended that this complex procedure be done by a dealer or a machine shop due to the accuracy needed to perform it safely and correctly.

### **NOTE :**

*Inspect and/or reface the valve seats anytime a valve or valve guide is replaced.*

1. Disassemble cylinder head (pag e60).
2. Place the new valve guides in the freezer section of a refrigerator for about an hour.



### **CAUTION**

Do not use a flame source (e.g. torch, burner, etc.) to heat the cylinder head. You will damage the head. Consult a specialty machine shop for proper method and equipment to heat prepare components for servicing.

When driving out the guides, use extra care not to damage the intake camshaft seals locating dowel pins on the right side of the head.

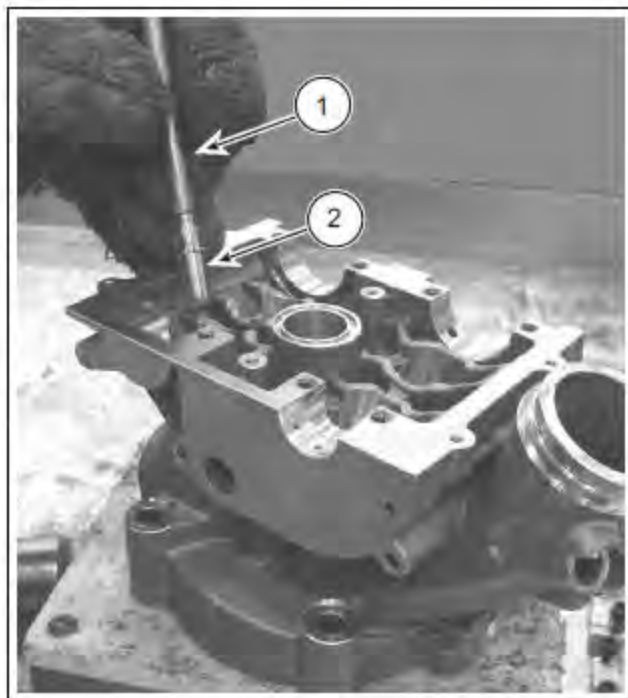
3. Heat cylinder head to 275 - 290°F (130 - 140°C). Use temperature indicator sticks that can found at most welding supply stores. Do not heat the cylinder head beyond 300°F (150°C).
4. Support the heated cylinder head and drive out the old guides from the combustion chamber side of the head.



**TOOL : CM-504829,  
Valve guide remover, installer**

5. To install the new guides - while the cylinder head is still heated, remove the chilled guides from the refrigerator, and install the new guide from the camshaft side of the head.

Place the cylinder head on block. Position them squarely in the guide hole and drive them in until bottomed using the special tool.



1. Tool
2. Guide

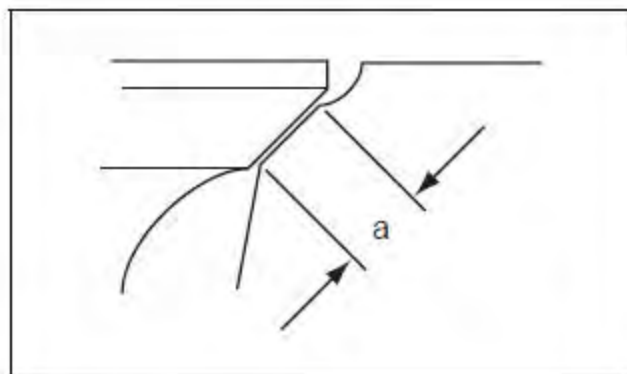
6. Install all guides and allow the cylinder head to cool to room temperature before continuing.
7. Apply cutting oil to the inner part of the guide guide and the reamer.

**TOOL : CM-505054,  
Valve guide reamer**

8. Insert the tool from the combustion side of the cylinder head, and rotate the tool (reamer) slowly clockwise.
9. Remove the tool and clean any reamed particles from the guide and cylinder head.
10. Measure the guide I.D. and inspect. Refer to "Valve guides, inspect" starting on page 70.

## VALVE SEATS, INSPECT

1. Remove any carbon deposits from the cylinder head.
2. Remove and clean the intake and exhaust valves of all carbon deposits.
3. Apply a light coat of Prussian blue to each valve seat.
4. Install the valve and tap the valve head against the seat without rotating the valve. Visually note the contact between the valve seat (cylinder head) and valve face (valve).
5. Remove the valve and inspect the valve seat. The dye will be transferred to the valve face where contact was made.
6. Measure the seat width.



a. Seat width



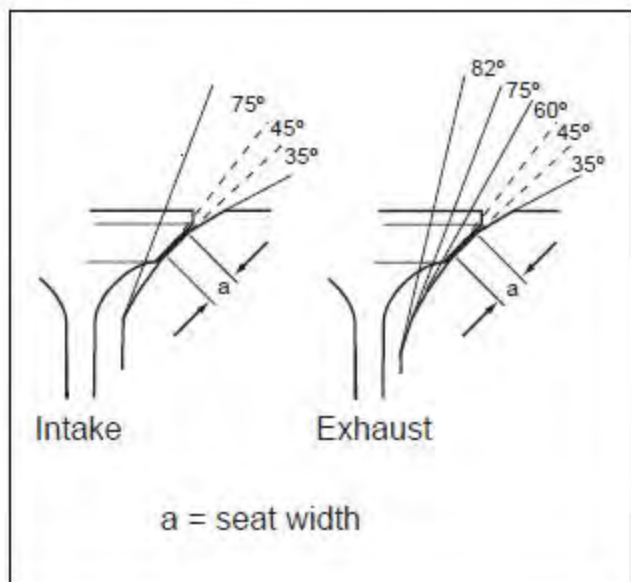
**Valve seat width, intake**  
0.0354 - 0.0433 in (0.9 - 1.1mm)

**Valve seat width, exhaust**  
0.0393 - 0.0472 in (1.0 - 1.2mm)

7. The seat width should be even and uniform. If the seat width is out of specification, reface the valve seat.

## VALVE SEATS, REFACE

1. Reface the valve seats using the correct cutting tool.



a. Seat width

**TOOL : SERDI SC608,**  
**Intake Valve seat cutter**

**TOOL : SERDI SC604**  
**Exhaust Valve seat cutter**

2. After cutting the valve seats, apply a lapping compound to the valve face, and lap in the newly refaced seat using light pressure.
3. When complete, clean any residual compound from the cylinder head, valve, and valve guides.
4. Reinspect the valve seats (page 73).

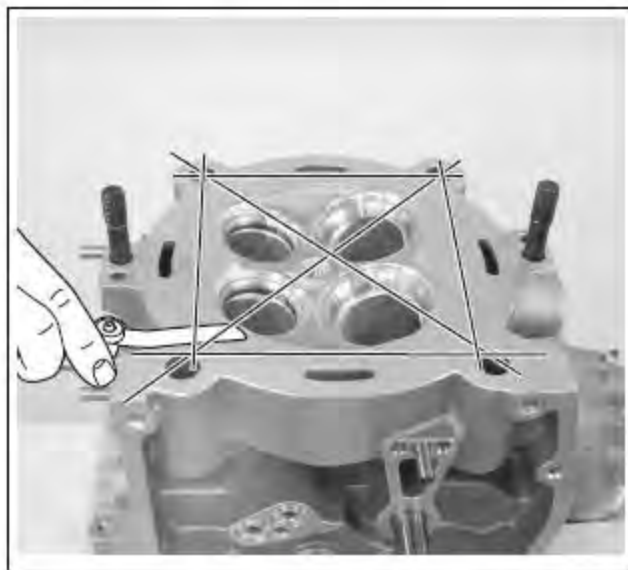


## CYLINDER HEAD, INSPECT

### CAUTION

Do not use a sharp tool to clean cylinder head. Use a rounded scraper and be extra careful not to damage valve seats and/or spark plug threads.

1. Disassemble the cylinder head (page 60).
2. Clean the cylinder head and remove any carbon deposits from the combustion chamber.
3. Inspect the cylinder head for scratches and damage.
4. Check for cracks in the area around the spark plug hole and the valve seat.
5. Using a feeler gauge and a straight edge to check the cylinder head for any warpage - place a straight edge across the cylinder head and measure with the gauge at several points.

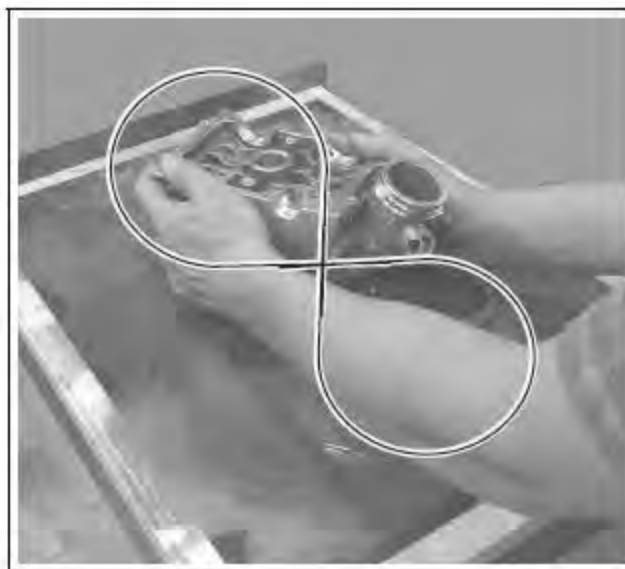


6. If warpage is out of specification, resurface the head.

### NOTE :

*You will need to remove the cylinder head helper studs.*

*To ensure even surface, sand in a figure-eight pattern while rotating head several times.*



7. Replace the head with a new one if the specified warpage limit cannot be achieved.



Cylinder head warpage limit  
limit - 0.002 in (0.05mm)

## CYLINDER HEAD, ASSEMBLE

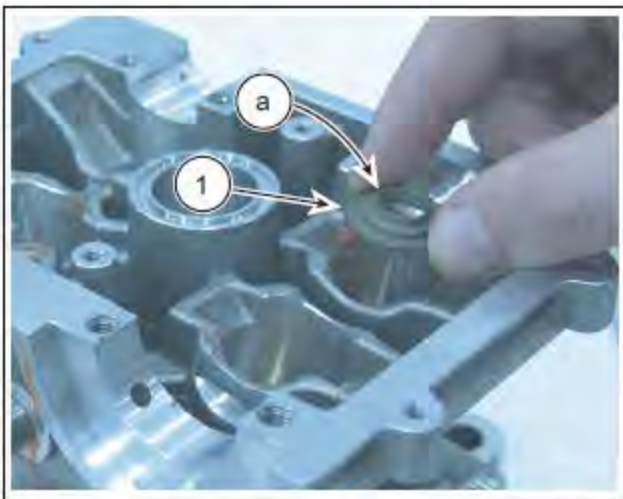
### CAUTION

Be careful not to damage the valve stem seals during assembly. Use a seal installer.

When installing new valves, replace the valve guides as well.

Always inspect new valves before assembly.

1. Make sure the cylinder head is completely clean.
2. Install the valve spring seat with the smaller end facing up. If you are not assembling with new components, return the seats to their original location.



- 1. Spring seat
- a. Small end

3. Install new valve stem seals onto the guides.

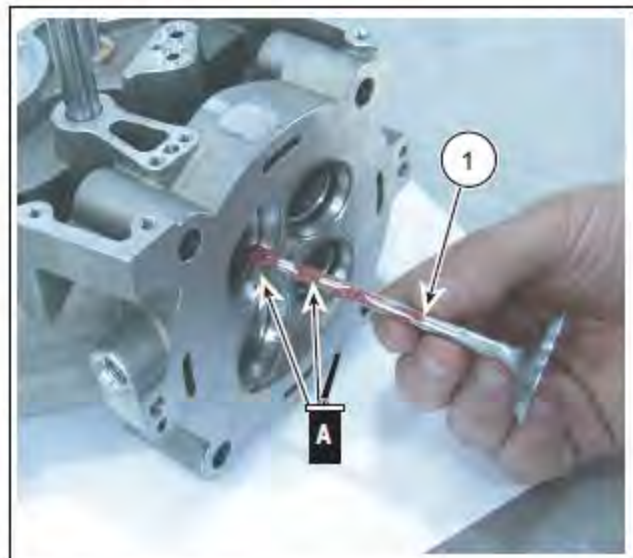


**TOOL :** Commercially available  
oil seal installer / remover

### CAUTION

Return each valve as removed.

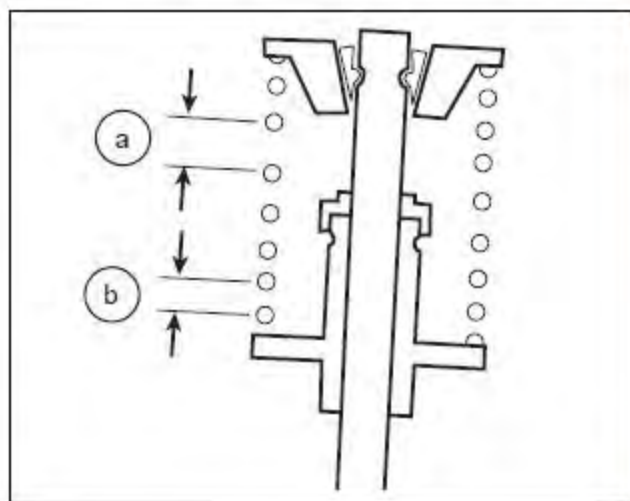
1. Apply a thin coat of molybdenum disulphide grease to each valve stem tip and stem. Then, carefully insert the valves into the guides. The valve should slide into the guide with little resistance.



1. Intake valve



- Now, from the top of the cylinder head, install the inner and outer valve springs with the larger pitch of both the inner/outer springs facing up.



- a. Larger pitch
- b. Smaller pitch

- Install the valve spring retainers (as removed) into the springs.



- Install the valve spring compressor onto the cylinder head. Then, compress the valve springs just enough to install the valve spring retainer locks. Use a small dab of assembly lube to hold the retainer locks in place until the spring is released and the tool is removed. When removing the tool, make sure that the retainer locks seat properly against the valve stem groove. If the locks are not seated properly,

they can come loose - resulting in severe engine damage.



**TOOL : CM-504828**  
**Valve spring compressor**

- Install the correct valve shim into each valve retainer.
- Apply a light film of engine oil to the inside of the valve buckets. Then, apply some assembly lube to outer surface of the buckets and inside the spring tower area (with a small nylon brush).
- Then, install the buckets into the cylinder head.

#### CAUTION

Do not force the valve buckets. They should to "slip fit" into the cylinder head. Use the tip of your finger to turn or "spin" the installed bucket to check for binding. If the bucket sticks or drags, or is difficult to install over the retainer and spring - something is wrong - re-inspect the bucket or the cylinder head bore.

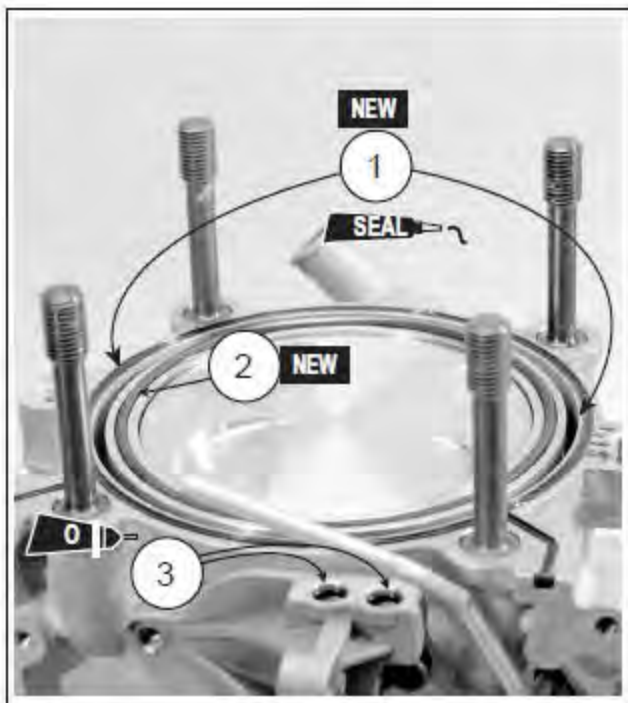
If you have replaced either camshaft, the buckets should be replaced new as well.

- Install the camshafts. Refer to "Camshafts, install" starting on page 53.



## CYLINDER HEAD, INSTALL

1. Position the crankshaft to TDC and install the TDC bolt (page 48).
2. Install a new cylinder head seal (1) into the groove and apply a very thin bead of silicone sealant. Then, install a new sleeve upper O-ring (2). And, inspect the oil supply tube O-rings (3)..

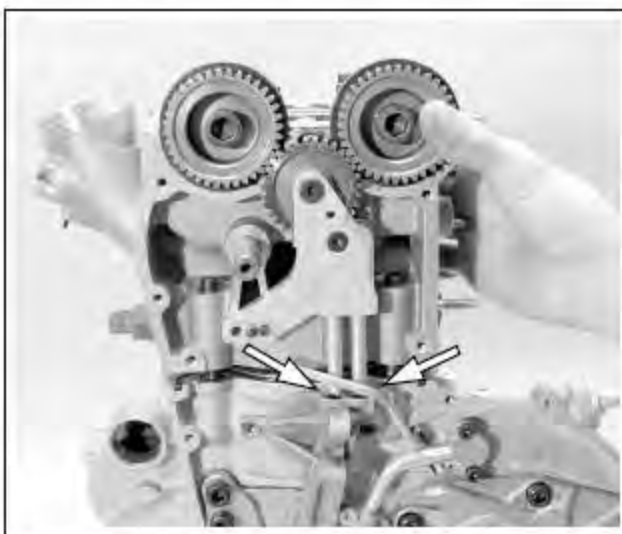


1. Seal
2. Sleeve O-ring (upper)
3. O-rings (in piston pin access cover)



This photo shows that the tabs on the end of the seal face down.

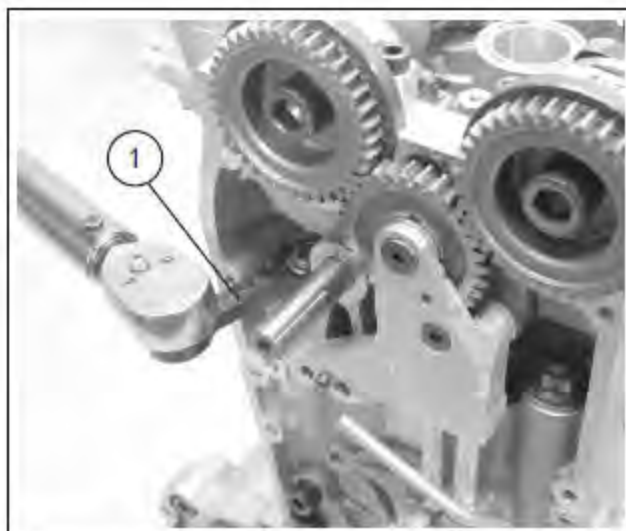
3. Apply clean engine oil to the ends of oil transfer tubes, and install them into the cylinder head. Check the condition of the O-rings in the idler shaft support bracket, and replace the O-ring if they are damaged (e.g., ripped, torn, or distended).
4. Position the oil supply tubes over the holes in the piston pin access cover and lower the cylinder head onto the crankcase.



### CAUTION


The special tool must be fitted on the torque wrench at a 90° angle (see photo) to achieve an accurate torque reading.

5. Apply a light coat of clean engine oil to both sides of the cylinder head washers, and install the washers onto the cylinder head studs with the rounded side of the washer facing down.
6. Then, install the stud nuts. Tighten the cylinder head stud nuts in 3 stages and in a criss-cross pattern to the specified torque.

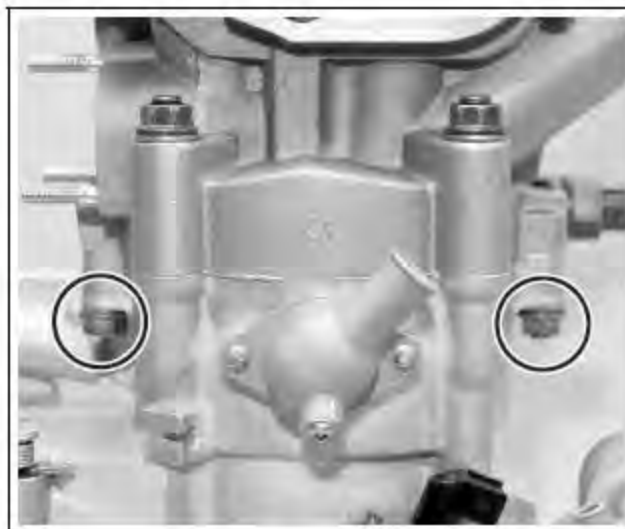


1. Special tool
2. Cylinder head stud nut
3. Washer


**TOOL : CM-504831**  
**Torque adapter**

	<b>Cylinder head stud nuts</b> stage 1 - 16.2 lbf·ft (22.0 N·m) stage 2 - 25.8 lbf·ft (35.0 N·m) stage 3 - 31.0 lbf·ft (42.0 N·m)
---	--

7. Now, install the washers and nuts on the cylinder head helper studs. Tighten the nuts evenly in 2 stages tighten to the specified torque.



1. Cylinder head helper stud nuts

	<b>Cylinder head helper stud nuts</b> stage 1 - 8.1 lbf·ft (11.0 N·m) stage 2 - 16.2 lbf·ft (22.0 N·m)
--	--

# Sleeve (and piston)

Unit: mm (in)

ITEM			STANDARD	SERVICE LIMIT
Sleeve	bore taper		-	0.05 (0.00197)
	bore out of round		-	0.05 (0.00197)
	ID		94.985 - 95.015 (3.740 - 3.741)	95.050 (3.742)
Piston	skirt diameter	Wiseco	94.915 - 94.925 (3.7368 - 3.7371)	94.860 (3.7348)
Rings	top ring, side clearance		0.050 - 0.085 (0.0019685 - 0.0033464)	0.12 (0.004724)
	2nd ring, side clearance		-	0.127 (.005)
	top ring, end gap		0.35 - 0.55 (0.014 - 0.022)	0.85 (33)
	2nd ring, end gap		0.35 - 0.55 (0.014 - 0.022)	0.85 (33)
Piston pin	wrist pin O.D.		17.995 - 17.998 (0.708 - 0.709)	-
	wrist pin bore I.D.		18.005 - 18.010 (0.7089 - 0.7090)	-
	Piston wrist pin bore-to-pin clearance		0.007 - 0.015 (0.0002755 - 0.00059)	-

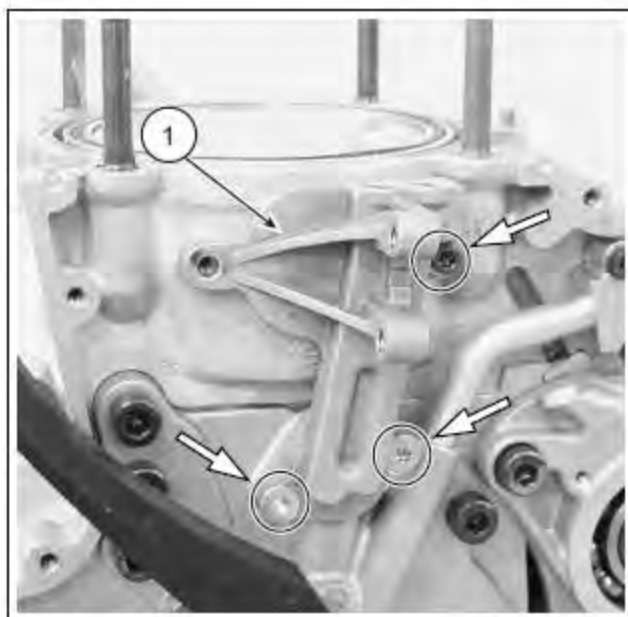


## SLEEVE (AND PISTON), REMOVE

### CAUTION

Be sure to clean the piston and ring grooves thoroughly. Residue from the tape will damage the rings and piston.

1. Remove cylinder head (page 58).
2. Remove the coolant outlet cover (page 26).
3. Remove the piston pin access cover.



1. Piston pin access cover.

4. Position the crankshaft to bottom dead center (BDC).
5. Thoroughly clean the inner sleeve walls with contact cleaner and a clean shop towel.

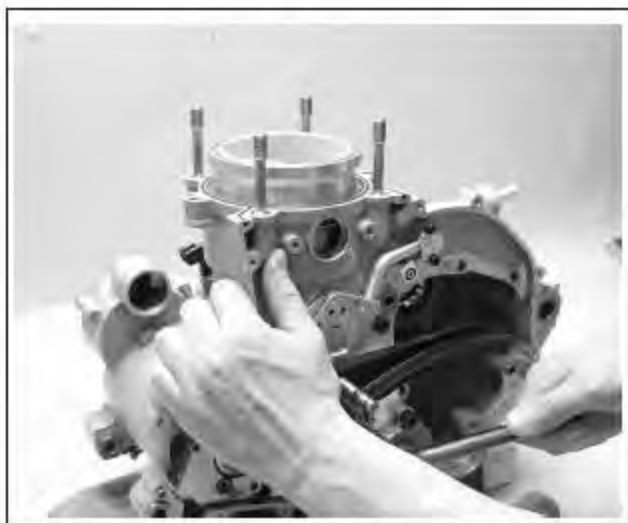
Make sure the sleeve wall is completely dry.

6. Then, line the inner walls evenly with 2" masking tape. Make sure you apply the tape without wrinkles.



7. Carefully turn the crankshaft nut clockwise until the top piston ring contacts the tape edges. Then, . . . slowly continue rotating the crankshaft to create an even and building pressure on the sleeve. When the sleeve is free of the crankcase bore, lift the sleeve out with your hands.

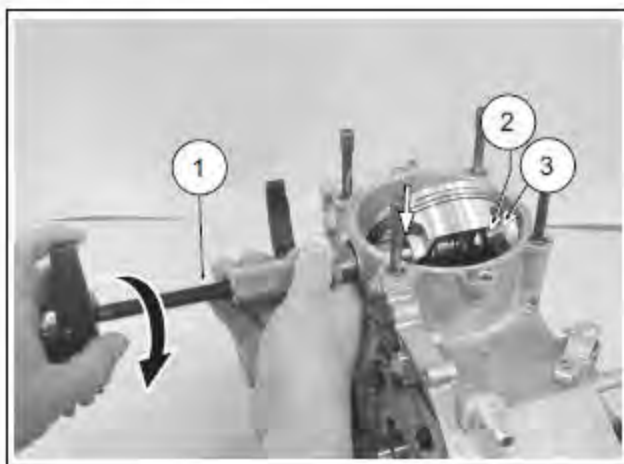
If the tape slides up the sleeve while you are turning the crankshaft nut, the walls were not clean enough or you were turning the crankshaft too fast.



8. Remove the left and right piston wrist pin circlips through the holes in the crankcase, and discard them.



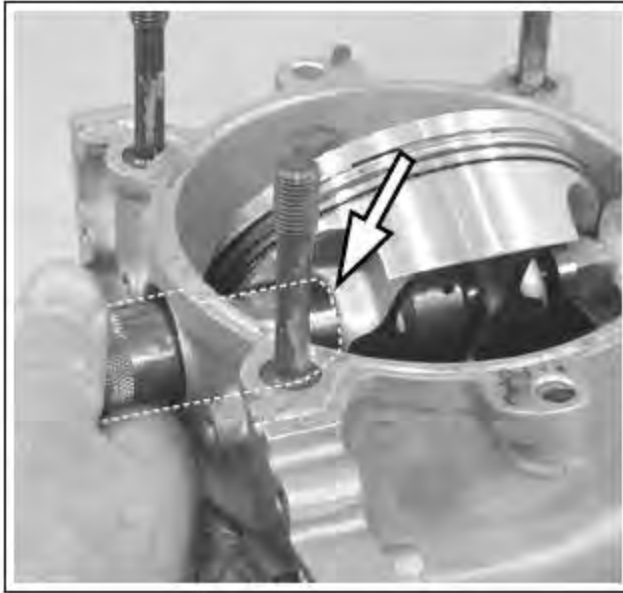
9. Insert the special tool through the piston pin access cover hole (left side of crankcase), through the wrist pin, and install the roller bushing and nut onto the tool end. Make sure the tool end locates against the piston properly.



- 1. Tool
- 2. Bushing
- 3. Nut

#### **⚠ WARNING**

Wear eye protection. Circlips and E-clips can accidentally “pop” or “fling” off as you are attempting to remove them resulting in severe eye injury to you and/or bystanders.



TOOL : CM-504836,  
Piston pin extractor.

10. When the wrist pin is out - remove the piston.



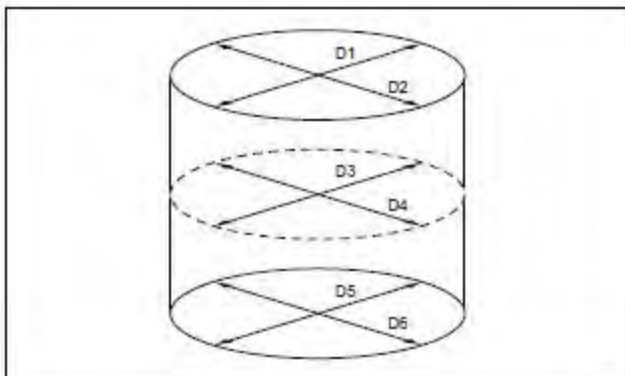
## SLEEVE, INSPECT

1. Inspect piston sleeve O-ring (3) for tears and cracks.



1. Sleeve
2. Sleeve marking on exhaust side "Dot"
3. O-ring

2. Inspect inner sleeve walls for scratches and wear. Replace if damaged.
3. Measure sleeve at three levels.



4. Take maximum reading to determine sleeve wear.

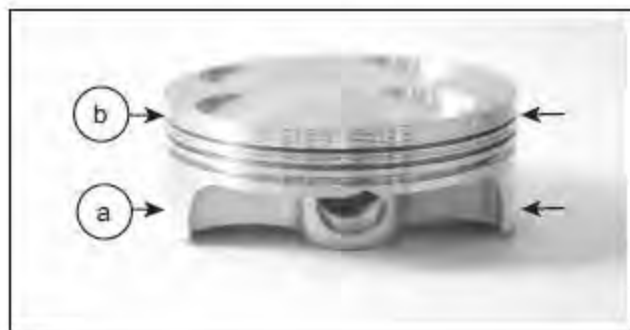
	<p><b>Sleeve bore taper limit - 0.00197 in (0.05 mm)</b></p> <p><b>Sleeve bore out of round limit - 0.00197 in (0.05 mm)</b></p>
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Taper = (maximum D1 or D2 – maximum D5 or D6)

Out of round = (maximum D1, D3, or D5 – maximum D2, D4, or D6)

## PISTON, INSPECT

1. Clean the piston to remove any carbon build up on the top and in the ring grooves.
2. Measure the piston skirt diameter.
3. Measure the piston O.D. 90° from the piston pin hole.

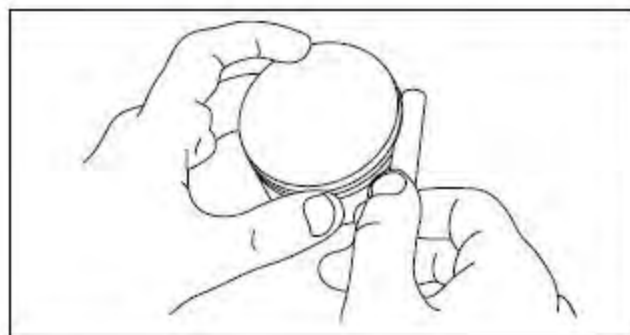


- a. Skirt diameter
- b. O.D.



**Piston skirt O.D.**  
**standard - 7.7368 - 3.7371 in**  
**(94.915 - 94.925 mm)**  
**limit - 3.7346 in (94.860mm)**

4. Use a feeler gauge to measure ring-side clearance. If out of specification, replace piston and rings.



- a. Ring side clearance



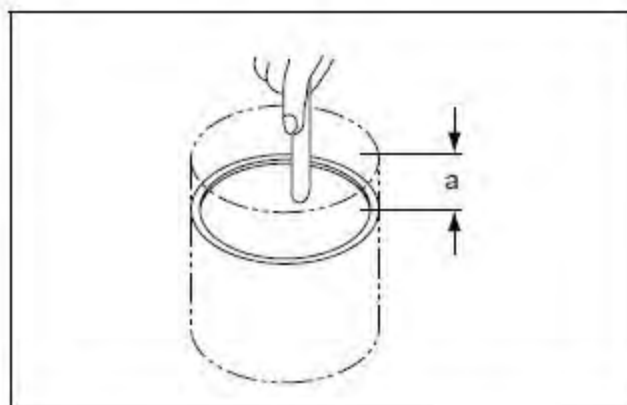
**Piston, top ring, side clearance**  
**standard - 0.001968 ~ 0.0033464 in**  
**(0.050 ~ 0.085 mm)**  
**limit - 0.004724 in (0.12 mm)**

**Piston, 2nd ring, side clearance**  
**limit - 0.005 in (0.127 mm)**

5. Complete the following for both the top and second ring:

Insert the ring into the sleeve. Then, use the piston to position the ring to a depth of 10 mm inside the sleeve and at a right angle to the sleeve bore.

6. Measure the ring end gap.



- a. Depth



**Piston, top ring, end gap**  
**standard - 0.014 ~ 0.0022 in**  
**(0.35 ~ 0.55 mm)**  
**limit - 0.0334 in (0.85 mm)**

**Piston, 2nd ring, end gap**  
**standard - 0.014 ~ 0.0022 in**  
**(0.35 ~ 0.55 mm)**  
**limit - 0.0334 in (0.85 mm)**

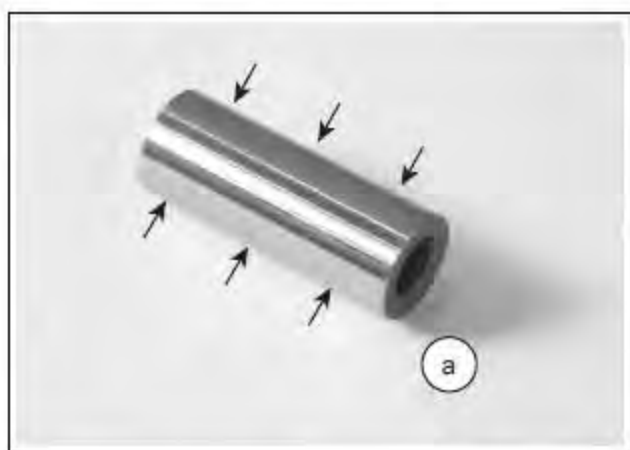
7. Inspect piston pin for discoloration and grooves.

8. Measure the piston wrist pin bore I.D. Take measurements in the X and Y axis and take the maximum reading.



a. Piston wrist pin bore I.D.

9. Measure the piston wrist pin O.D.



a. Piston wrist pin O.D.

10. Calculate the piston wrist pin-to-piston pin bore clearance. Wrist pin bore - wrist pin O.D. = clearance.



**Piston pin O.D.**  
0.708 ~ 0.709 in  
(17.995 ~ 17.998 mm)

**Piston wrist pin bore I.D.**  
0.7089 ~ 0.7090 in  
(18.005 ~ 18.010 mm)

**Piston-to pin-clearance**  
standard - 0.0002755 ~ 0.00059 in  
(0.007 ~ 0.015 mm)

## PISTON, ASSEMBLE

### CAUTION

Do not over lap the ends of the oil expander; excessive oil usage will occur and the engine will smoke. The engine may be damaged.

Install top and second ring with the manufacturer's mark up.

### NOTE :

*The piston has an arrow mark on the exhaust side.*

1. Install the oil ring expander into the piston oil ring groove with the butted tips facing the intake side of the piston.

Be sure the tips are butted together and not overlapped. (see illustration).

Install the upper (above the expander) and lower (below the expander) oil rings onto the piston.

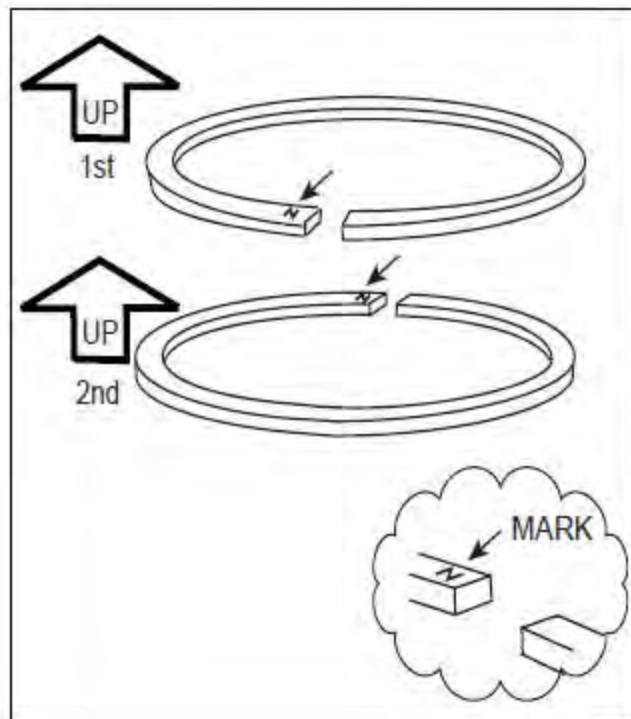
Position each of the three rings.



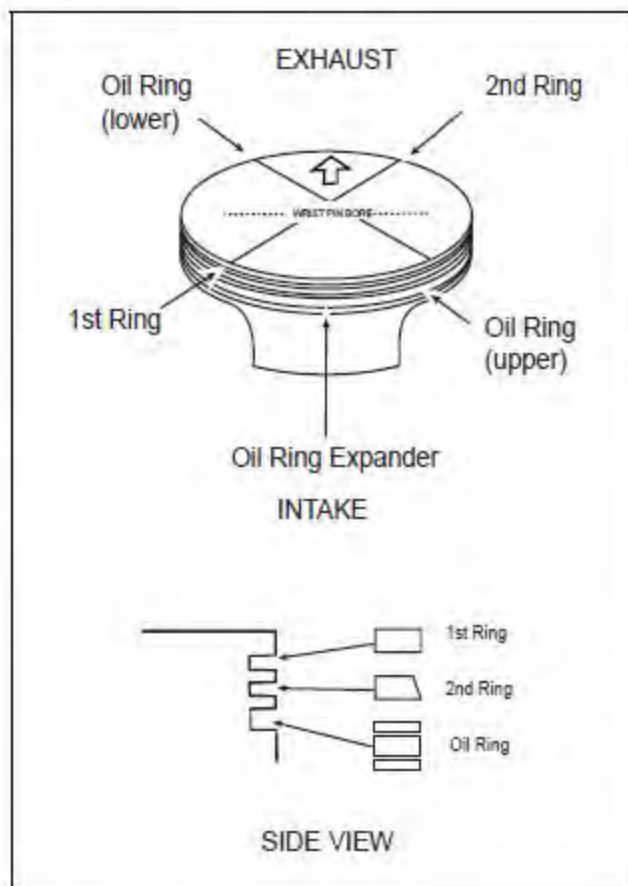
- a. Oil ring (butted end)
- b. Lower oil ring gap
- c. Upper oil ring gap



2. Install the 2nd ring onto piston with the manufacturer's mark facing up.
3. Install the first ring onto the piston with the manufacturer's mark facing up.



4. Position all ring gaps according to the illustration.



## PISTON, INSTALL

1. Refer to "Sleeve (and piston), install" starting on page 88.

## SLEEVE (AND PISTON), INSTALL

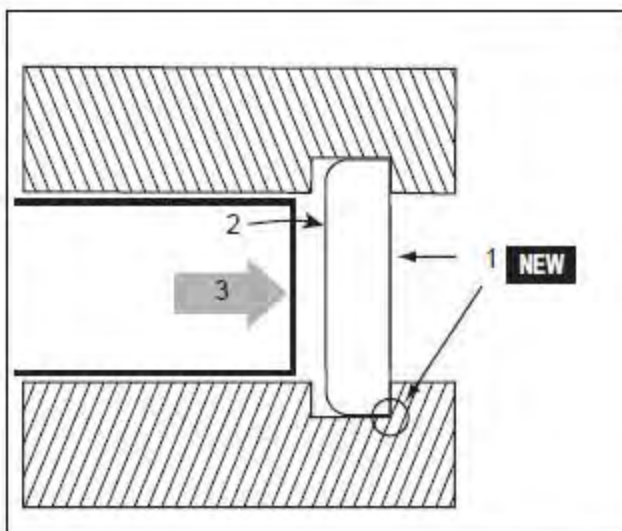
### CAUTION

Do not reuse piston pin circlips when re-installing the piston pin. Make sure they are seated properly in the grooves. Using old circlips or installing them improperly will increase the risk of the clip and wrist pin becoming dislodged during engine operation; this will result in **EXTREME** engine damage.

Also, make sure that the flat side of the clip faces out of the wrist pin bore.

Make sure piston ring gaps are positioned properly before installation into the sleeve. If they are positioned incorrectly, the engine may smoke excessively, performance may be significantly reduced or damage can result. Refer to "Piston, assemble" starting on page 86.

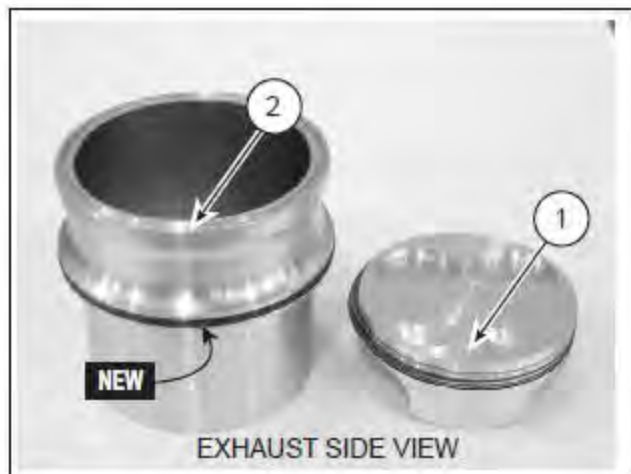
3. Install a new right side wrist pin circlip with the flat side of the clip facing out of the pin bore. Position the open end of the circlip downward.



1. Flat side
2. Rounded side
3. Thrust

1. Assemble the piston (page 86).
2. Align the arrow on mark (1) on the piston with dot marking (2) on the sleeve.

4. Lubricate the piston, rings, and inner sleeve walls with clean engine oil or assembly lube.
5. Check the piston rings gap alignment. Then, using a ring compressor install the piston into the bottom end of the sleeve.



1. Piston mark (exhaust side)
2. Sleeve "dot"



**TOOL : CM-503876**  
**Piston ring compressor**

6. Position the piston in the sleeve so that the wrist pin relief (2) is parallel to the bottom edge of the sleeve rim. Recheck the alignment of the sleeve and piston markings - correct if necessary.



1. Sleeve mark aligned with piston arrow (exhaust)
2. Piston installed into sleeve evenly to piston wrist pin relief.

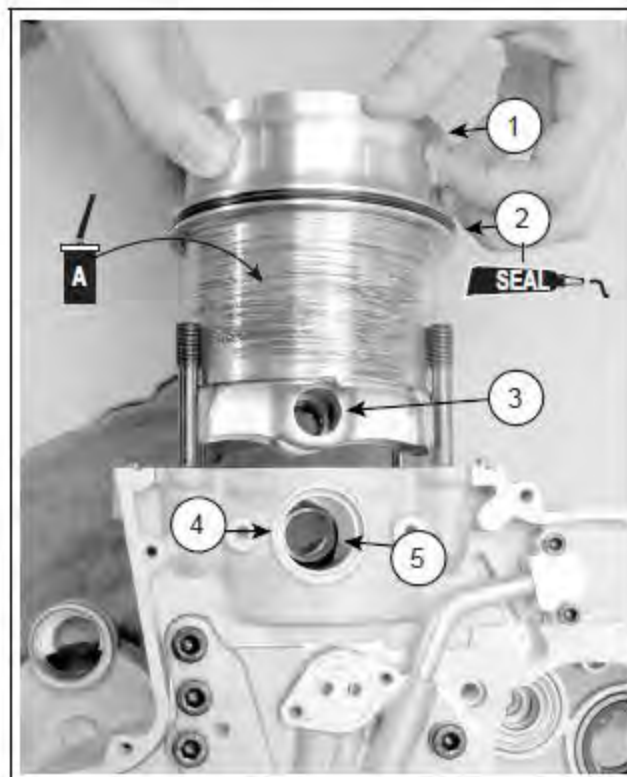
7. Position the crankshaft to top-dead-center (TDC), and install the TDC bolt. This will help maintain the connecting rod in position.
8. Lube inner crankcase cylinder walls and lower outer sleeve O-ring walls below the O-ring groove with assembly lube.

#### NOTE :

*Before installing the sleeve, if possible, lay the crankcase with the left side facing up. This will help keep the connecting rod from falling to either side so that it can be easily mated with the piston and sleeve.*

*When the crankcase is upright, the connecting rod will tend to fall to one side or the other.*

9. Position the sleeve and piston pair over the sleeve bore with the dot on the sleeve facing the exhaust side (rear) of the case.



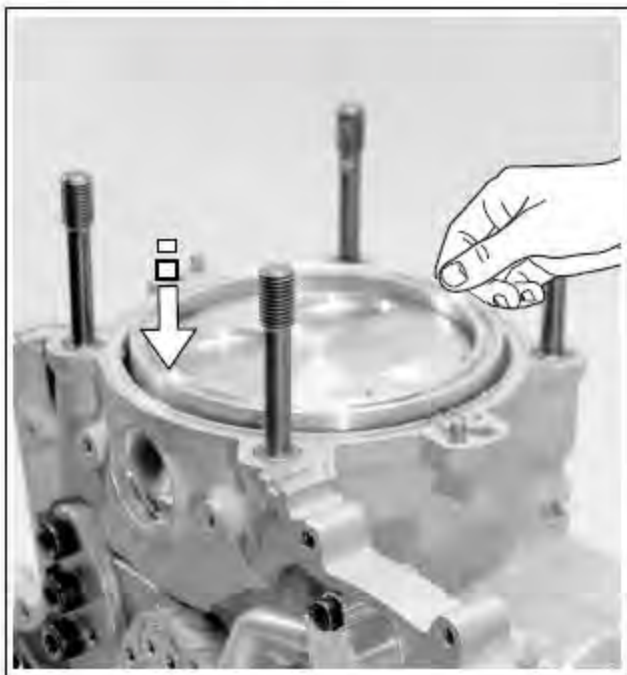
1. Sleeve dot marking
2. O-ring
3. Wrist pin bore
4. Piston pin access cover hole
5. Connecting rod small end

10. Apply assembly lube to the wrist pin end and outside diameter, and insert through the piston pin access cover hole (left side of case) into the piston wrist pin hole until it meets the right circlip. Do not drive the wrist pin against the circlip; this could lead to damage of the piston circlip groove.
11. Install the left circlip (new). Make sure the clip is properly seated in the groove, the flatter side facing out, and the opening in the clip is facing downward.



12. Position the sleeve squarely in the sleeve bore, and slowly lower it into the crankcase. Before the sleeve seal falls below the top edge of the crankcase, apply a thin film of silicone seal onto the seal. Avoid getting any sealant on the sleeve edge that bottoms on the crankcase walls.

Continue inserting the sleeve into the crankcase - it should slip into the case bore within a minimal effort.



**TOOL : CM-504826**  
**Cylinder sleeve installer**



15. Remove the special tool.

13. Now, with enough of the cylinder head stud threads exposed, install the special tool onto the cylinder head studs over the sleeve.

#### CAUTION

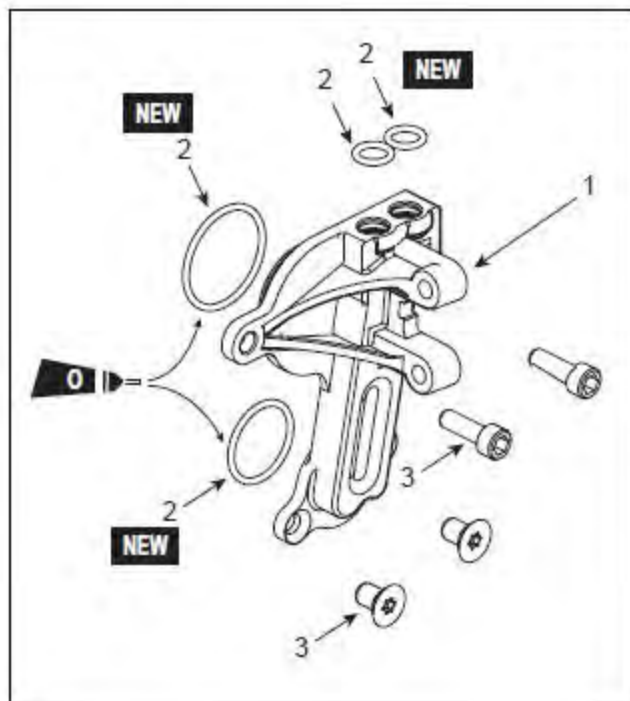
When tightening the nuts, be sure to tighten the nuts in 2 stages and in a criss-cross pattern.

14. Apply some clean engine oil to the washers and stud nuts and install onto the studs. Then, tighten in 2 stages to the specified torque.



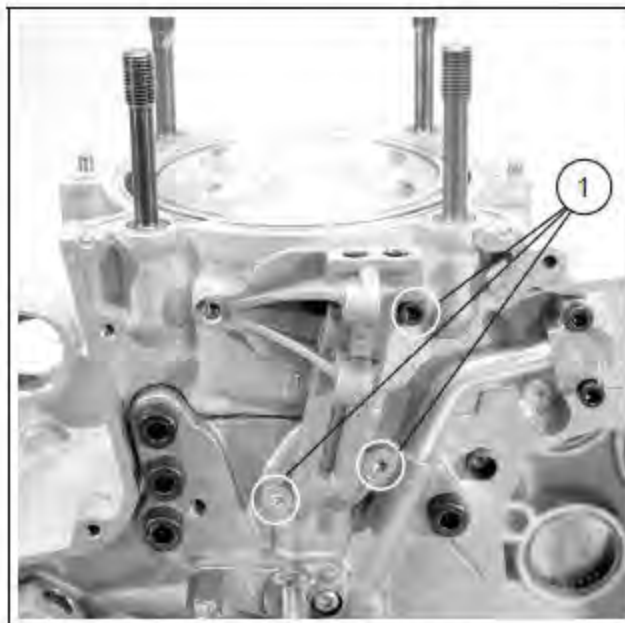
**Cylinder head stud nuts**  
stage 1 - 17.0 lbf·ft (23.0 N·m)  
stage 2 - 31.0 lbf·ft (42.0 N·m)

16. Apply some O-ring lubricant to the O-rings, and install the piston pin access cover.



- 1. Piston pin access cover
- 2. O-rings (new)
- 3. Bolts

17. Install the bolts. Tighten to the specified torque.

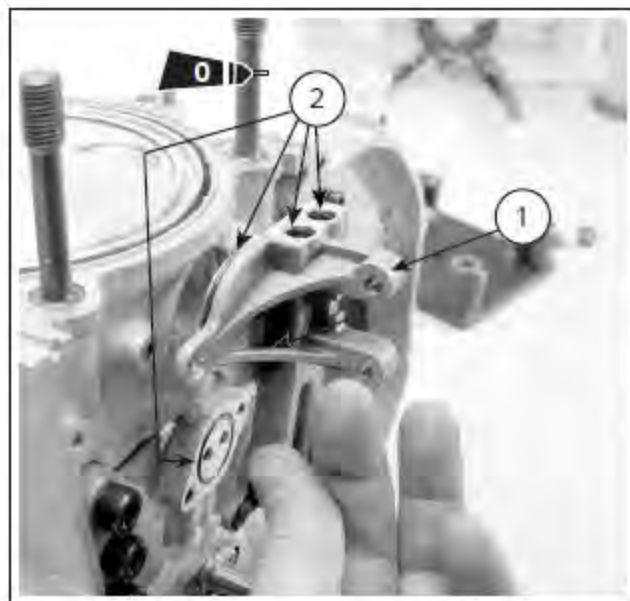


The upper left bolt is installed with the timing chain assembly.

- 1. Bolts



**Piston pin access cover bolts**  
3.3 lbf·ft (4.5 N·m)



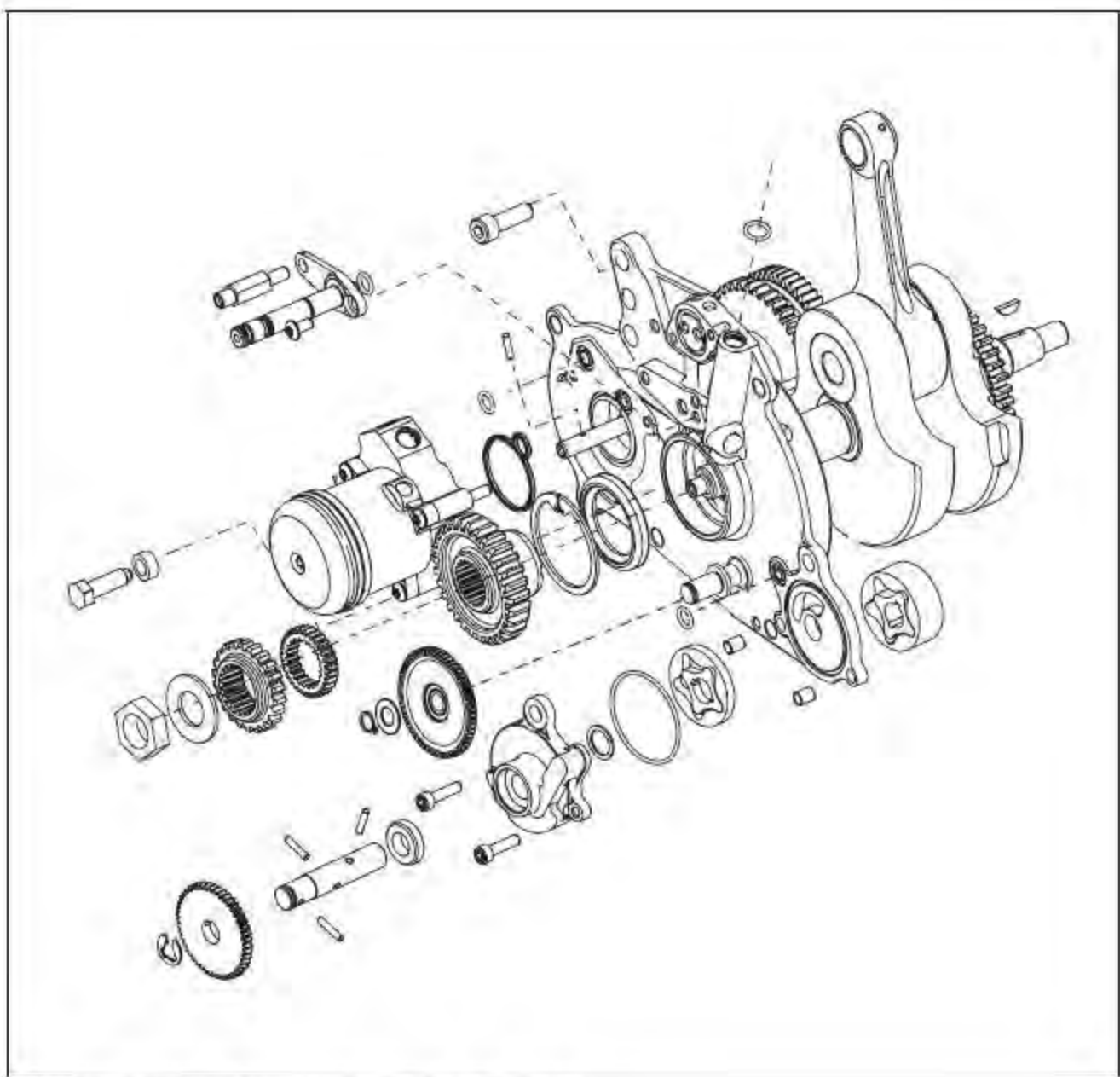
- 1. Piston pin access cover
- 2. O-rings

# Crankshaft cartridge plate

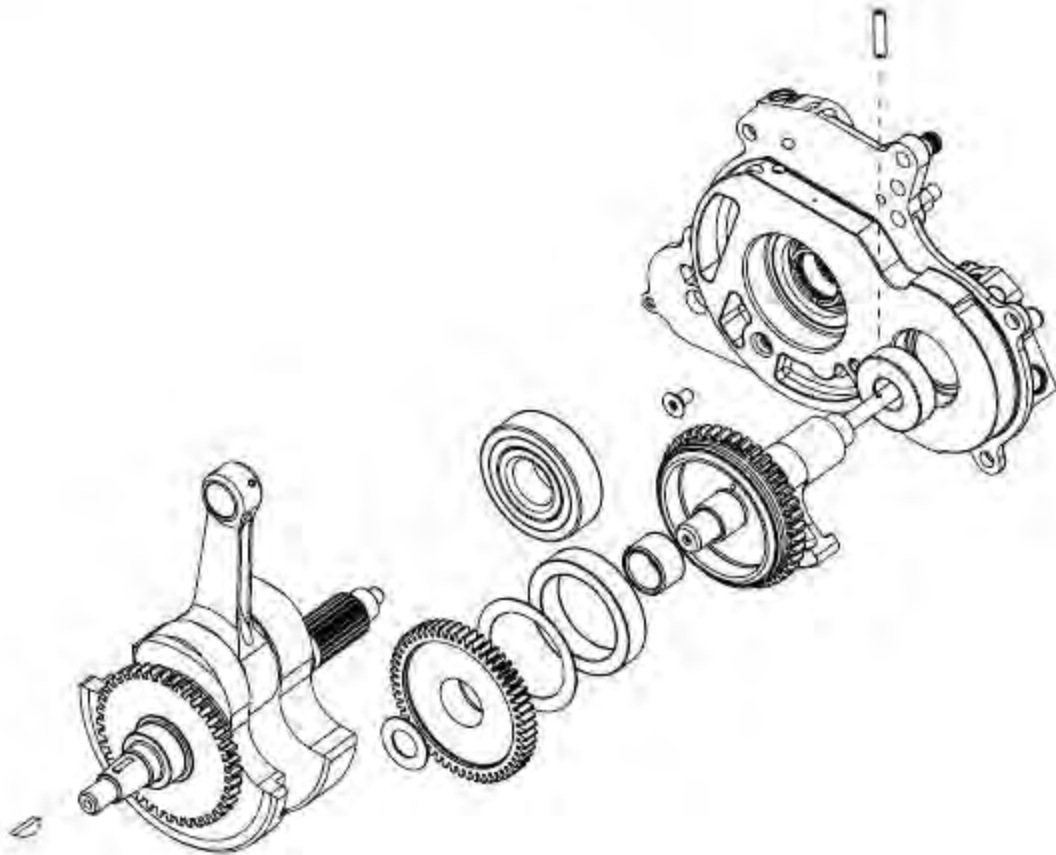
Unit: mm (in)

ITEM			STANDARD	SERVICE LIMIT
Crankshaft	Runout	Right	0 - 0.02 (0 - 0.000787)	0.05 (0.001968)
		Left	0 - 0.06 (0 - 0.00236)	0.15 (0.0059)
	Small end free play		0.25 - 0.50 (0.00984 - 0.01968)	-
	Big end side clearance		0.02 - 0.18 (0.000787 - 0.00708)	0.40 (0.01574)
	Big end radial clearance		-	0.05 (0.001968)
	Crankwidth		73.000 - 73.1000 (2.874 - 2.8779)	-
Engine oil pressure pump	tip clearance		0.15 (0.0059)	0.25 (0.00984)
	side clearance		0.16 - 0.25 (0.006299 - 0.00984)	0.30 (0.01181)
	Rotor depth clearance		0.05 - 0.09 (0.001968 - 0.00354)	0.14 (0.00551)
	Outer rotor thickness		5.750 - 5.763 (0.2263 - 0.2268)	-
Engine oil scavenge pump	Tip clearance	SM	0.15 (0.0059)	0.25 (0.00984)
		LG	0.15 (0.0059)	0.25 (0.00984)
	Side clearance	SM	0.16 - 0.26 (0.006299 - 0.01023)	0.35 (0.013779)
		LG	0.16 - 0.26 (0.006299 - 0.01023)	0.35 (0.013779)
	Rotor depth	SM	0.05 - 0.10 (0.001968 - 0.003936)	0.15 (0.0059)
		LG	0.05 - 0.10 (0.001968 - 0.003936)	0.15 (0.0059)
	Outer rotor thickness	SM	4.737 - 4.763 (0.1732 - 0.1875)	-
		LG	15.850 - 15.875 (0.624 - 0.625)	-
Starter clutch	friction plate thickness		(1) 2.00 ± 0.05 (0.07873 ± 0.001968)	1.85 (0.0728)
			(2) 1.50 ± 0.05 (0.059 ± 0.001968)	1.35 (0.0531)
	Metallic plate thickness		1.000 ± 0.025 (0.03937 ± 0.000984)	0.950 (0.0374)





**ASSEMBLY VIEW : Crankshaft cartridge plate (front)**

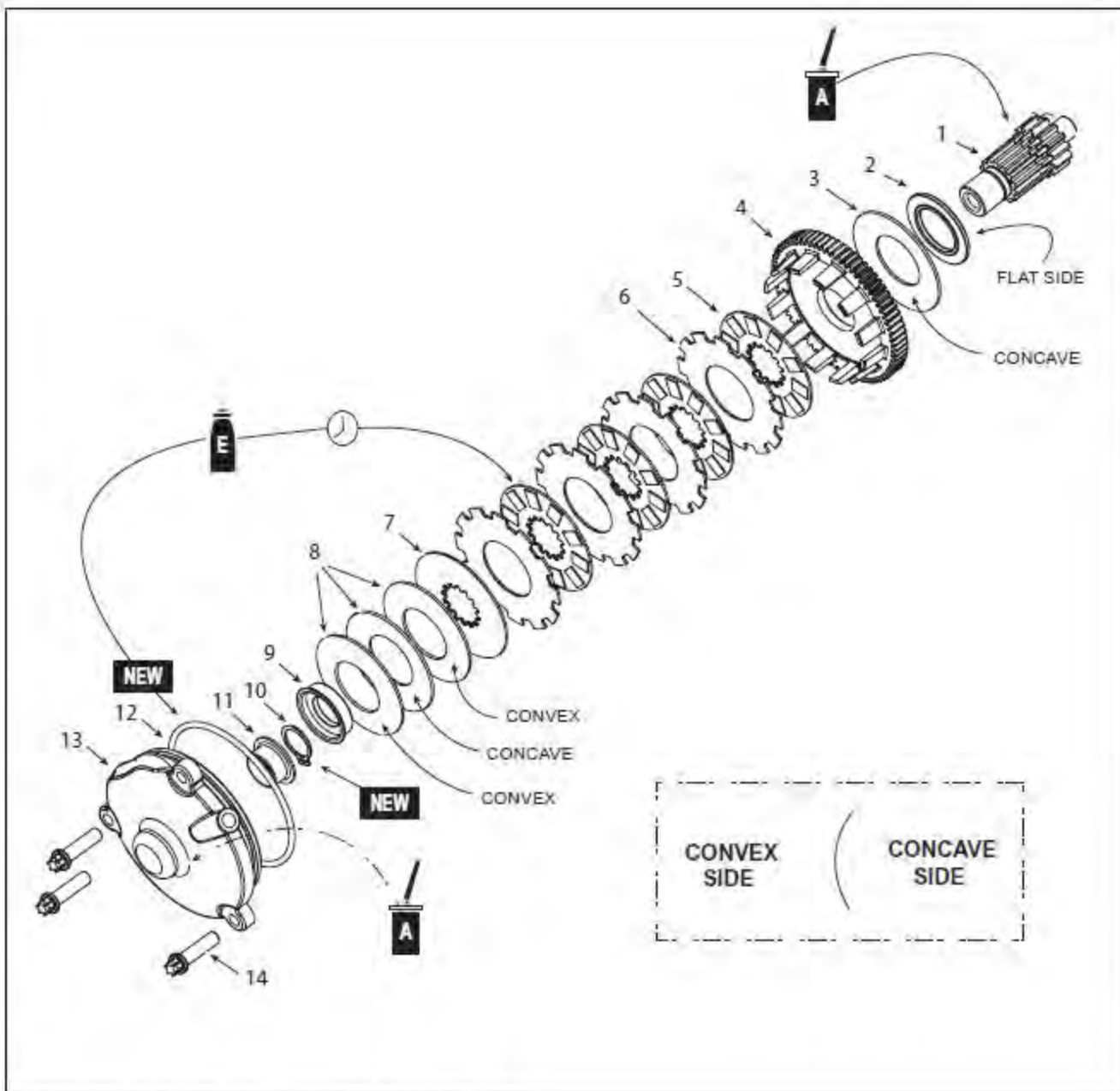


ASSEMBLY VIEW : Crankshaft cartridge plate (rear)



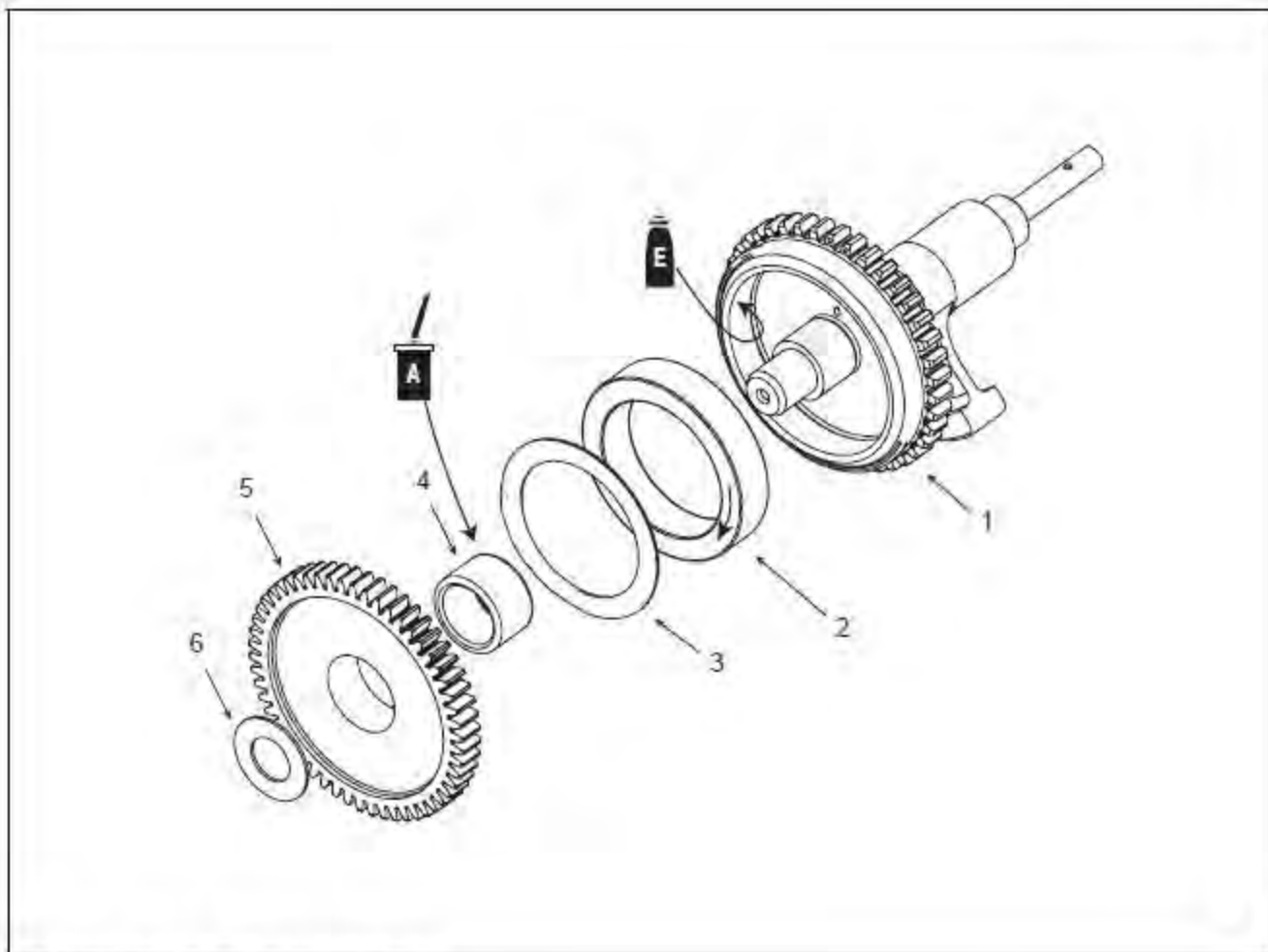
- 2001-2002 Cannondale Motorcycle & ATV Engine Service Manual





**ASSEMBLY VIEW : Starter clutch & cover (2)**

- |                        |                   |           |
|------------------------|-------------------|-----------|
| 1. Shaft               | 7. Pressure plate | 13. Cover |
| 2. Washer              | 8. Spring         | 14. Bolts |
| 3. Spring              | 9. Washer         |           |
| 4. Housing             | 10. Circlip       |           |
| 5. Friction plates (4) | 11. Washer        |           |
| 6. Metallic plates (4) | 12. Cover O-ring  |           |

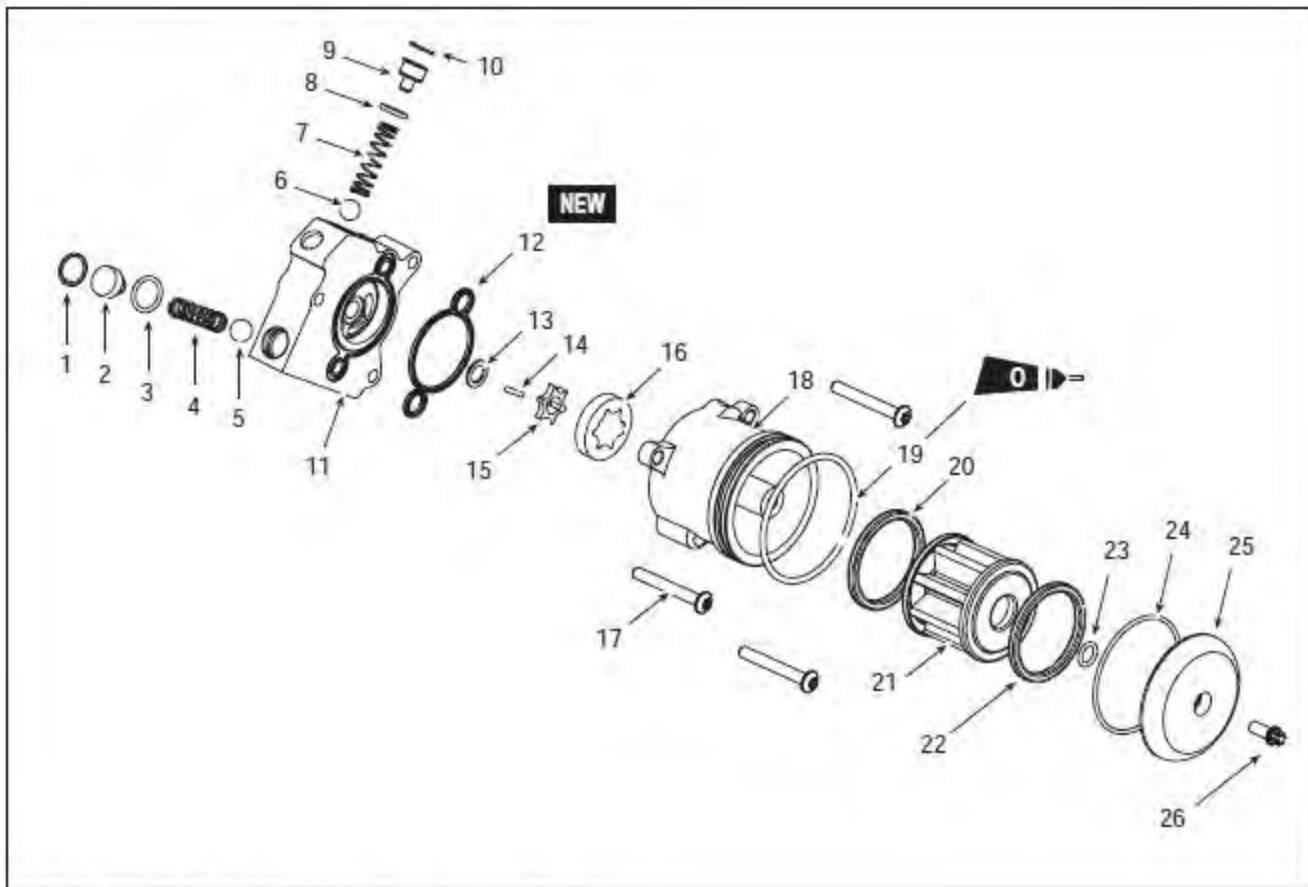


**ASSEMBLY VIEW : Balance shaft**

- 1. Shaft
- 2. Sprag clutch

- 3. Washer
- 4. Bearing

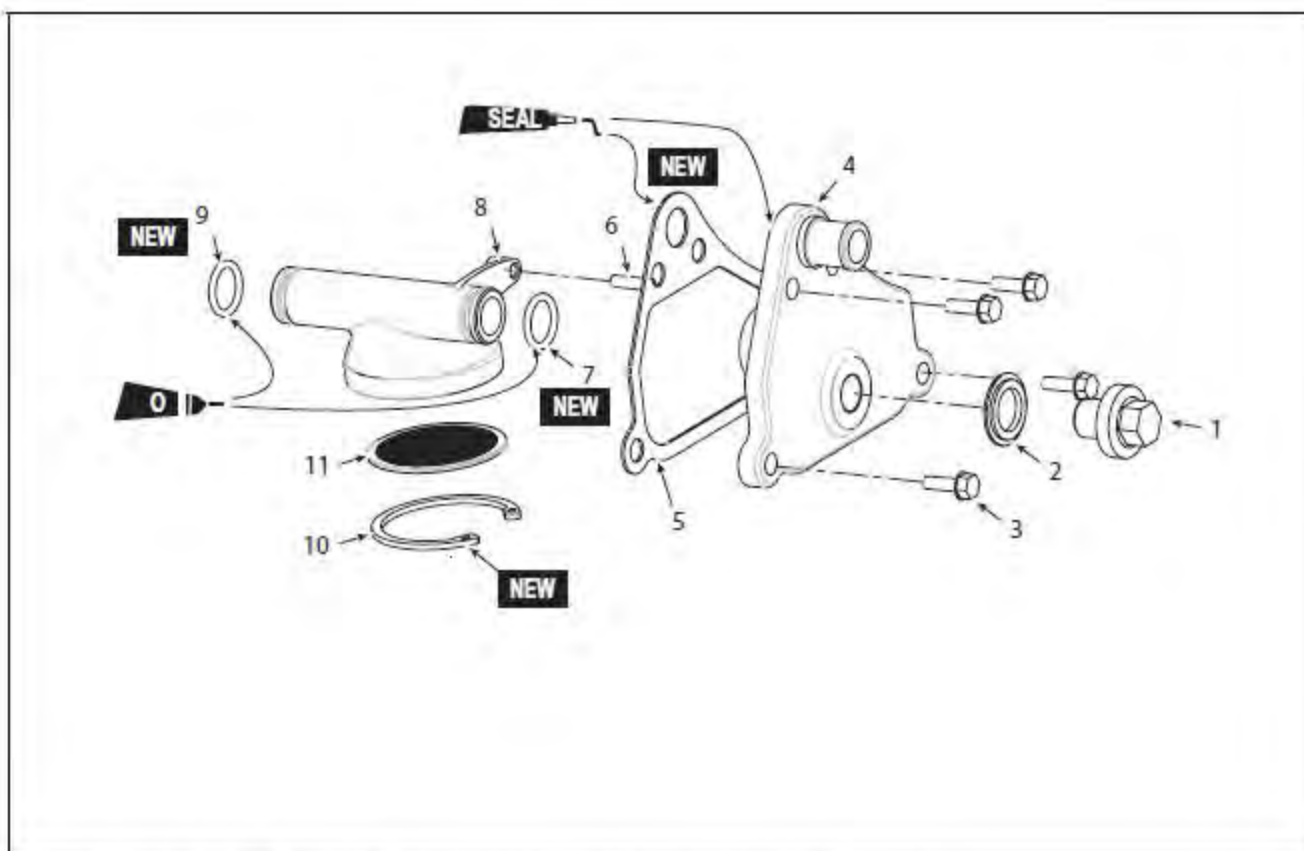
- 5. Gear
- 6. Thrust washer



**ASSEMBLY VIEW : Engine oil pressure pump**

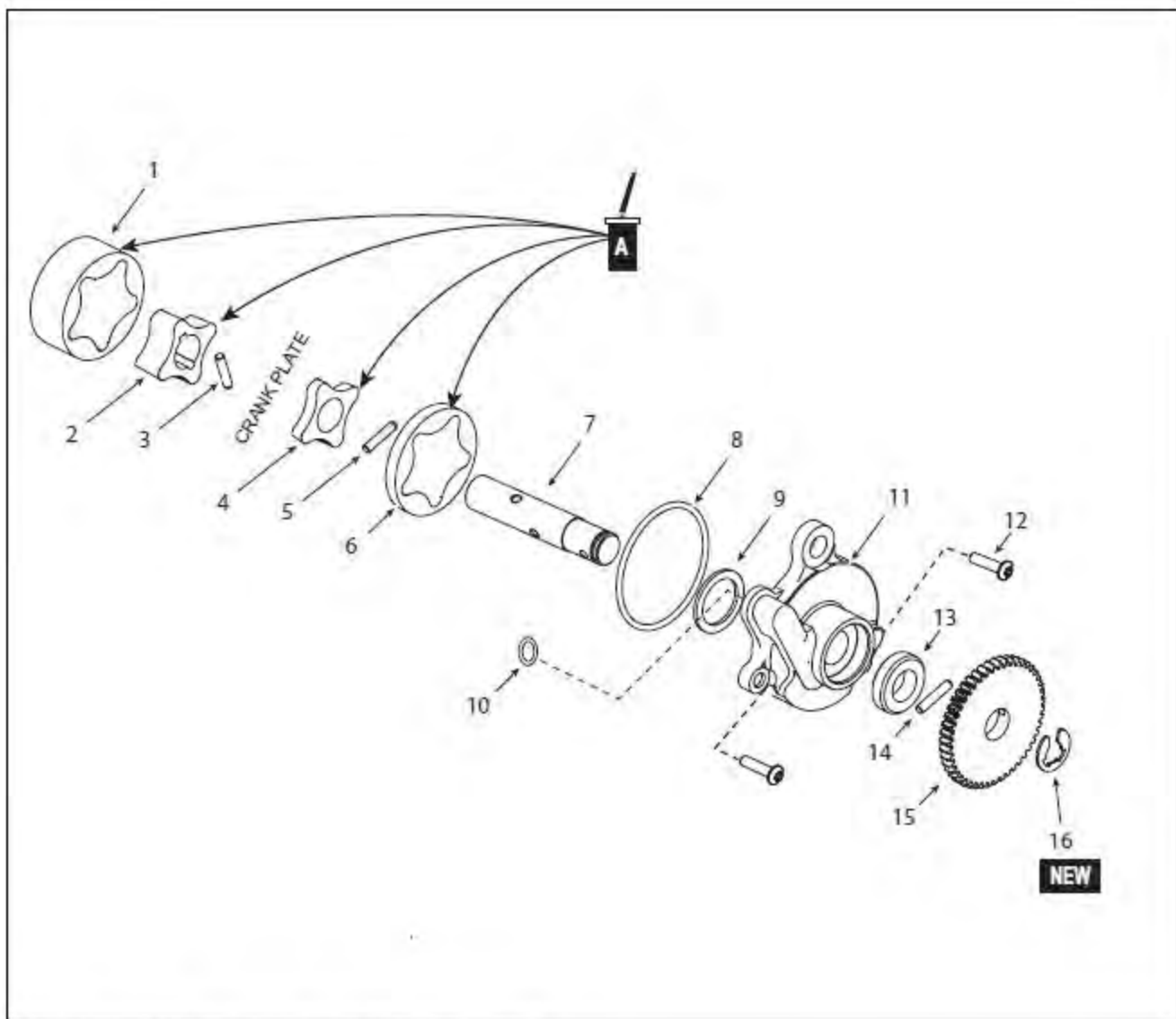
- |               |                    |                            |
|---------------|--------------------|----------------------------|
| 1. Circlip    | 10. Circlip        | 19. Filter Housing O-ring  |
| 2. Cap        | 11. Pump Housing   | 20. Seal                   |
| 3. O-ring     | 12. Seal           | 21. Filter element         |
| 4. Spring     | 13. Washer         | 22. Seal                   |
| 5. Check ball | 14. Pin            | 23. Cover O-ring (smaller) |
| 6. Check ball | 15. Inner rotor    | 24. Cover O-ring (larger)  |
| 7. Spring     | 16. Outer rotor    | 25. Cover                  |
| 8. O-ring     | 17. Bolts (3)      | 26. Cover bolt             |
| 9. Cap        | 18. Filter housing |                            |





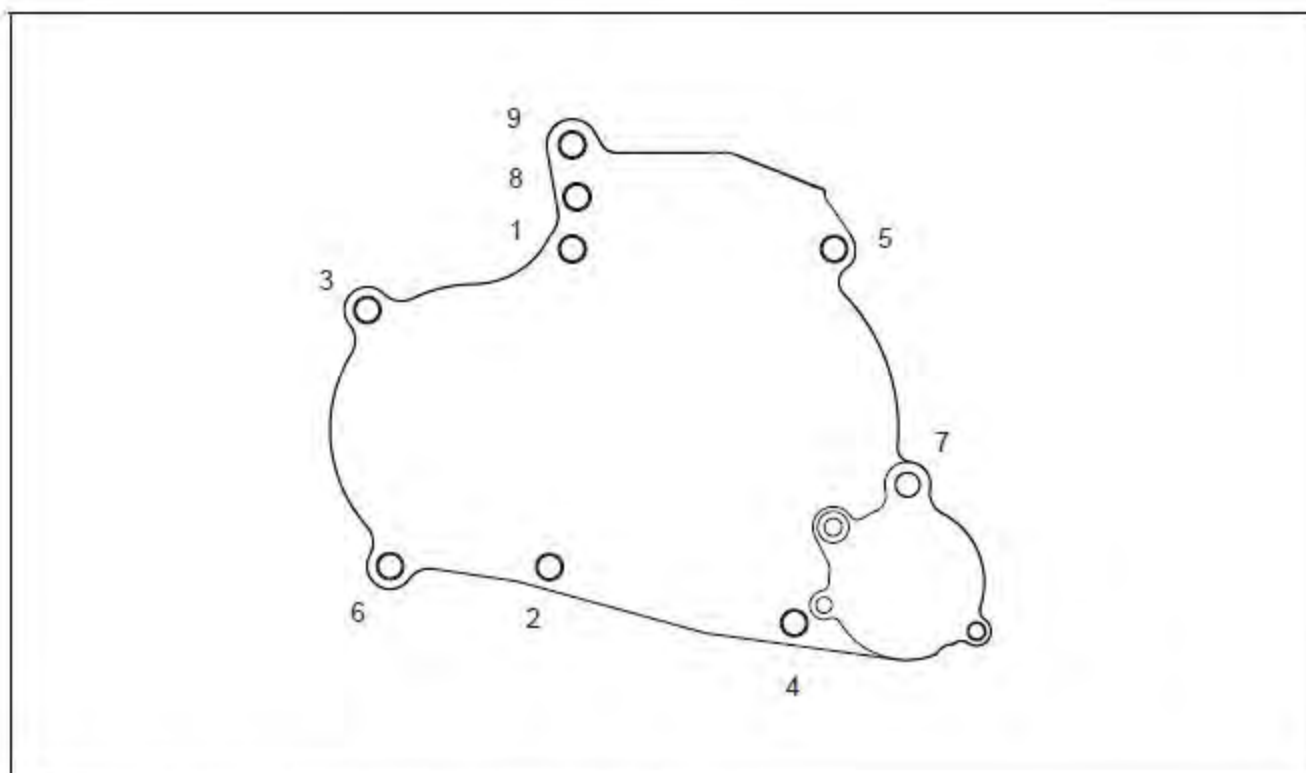
**ASSEMBLY VIEW : Engine oil scavenge pump pickup assembly & cover**

- |                   |             |
|-------------------|-------------|
| 1. Drain bolt     | 7. O-ring   |
| 2. Sealing washer | 8. Pickup   |
| 3. Bolt           | 9. O-ring   |
| 4. Cover          | 10. Circlip |
| 5. Gasket         | 11. Screen  |
| 6. Pin            |             |



**ASSEMBLY VIEW : Engine oil scavenge pump**

- |                        |            |                |
|------------------------|------------|----------------|
| 1. Rotor (Large outer) | 7. Shaft   | 13. Seal       |
| 2. Rotor (Large inner) | 8. O-ring  | 14. Pin        |
| 3. Pin                 | 9. Washer  | 15. Drive gear |
| 4. Rotor (Small inner) | 10. O-ring | 16. E-clip     |
| 5. Pin                 | 11. Cover  |                |
| 6. Rotor (Small outer) | 12. Bolt   |                |



**ASSEMBLY VIEW : Crankshaft cartridge plate bolt pattern**

**NOTE :**

*The numbers above indicate the proper bolt tightening sequence.*

**CAUTION**

Bolts numbered 1, 7, 8 and 9 are M8X25. Bolts numbered 2, 3, 4, 5, and 6 are M8X20. It is important that you place the right length bolt where it belongs.



## CRANKSHAFT CARTRIDGE PLATE, REMOVE

### **⚠ WARNING**

Wear eye protection. Circlips and E-clips can accidentally "pop" or "fling" off as you remove them. This can result in severe eye injury to you and/or bystanders.

### **CAUTION**

Avoid damaging the right crankshaft oil seal.

### **NOTE :**

*We recommend replacing the seal, but use some masking tape to cover the threaded end of the crankshaft if you intend to preserve and re-use it. And, as you are removing the plate from the left side of the case support the crankshaft end as it passes through the seal.*

1. Remove the cylinder head (page 58).
2. Remove the clutch assembly (page 163).
3. Remove the coolant outlet cover (page 26).
4. Remove the sleeve and piston (page 81).
5. Remove the flywheel (page 178).
6. Remove the 2 O-rings, circlip and right timing chain guide from the timing chain pivot shaft.

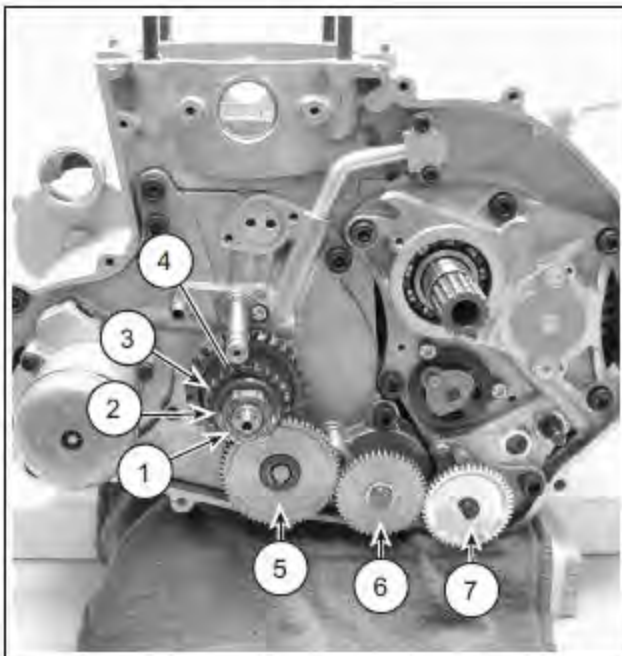
### **NOTE :**

*Install the TDC bolt to secure the crankshaft as you remove the crankshaft nut.*

7. Remove the crankshaft nut (1), washer (2), timing chain drive gear (3), and scavenge pump drive gear (4) from the crankshaft end. Then remove the scavenge pump idler gear (5), scavenge pump drive ring gear (6), and transmission pump drive gear (7).

### **NOTE :**

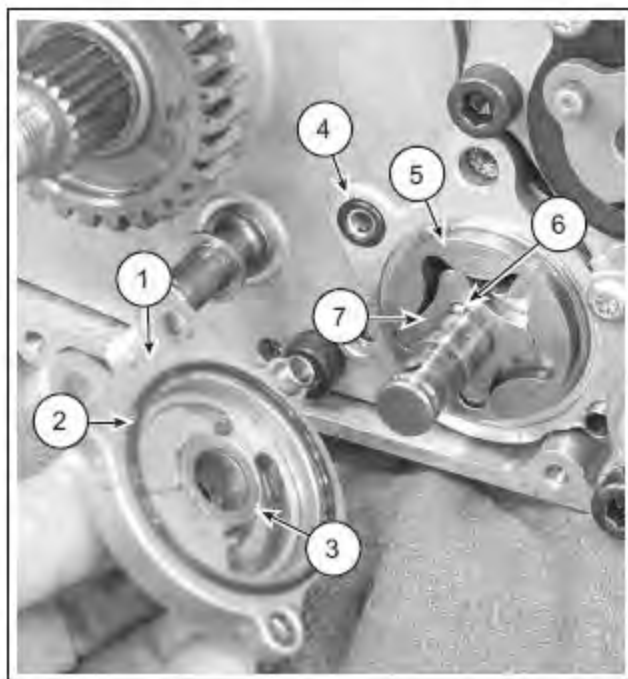
*Be sure to keep the scavenge pump and transmission pump drive shaft pins where you will not lose them.*



1. Crankshaft nut
2. Washer
3. Timing chain drive gear
4. Pump drive ring gear
5. Scavenge pump idler gear
6. Scavenge pump drive gear
7. Transmission pump drive gear

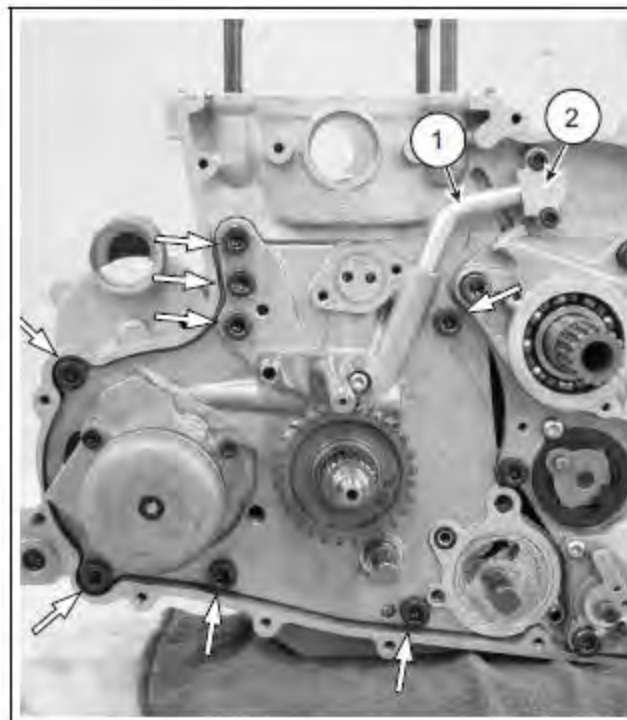
8. Remove the cartridge plate bolt that passes through the scavenge pump cover and the two smaller cover bolts.
9. Remove the scavenge pump cover by working it off gradually, and do not use any kind of tool to pry it. Once the cover is removed, make sure you notice the washer on the inner surface of the cover.

10. Remove the inner and outer rotors and shaft pin from the shaft. Again, keep the shaft pin where you will not lose it.



- 1. Cover
- 2. Cover seal
- 3. Cover washer
- 4. O-ring
- 5. Outer rotor
- 6. Shaft pin
- 7. Inner rotor

11. Remove the remaining crankshaft cartridge plate bolts, engine oil supply tube, and adapter block. Be sure to note the location of the adapter block to case o-ring when removing the oil tube.

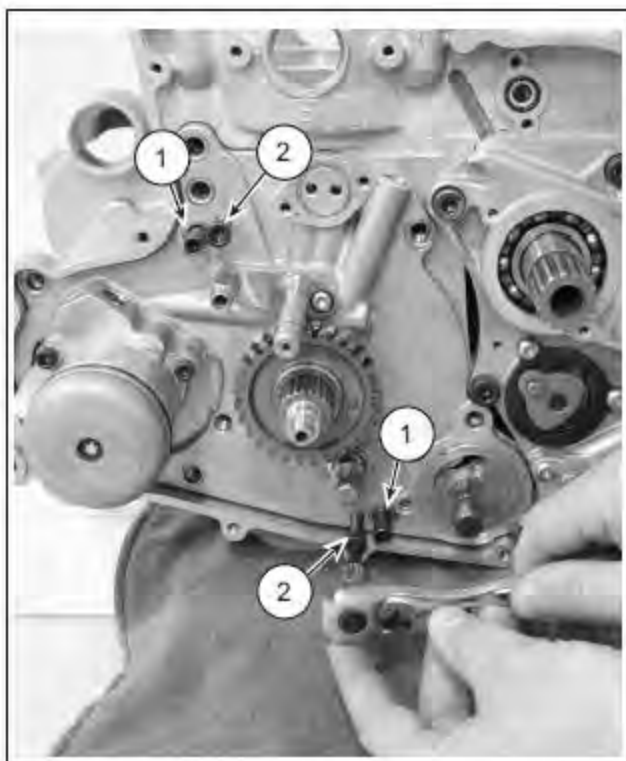


- 1. Tube
- 2. Adapter block



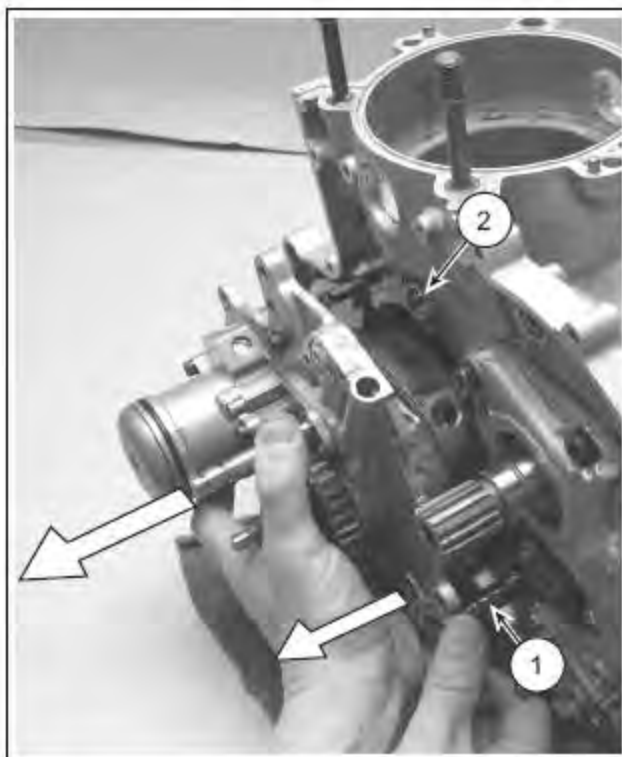
12. Install special tools through the plate into the case in the locations shown.

Thread 2 M6x1.0X25 bolts into the cartridge plate finger tight in the locations indicated (see photo). Now, slowly tighten the bolts alternately, and extract the plate. Also, as you alternate between bolts, tap the right end (flywheel side) of the crankshaft with a rubber mallet to aid in the removal of the cartridge plate assembly.



- 1. Tool
- 2. Bolts

13. Remove the crankshaft cartridge plate from the crankcase. As it exits the case, make sure you continue to keep it straight. And, remember, take care not to damage the right crankshaft seal as the crankshaft exits through the seal. You will have to position the connecting rod to bottom-dead-center (BDC) so the small end of the connecting rod can pass through the opening in the crankcase wall.



- 1. Scavenge pump shaft
- 2. Connecting rod (out through crankcase opening)

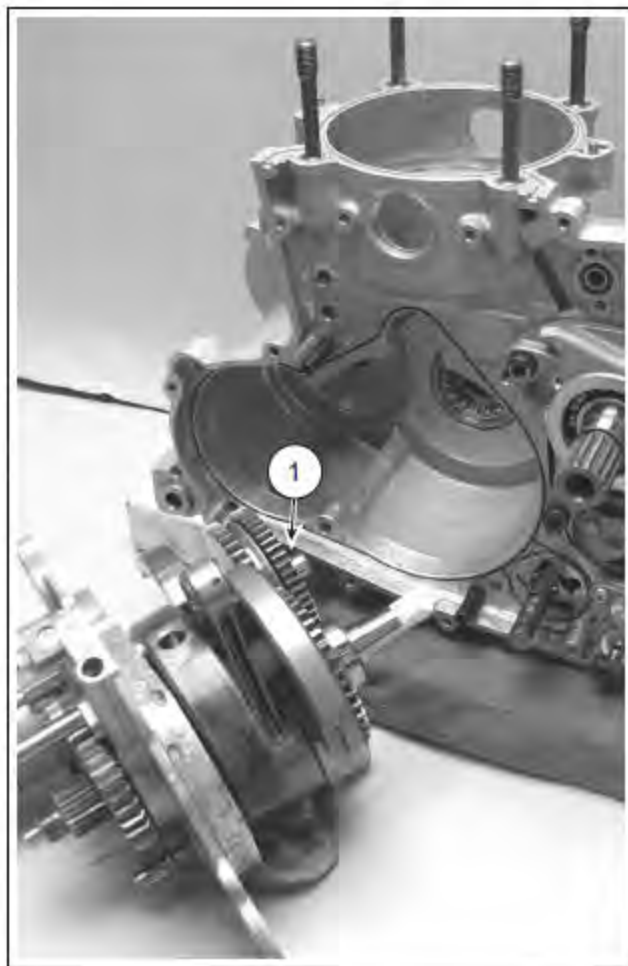
**TOOL : CM-503874**

**Crankshaft cartridge alignment pins**



### CAUTION

Look for the balance shaft thrust washer. It should be on the balance shaft. If its not, it could be adhering to the crankcase wall or fallen down into the scavenge pump cavity.



1. Thrust washer on balance shaft end

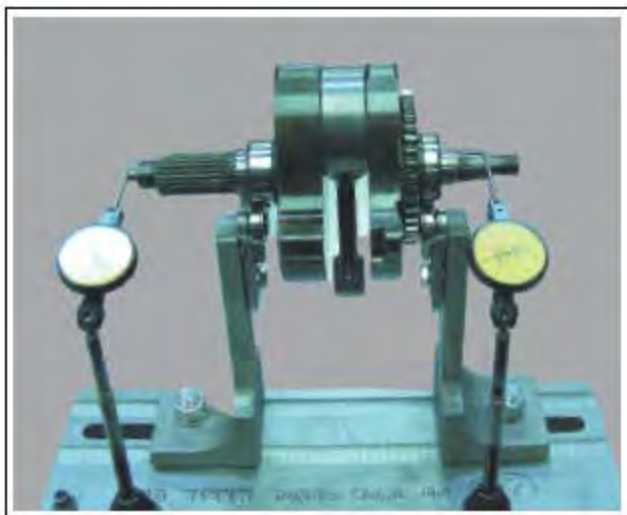
## CRANKSHAFT, INSPECT

Consult the table at the beginning of this section for service specifications of the following items.

1. Make sure connecting rod rotates freely.
2. Inspect oil passages for clogging by blowing compressed air through oil passages.
3. Inspect counterweights for cracking, scoring, and/or other damage.



4. Measure crankshaft runout limit.



6. Measure connecting rod big end side clearance.



5. Measure small end freeplay.



7. Measure crankwidth.





**Crankshaft runout standard**  
right 0 - 0.000787 (0 - 0.02mm)  
left 0 - 0.00236 (0 - 0.06mm)  
limit  
right 0.001968 in (0.05mm)  
left 0.0059 in (0.15 mm)

**Crankshaft small end freeplay standard -**  
0.00984 - 0.01968 in  
(0.25 - 0.50 mm)

**Connecting rod big end side clearance standard -**  
0.00787 - 0.00708 in (0.02-0.18 mm)  
limit - 0.01574 in (0.40mm)

**Crankwidth**  
2.874 - 2.8779 in (73.0 - 73.1 mm)

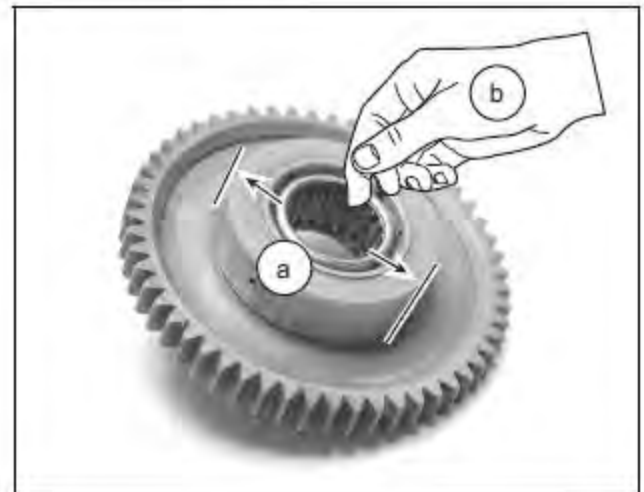
## BALANCE SHAFT, INSPECT

Consult the table at the beginning of this section for service specifications of the following items.

1. Inspect the gear bore for scarring or grooves.  
Replace as necessary.



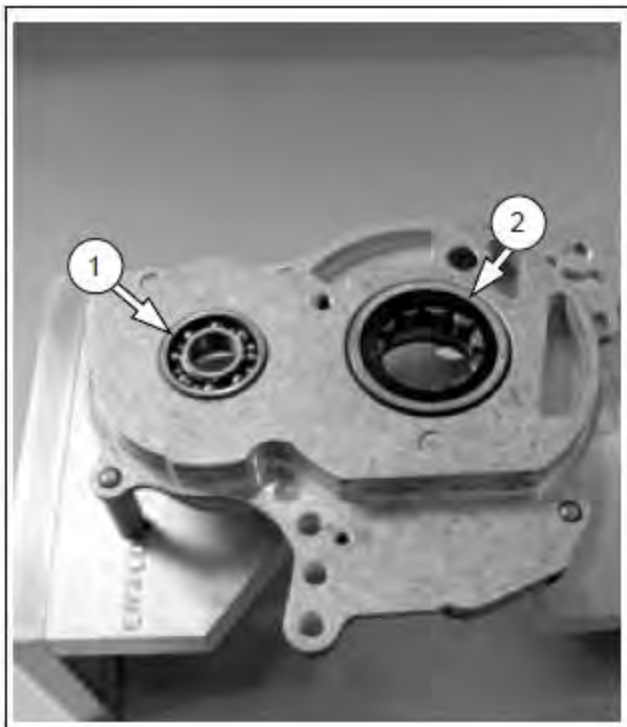
2. Measure the gear O.D (a).  
Inspect for scarring or grooves. Replace as necessary.  
Check the bearing condition (b).





## CRANKSHAFT CARTRIDGE PLATE, ASSEMBLE

1. Heat the bare cartridge plate 15-20 minutes at 100C° ( 212F°).
2. Install the bearings into the plate.



3. Install the crankshaft seal with markings facing out.

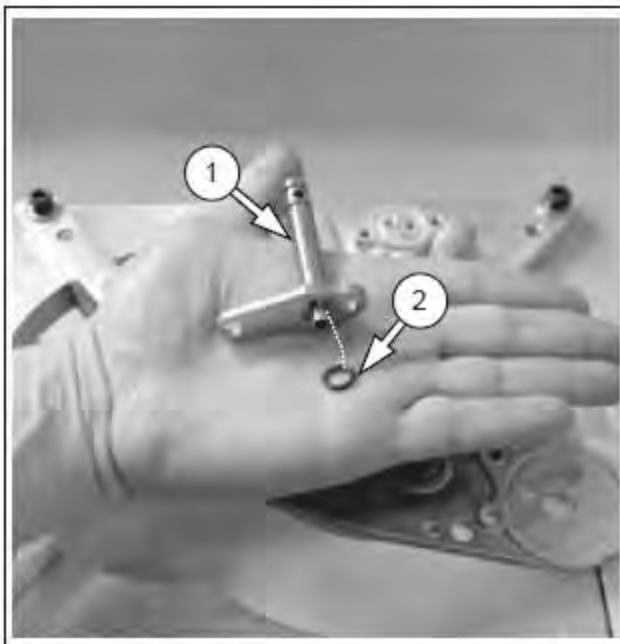
TOOL : CM-502462  
Driver handle

TOOL : CM-502449  
oil seal installer, 32mm

4. Install the retaining ring with the flat side up.



5. Install the o-ring onto the timing chain tensioner shoe pivot shaft.



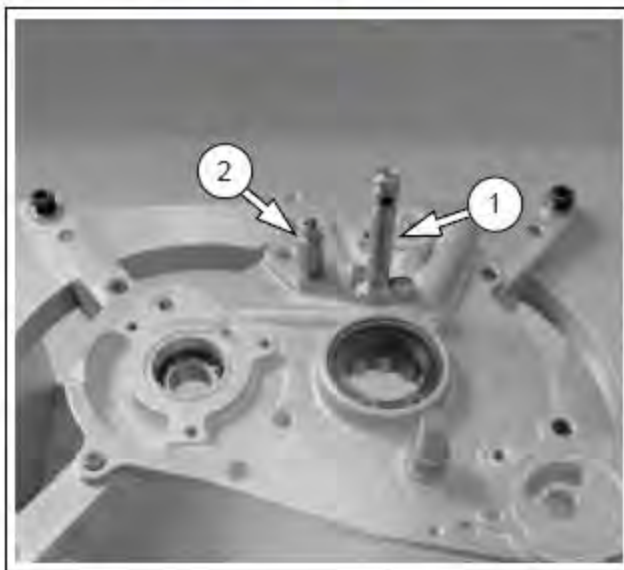
1. Shaft
2. O-ring

6. Install the timing chain tensioner shoe pivot and left timing chain guide pivot onto the plate. Hand-tighten each before tightening to the specified torque(s). Install the crankshaft assembly into the plate with the crank on the crank shaft gear facing the balance shaft bearing.



**Timing chain tensioner shoe pivot**  
3.3 lbf·ft (4.5 N·m)

**Left timing chain guide pivot**  
7.4 lbf·ft (10.0 N·m)



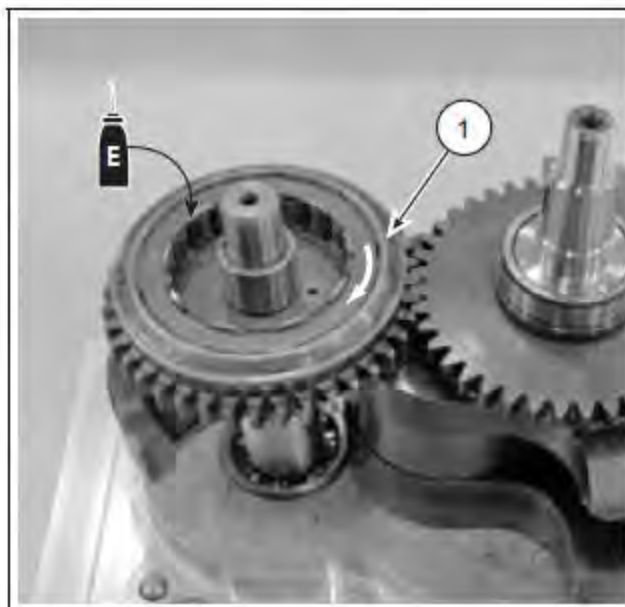
1. Timing chain tensioner shoe pivot  
2. Left timing chain guide pivot



7. Align the mark on the crankshaft gear with the mark in the balance shaft, and then install the balance shaft into the plate.



8. Apply assembly lube to the balance shaft "cup", and install the sprag (one way) clutch into the balance shaft with the arrow marking on the clutch facing up (see photo).



1. Arrow mark

9. Install the thrust washer onto the sprag clutch.



11. Apply some assembly lube to the shaft end, and install the thrust washer onto the shaft end.

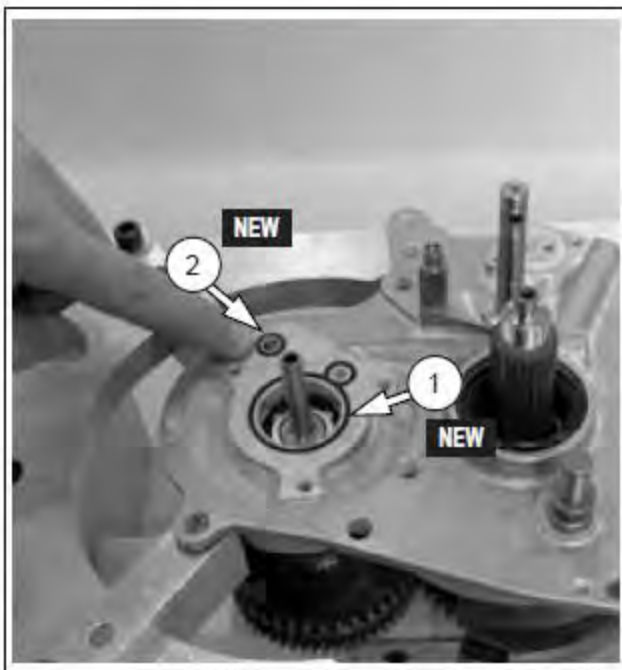


10. Install the starter gear into the sprag clutch.

Test for proper operation of the clutch by making sure it turns only in the direction indicated in the arrow (see the photo).



12. Install a new engine oil pressure pump seal (1) and O-ring (2) into the plate.



- 1. Seal
- 2. O-ring



13. Install the engine oil pressure pump housing onto the plate.



15. Install the shaft pin into the balance shaft.



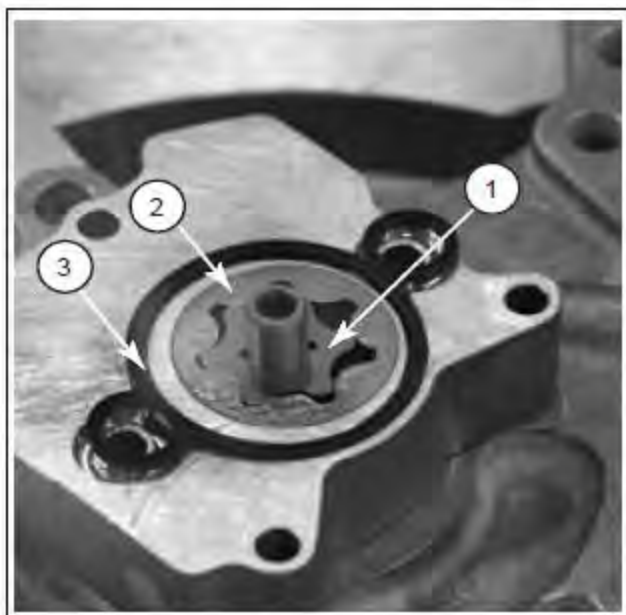
14. Install the thrust washer onto the balance shaft end.



16. Install the inner rotor (1) over the shaft pin, outer rotor (2), and filter housing seal (3).

NOTE :

*Be sure to notice the square and rounded ends of the dowel pin and the matching groove of the inner rotor.*



- 1. Inner rotor
- 2. Outer rotor
- 3. Filter housing seal

NOTE :

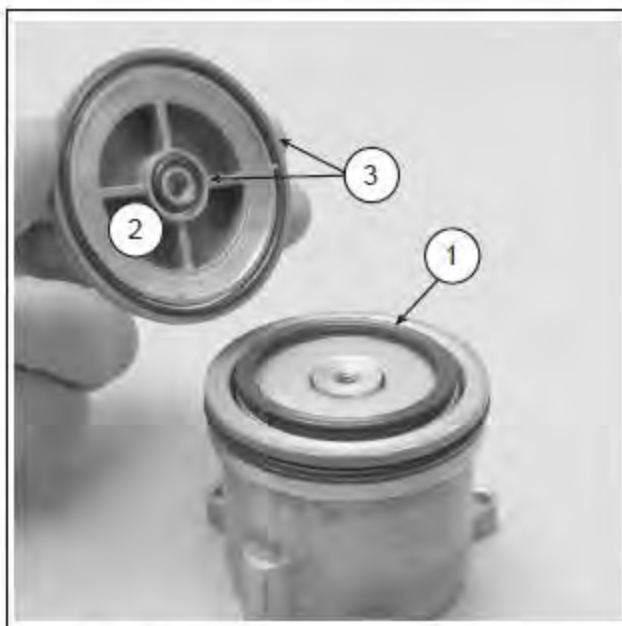
*Use assembly lube to hold the seal in the proper position on the filter.*

17. Make sure the O-ring is installed on the housing. Then install the engine oil filter (1) and lower seal (2) into the housing (3).



- 1. Filter
- 2. Lower seal
- 3. Housing

18. Install the upper seal (1), and housing cover (2). Make sure the cover O-rings (3) are in good condition, if not replace.



- 1. Upper seal
- 2. Cover
- 3. O-rings

19. Install the cover bolt. Tighten to the specified torque.



**Engine oil filter cover bolt**  
**3.3 lbf·ft (4.5N·m)**

20. Install the engine oil filter housing onto the pump housing and tighten the bolts to the specified torque



**Engine oil filter housing bolt**  
**3.3 lbf·ft (4.5N·m)**

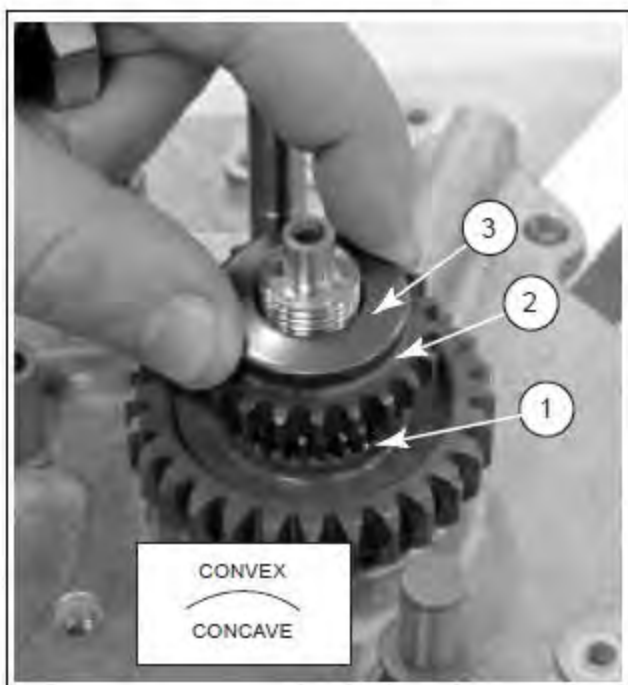


21. Inspect the condition of the O-ring on the inner diameter of the primary gear, and install onto crankshaft. Use O-ring lubricant to avoid damage during installation.





22. Install pump drive ring gear (1), timing chain drive gear (2), and beveled washer with the convex side up (3) onto the crankshaft end.



- 1. Pump drive ring gear
- 2. Timing chain drive gear
- 3. Beveled washer (convex side up)

23. Install the crankshaft nut finger tight so that the gears slide fully into position on the crankshaft. The crankshaft nut will be torqued to specification after installation into the case.



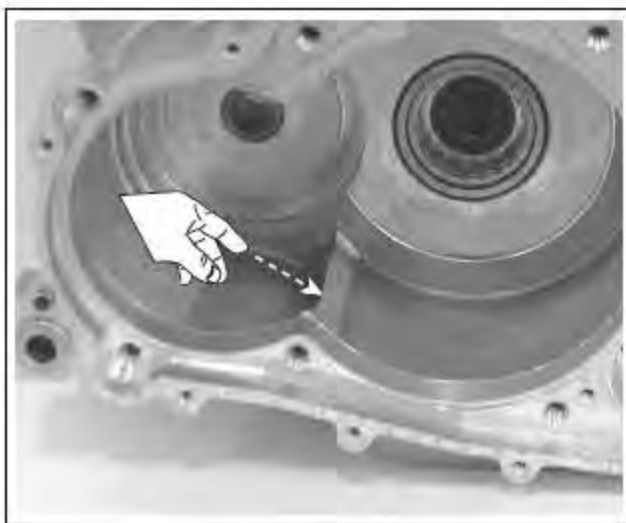
24. Install the TDC bolt and spacer finger tight.

**NOTE :**

*The TDC bolt is tightened to the specified torque later after it is used to hold crankshaft in the top-dead-center (TDC) position.*

## CRANKSHAFT CARTRIDGE PLATE, INSTALL

1. Confirm that no contaminants or hardware have inadvertently slipped into the scavenge pump cavity before continuing. Remove any if found.



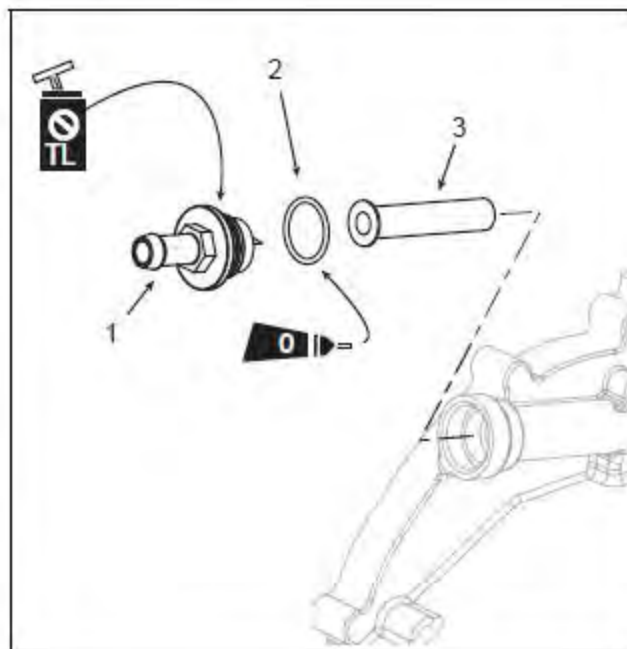
2. Install the right crankshaft oil seal with markings facing out (toward the flywheel).



**TOOL : CM-502462**  
Drive handle

**TOOL : CM-502464**  
20mm oil seal installer

3. Install the engine oil inlet filter screen (3). Apply assembly lube to the O-ring. Tighten the fitting to the specified torque.



1. Fitting
2. O-ring
3. Filter (screen)



**Engine oil inlet fitting**  
**18.0 lbf·ft (25.0 N·m)**

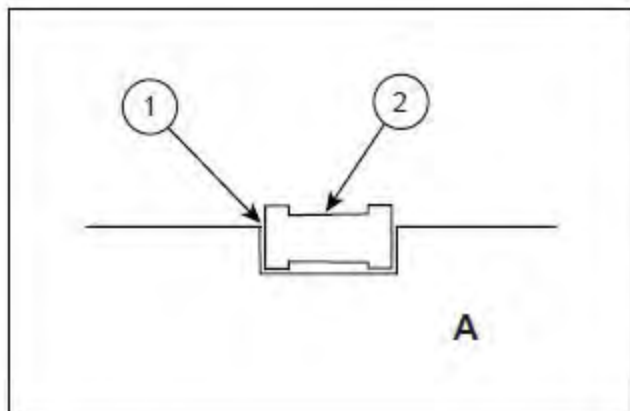
4. Apply o-ring lubricant/assembly aid to the o-ring (2) groove and install a new o-ring seal into the case groove (1).

**NOTE :**

When installing, be sure not to twist the O-ring in the groove (see illustration A).

Lay the o-ring over the entire length of the groove first. Then, starting at the o-ring branch, work it into the groove (see photo B).

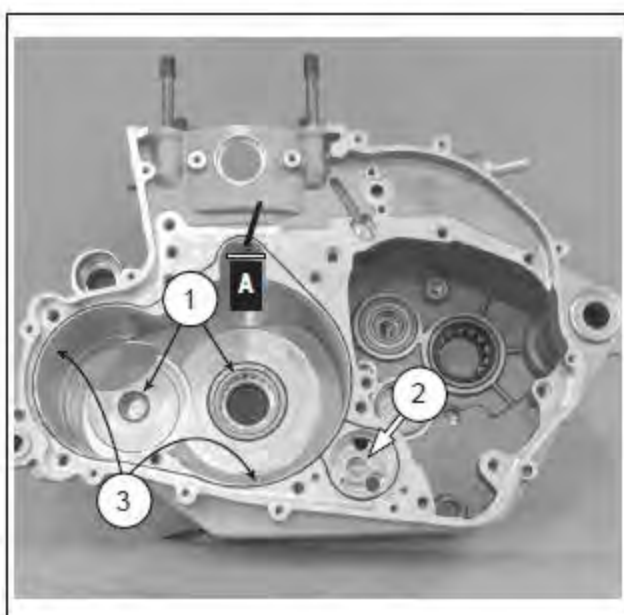
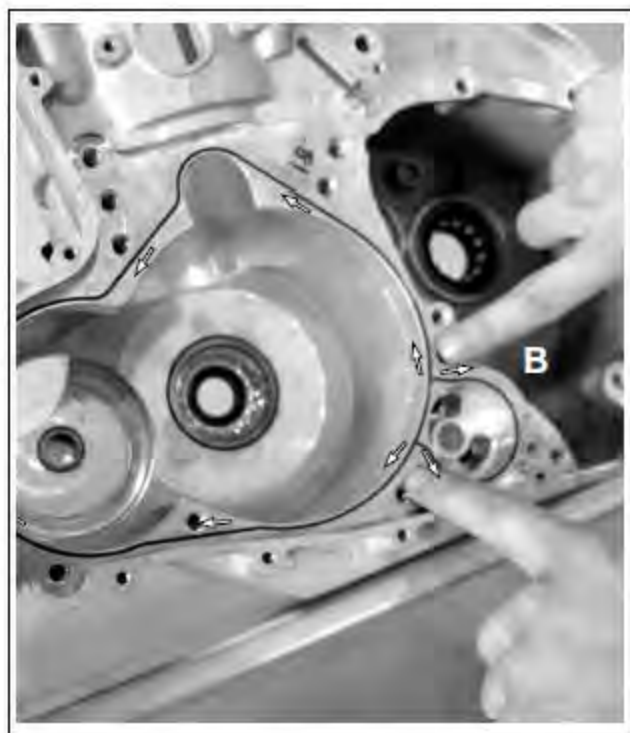
If it bulges at the end of the perimeter, carefully drag the length back into the groove (see photo C).



- 1. Groove
- 2. O-ring



- 5. Apply assembly lube to the bearings and right oil seal lip (1), scavenge pump cavity (2), plate and case contact surfaces (3).



- 1. Bearings
- 2. Scavenge pump cavity
- 3. Contact surfaces

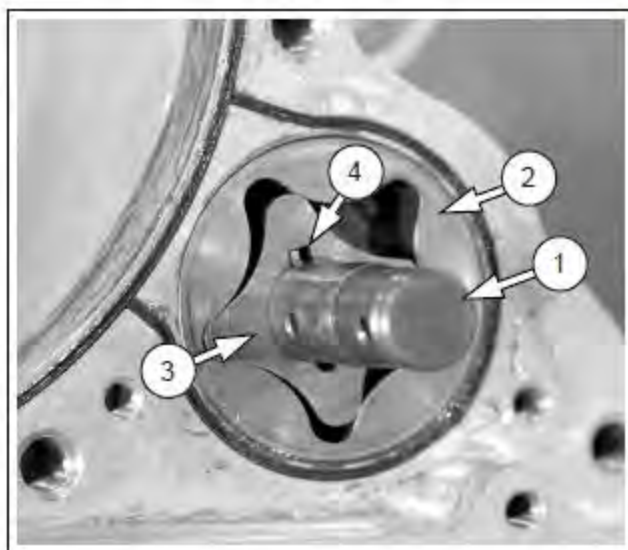


6. Insert the pin (3) into the scavenge pump drive shaft (1), and slide the inner rotor (2) over the pin so the pin does not drop out. The pin has a round and squared end. Be sure to note this when sliding the gear over the pin.



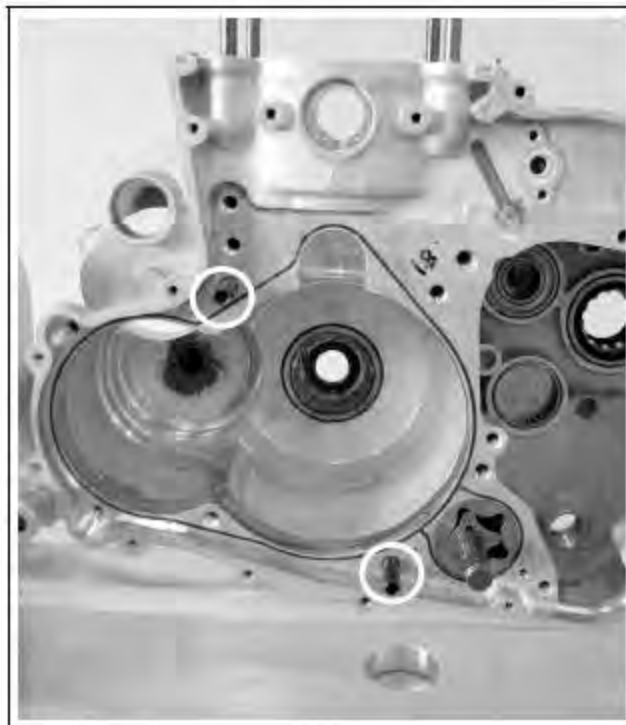
1. Shaft
2. Inner rotor
3. Pin (rounded end)

7. Install the outer rotor onto the shaft over the inner rotor, and install the assembly into the scavenge pump cavity. Apply lubricant to the rotor and case bore.



1. Shaft
2. Outer rotor
3. Inner rotor
4. Pin (rounded end)

8. Spin the shaft with your fingers; it should move freely with no binding or dragging.
9. Install the special tools (plate guides) into the case finger tight.

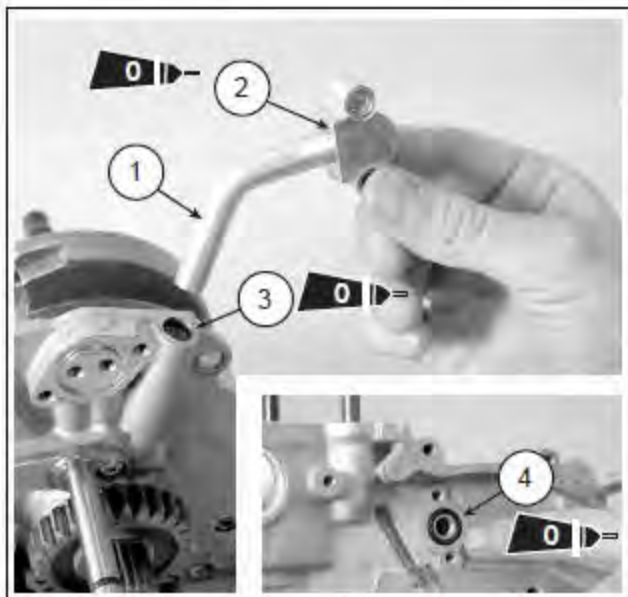


**TOOL : CM-503874**  
Crankshaft cartridge aligner

#### CAUTION

Always install the cartridge plate with the engine oil pressure pump assembly and filter housing installed. This will help assure that the balance shaft maintains its relationship with the crankshaft.

10. Install the oil return tube (1) with the return fitting (2) onto the plate. Then, use some O-ring lubricant assembly aid and install the fitting O-ring (4) onto the case. Be sure to inspect the plate O-ring (3).



1. Oil return tube
2. Fitting
3. O-ring
4. Fitting O-ring

11. Position the crankshaft and balance shaft as shown in the photo below.



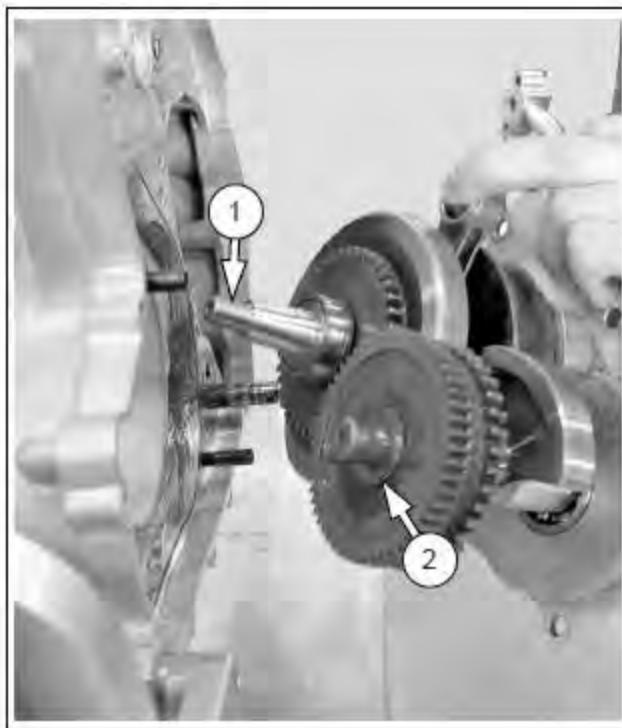
#### CAUTION

Be careful to not allow the threads on the crankshaft to drag across the right crankshaft oil seal; the threads are sharp and can tear the seal. Use some masking tape on the threads to help guard against tearing the seal.

Make sure the balance shaft thrust washer is installed on the shaft before installing the plate. Use some assembly lube to help hold it in place.

When installing the plate with the rubber mallet, Tap, do not strike the plate. Aside from damaging the plate, striking will dislocate the thrust washer causing it to come off the end of the shaft. Work carefully and confirm that the washer is in place before the end of the shaft locates in the bearing on the right side of the crankcase. You can inspect before the shaft enters the bearing by looking into the starter clutch housing.

12. Carefully install the cartridge plate into the case.



1. Threads
2. Thrust washer



### CAUTION

Do not lay the crankcase on its side while installing the plate. The thrust washer on the balance shaft end may dislodge without your knowledge. It will surely damage the engine if it's floating about in the crankcase.

Do not use the plate mounting bolts to insert the cartridge plate. Damage to the plate will result.

13. Carefully tap the plate with a rubber mallet at the locations indicated in the photo until the plate is fully installed into the case.

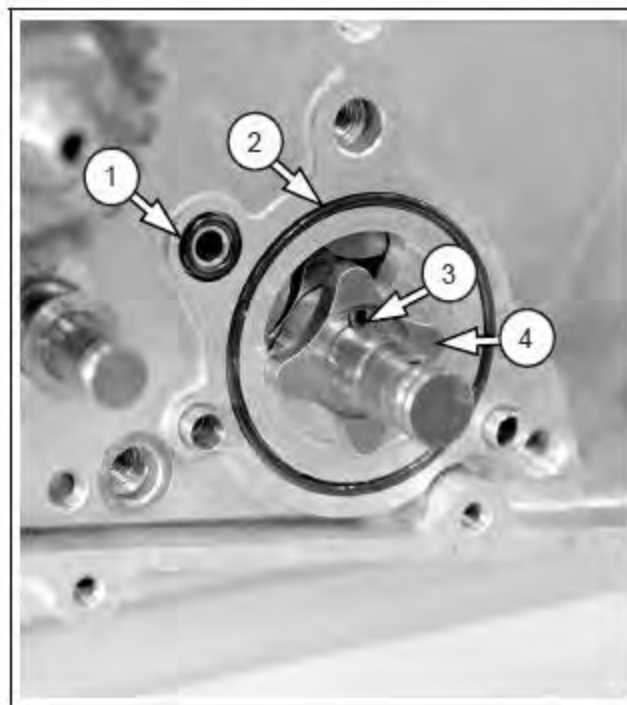


### NOTE :

*Gently tap where indicated.*

14. Remove the special tools.

15. Install the scavenge pump O-ring (1) and seal (2). Install the pin (3) into the scavenge pump drive shaft (4), and install the inner rotor.



1. O-ring
2. O-ring
3. Pin
4. Inner rotor

### NOTE :

*Be sure to notice the rounded and square end of the pin and the matching groove in the rotor.*

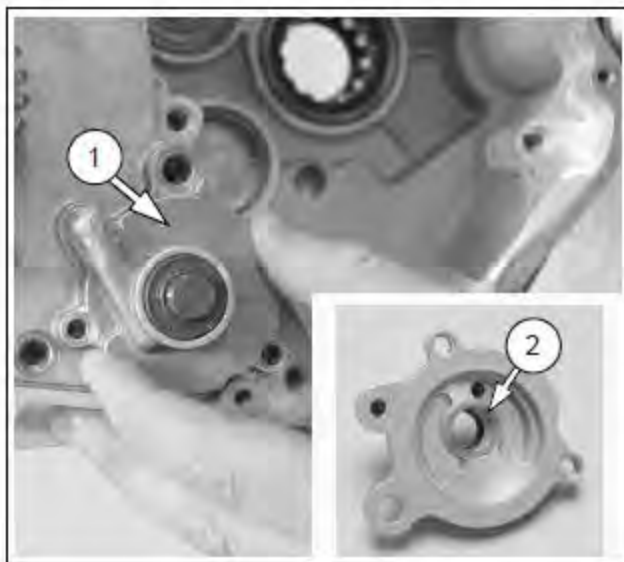


16. Apply some assembly lube to the plate side face of the outer rotor, and center it within the o-ring. The assembly lube should be enough to "stick" it in place for the cover installation. Sticking the outer rotor to the plate as described makes installing the cover much easier.



1. Outer rotor

17. Apply some clean engine oil to the seal lips and guide the scavenge pump cover onto the shaft and over the outer rotor. Do not install the cover bolts...yet.

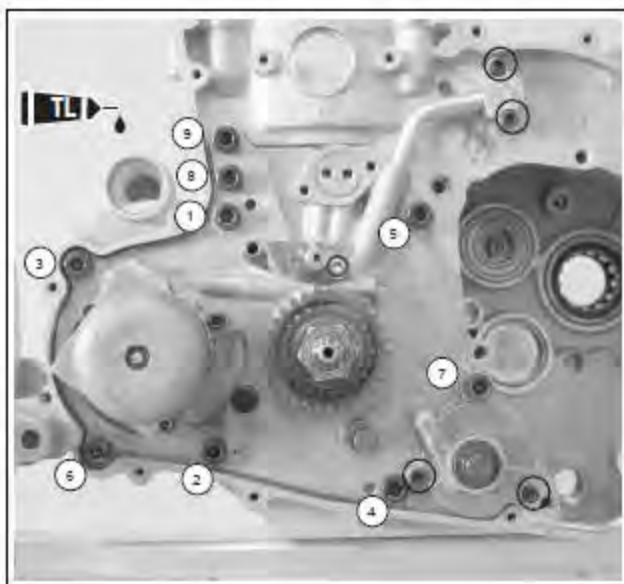


- 1. Scavenge pump cover
- 2. Washer

### CAUTION

Before installing the scavenge pump cover, make sure the flat washer inside the cover (2) is present.

18. Apply Loctite #242 to each cartridge plate mounting bolt and install until the bolt heads contacts plate. Then, in the pattern illustrated, tighten all bolts in 2 stages to the specified torque.





**Crankshaft cartridge plate bolt(s)**  
Stage 1 - 8.9 lbf·ft (12.0 N·m)  
Stage 2 - 16.2 lbf·ft (16.2 N·m)

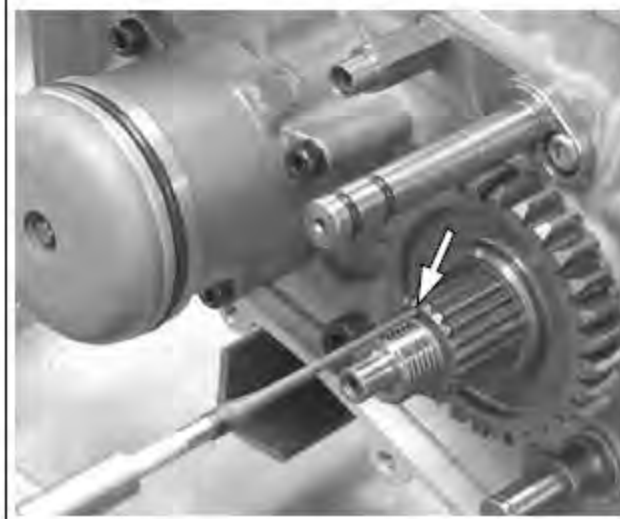
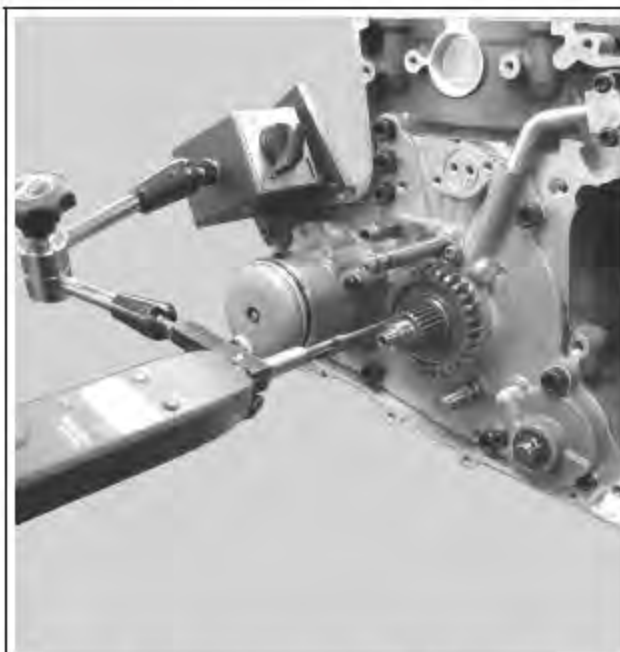
**Scavenge pump cover bolts**  
3.3 lbf·ft (4.5 N·m)

**Oil return tube fitting bolts**  
3.3 lbf·ft (4.5 N·m)

19. Install the scavenge pump cover bolts. Then, turn the shaft - it should turn completely without binding. Depending on your strength, you may find it difficult to spin the shaft with your fingers - it will not spin freely but it should not bind or drag.

20. Install the oil return tube fitting bolts. Tighten to the specified torque.

21. Remove the crankshaft nut, timing chain drive gear and oil pump drive gear from the crankshaft end and measure the side clearance.



Position the dial indicator probe tip on the crankshaft end as shown. Make sure the threads of the crankshaft end do not interfere with the reading.



**Crankshaft side clearance**  
0.000787 - 0.00708 in  
(0.02 - 0.18mm)

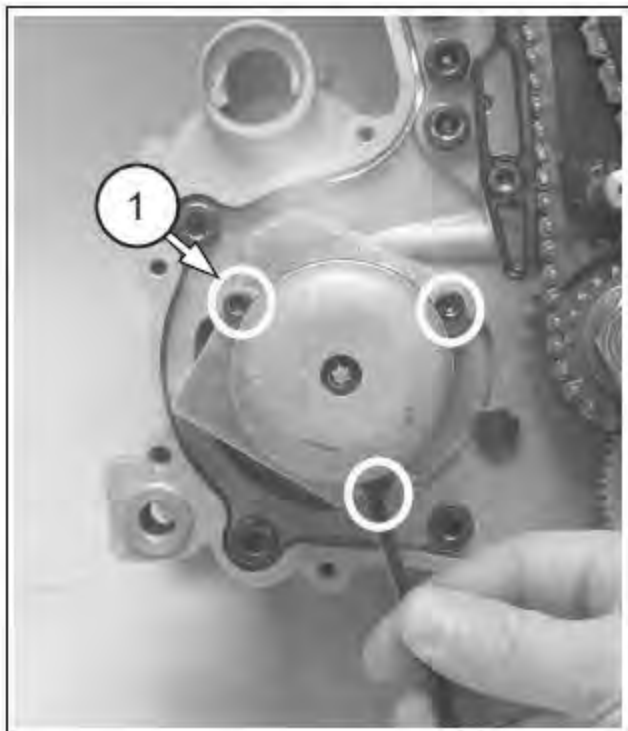
22. If out of specification, check that the crankcase bearings are seated properly and that the races installed on the crankshaft are installed correctly.

## ENGINE OIL PRESSURE PUMP, REMOVE

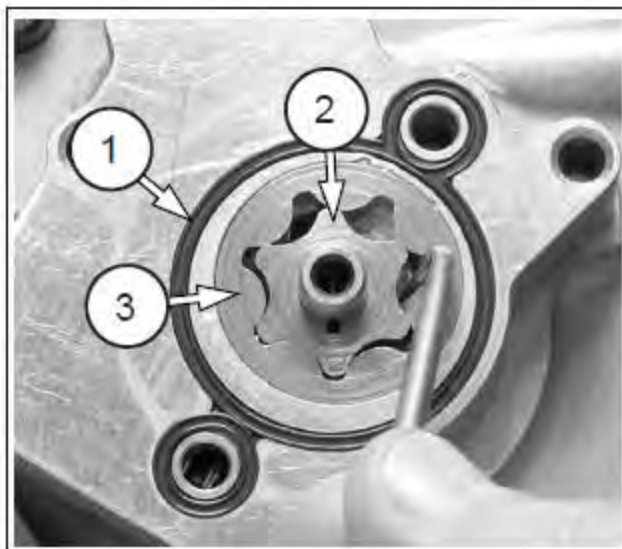
### NOTE :

*Be sure not to lose the pin. Also, notice that one end is rounded and the other is squared. The groove in the gear is shaped similarly. Use a magnetic hand.*

1. Remove the crankcase cover (page 21).
2. Remove the bolts (1), and remove engine oil filter housing.



1. Bolts

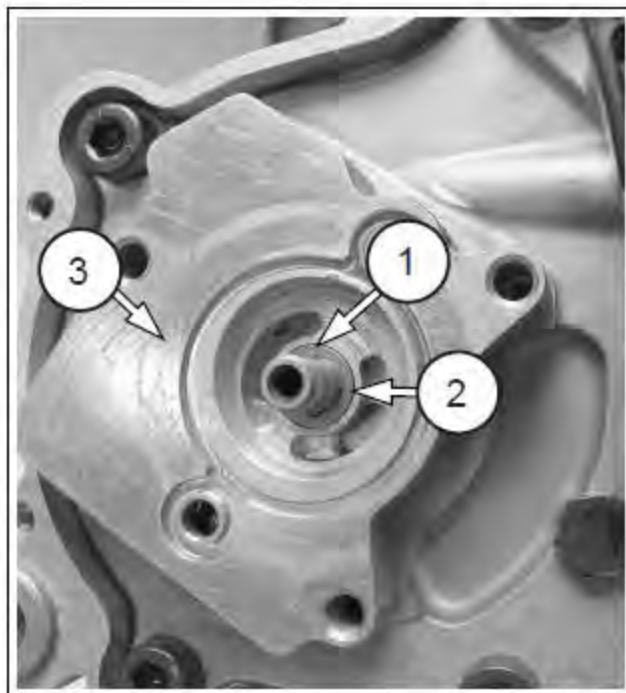


1. Seal
2. Inner rotor
3. Outer rotor

3. Use a small angled tip pick to carefully remove the outer (3) and inner (2) rotors.

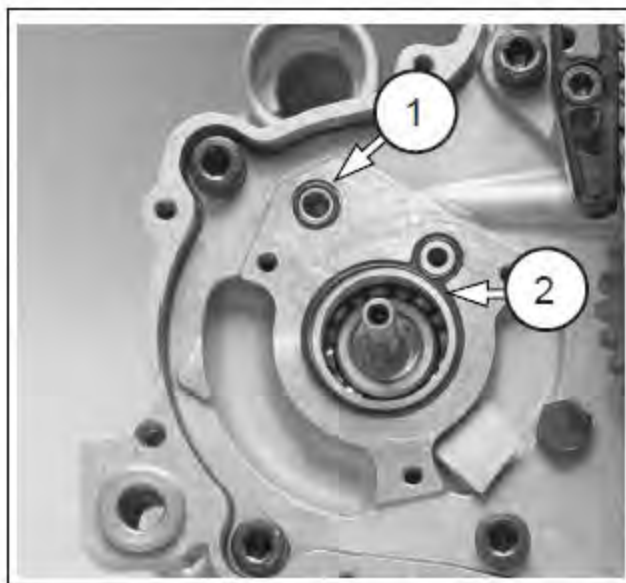


4. Remove the pin (1), washer (2), and pump housing (3).



1. Pin
2. Washer
3. Housing

5. Remove the O-ring (1) and seal (2).

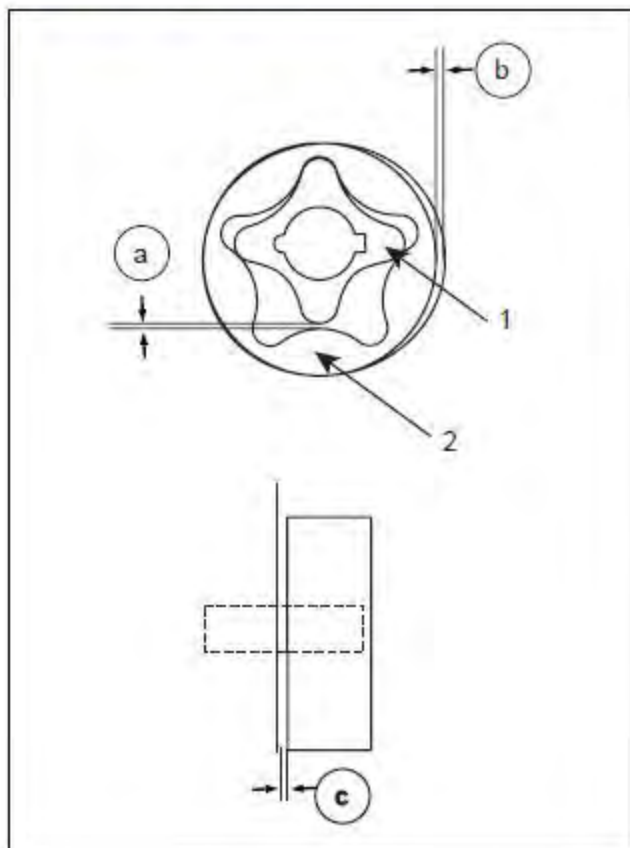


1. O-ring
2. Seal

## ENGINE OIL PRESSURE PUMP, INSPECT

1. Remove the engine oil pressure pump. Refer to "Engine oil pressure pump, remove" starting on page 122.
2. Inspect housing for deep scratches, warping, impaired mating surfaces, or other uncharacteristic wear.
3. Inspect o-rings and seals for cracks, tears, or other uncharacteristic wear.
4. Measure the installed tip clearance (a) between inner rotor (1) and the outer rotor (2).
5. Measure the installed side clearance (b) between the outer rotor (2) and the rotor housing (3).
6. Measure rotor housing depth.
7. Measure rotor thickness.
8. Calculate the end clearance (c).

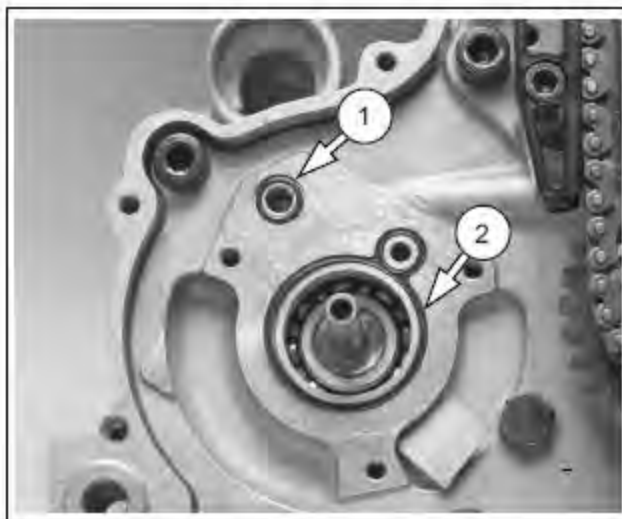
## Calculate end clearance



- 1. Inner rotor
- 2. Outer rotor
- a. Tip clearance
- b. Side clearance
- c. End clearance

## ENGINE OIL PRESSURE PUMP, INSTALL

1. Install the O-ring (1) and seal (2). Make sure the seal is installed properly without twisting.



- 1. O-ring
- 2. Seal



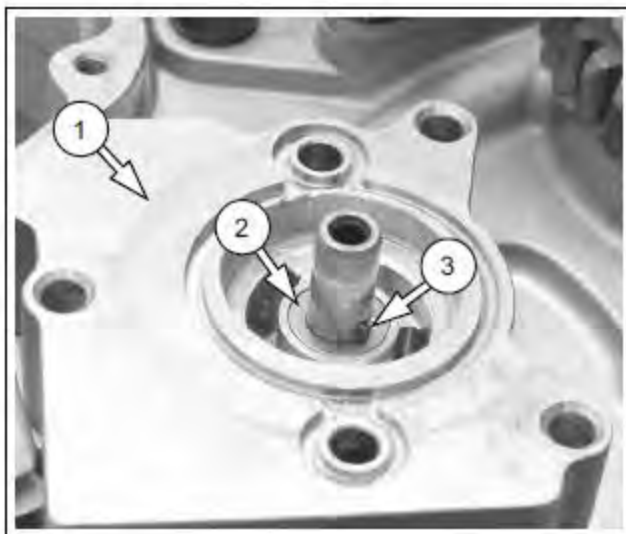
**Outer rotor to housing side  
clearance:**  
.30mm

**Rotor depth**  
0.001968 - 0.00354 in  
(0.05 - 0.09mm)

**Outer rotor thickness**  
0.2263 - 0.2268 in  
(5.750 - 5.763mm)

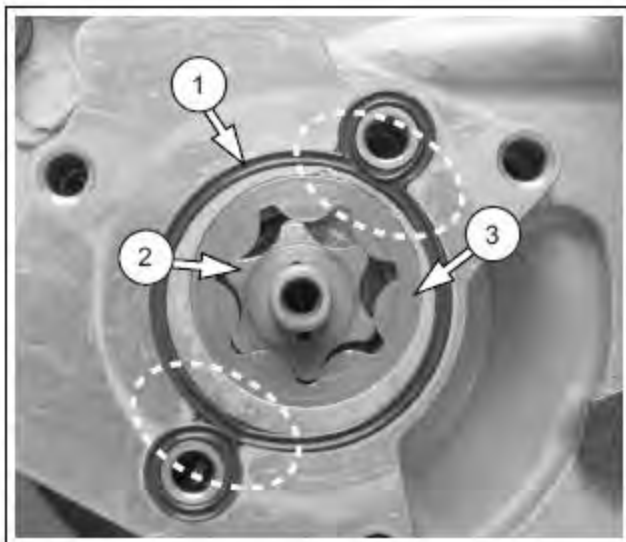
**End clearance:**  
.15mm

2. Install pressure pump housing (1), washer (2), and pin (3).



1. Housing
2. Washer
3. Pin

3. Apply assembly lube to the housing cavity, and install the inner rotor (1), then outer rotor (2). Then, install the seal (3).

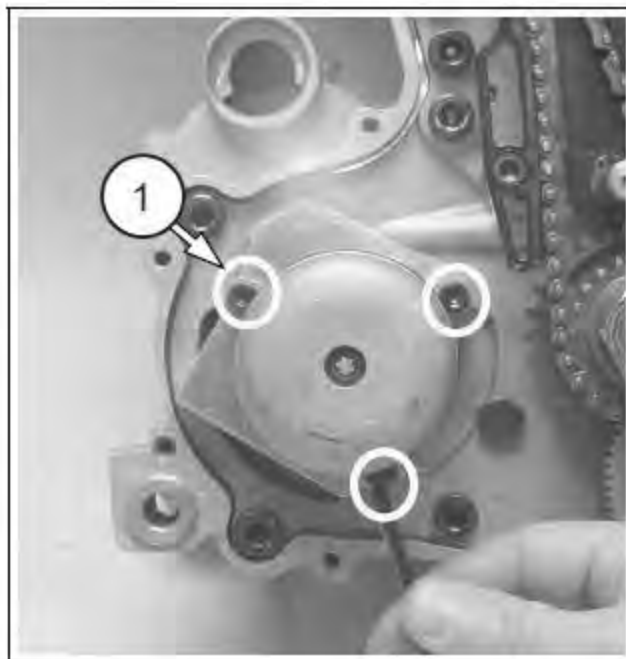


**NOTE :**

*Dotted line indicates that the seal is not symmetrical.*

1. Seal
2. Inner rotor
3. Outer rotor

4. Install engine oil filter housing. Tighten the bolts to the specified torque.



1. Engine oil filter housing bolts



**Engine oil filter housing bolts**  
3.3 lbf·ft (4.5 N·m)



## ENGINE OIL SCAVENGE PUMP, REMOVE

### NOTE :

Engine oil scavenge pump is not fully serviceable without removing the crankshaft cartridge plate assembly. Refer to "Crankshaft cartridge plate, remove" starting on page 102.

## ENGINE OIL SCAVENGE PUMP, INSPECT

1. Remove crankcase cartridge plate (page 102).
2. Inspect pump cover for deep scratches, warping, impaired mating surfaces, and other uncharacteristic wear.
3. Inspect the cover shaft seal. Replace if damaged.
4. Inspect cover seal and plate mating o-ring. Replace if damaged.
5. Perform the following on the smaller (head scavenge) and larger (crankcase sump scavenge rotors):

Measure the installed tip clearance (a) (between inner rotor (1) and the outer rotor (2)).

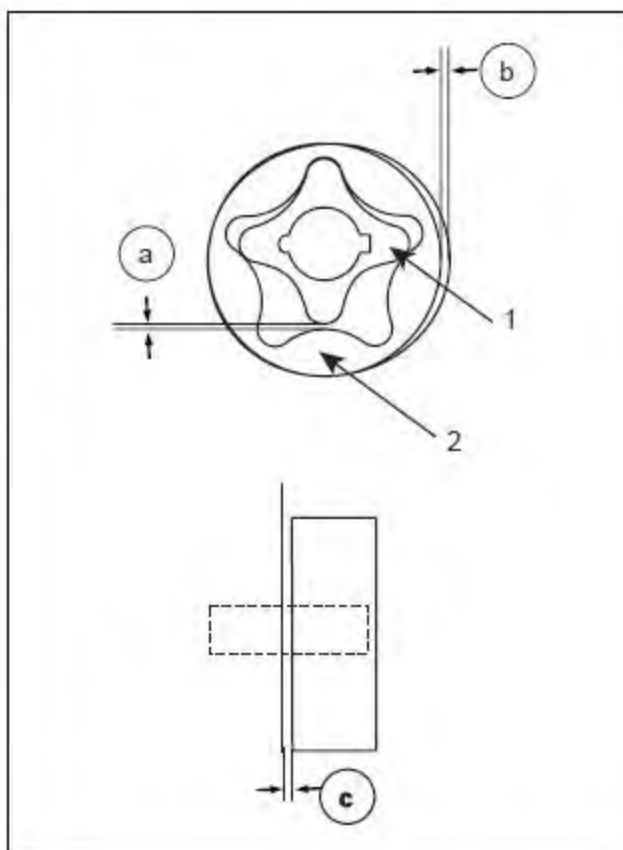
Measure the installed side clearance (b) between the outer rotor (2) and the rotor housing (3).

Measure rotor housing depth.

Measure rotor thickness.

Calculate the end clearance (c).

6. Measure the rotor depth.



1. Inner rotor
2. Outer rotor
- a. Tip clearance
- b. Side clearance
- c. End clearance

	<p><b>Outer rotor to housing side clearance:</b> .30mm</p> <p><b>Rotor depth</b></p> <p><b>Outer rotor thickness</b></p> <p><b>End clearance:</b> .15mm</p>
--	---

## ENGINE OIL SCAVENGE PUMP, INSTALL

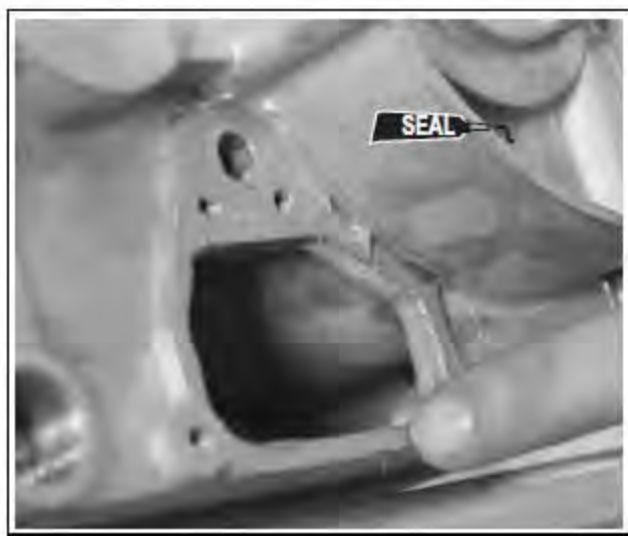
The engine oil scavenge pump is installed with the crankshaft cartridge plate (page 102).

## ENGINE OIL PICKUP ASSEMBLY & COVER, REMOVE

1. Remove engine oil drain bolt, and drain any remaining oil.
2. Remove the engine oil pickup assembly cover bolts.
3. Remove the cover and pickup assembly together.

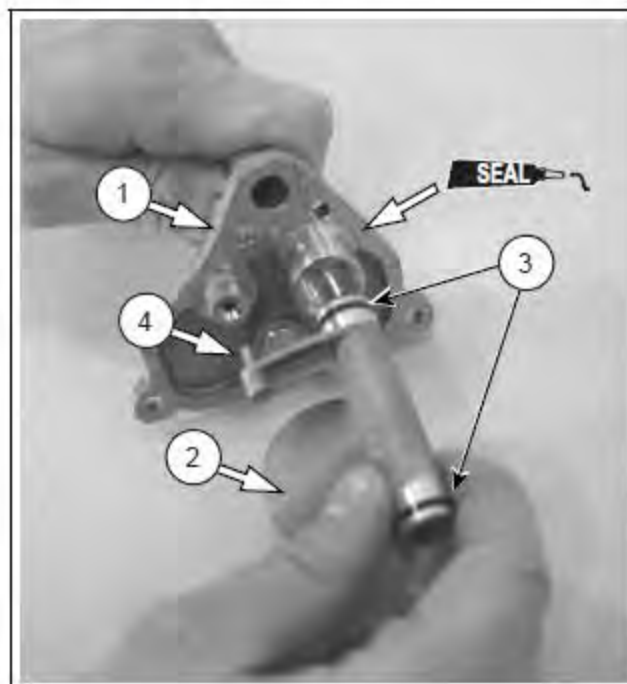
## ENGINE OIL PICKUP ASSEMBLY & COVER, INSTALL

1. Remove old gasket materials, and clean mating surfaces.
2. Apply a thin film of high-quality liquid silicone gasket maker to the engine oil scavenge pickup cavity mating surface.



3. Place a new gasket onto the applied sealer.

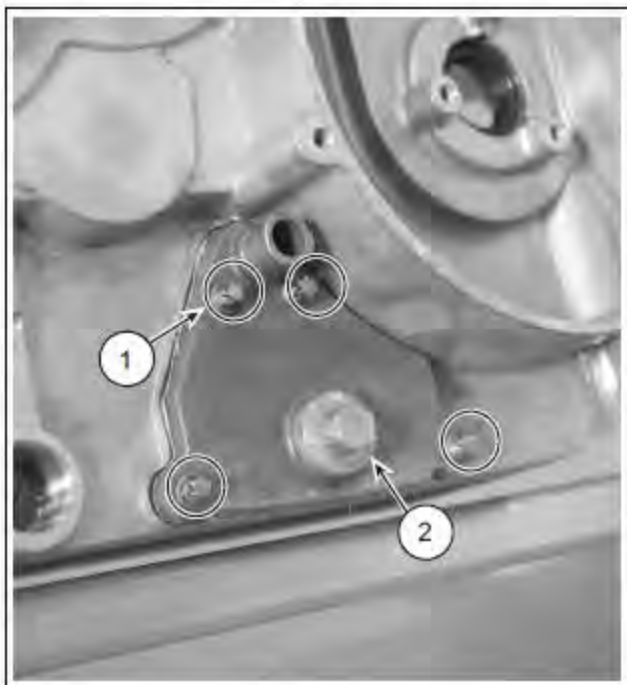
4. Apply some O-ring lubricant to the cover side pickup tube O-ring. Then, align the pickup tube locating pin with the hole in the cover, and install the pickup tube into the cover.



1. Cover
2. Pick-up
3. O-rings
4. Dowel

5. Apply a thin film of high-quality liquid silicone gasket maker to cover's mating. Surface apply some assembly lube to the pickup tube o-ring and insert the o-ring into the rear of the scavenge pump housing. Install the cover and pickup tube together into the case.

6. Install the cover bolts and tighten bolts evenly to the specified torque.



1. Cover bolts
2. Drain bolt



**Engine oil pickup cover bolts**  
3.3 lbf·ft (4.5 N·m)

7. Install the engine oil drain bolt.



**Engine oil drain bolt (crankcase)**  
6.0 lbf·ft (8.1 N·m)

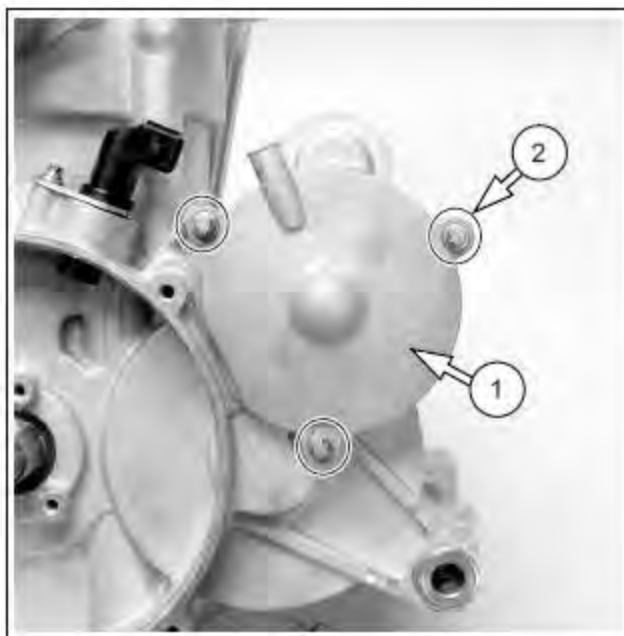
## STARTER CLUTCH, REMOVE

1. Remove the starter (page 175).

### CAUTION

Work the cover off carefully; do not pry it off. Using sharp instruments can damage mating surfaces (e.g. deep scratches, gouging, or scarring).

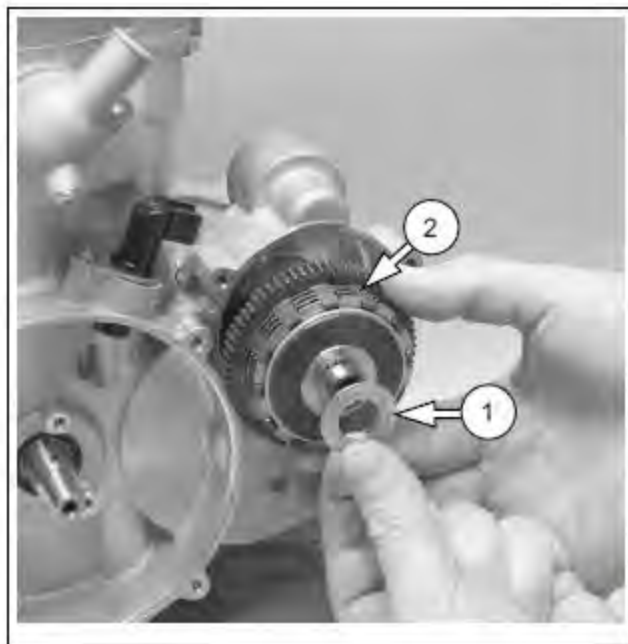
2. Remove the bolts (2), and carefully remove the starter clutch cover (1).



1. Cover
2. Bolts



3. Remove the flat washer (1) and starter clutch assembly (2) from the case housing.



1. Washer
2. Starter clutch assembly

## STARTER CLUTCH, DISASSEMBLE

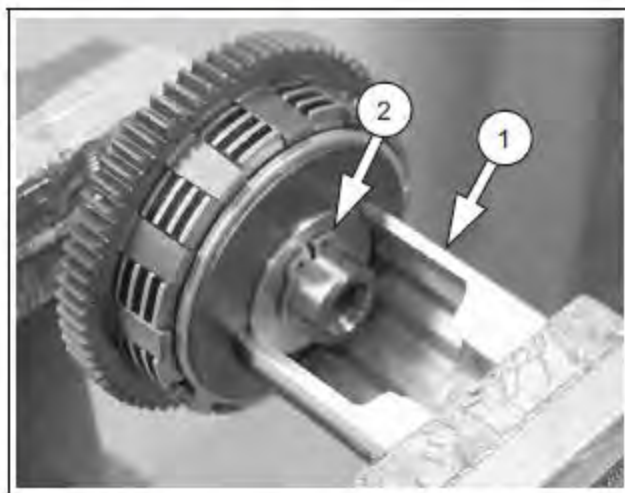
### CAUTION

Only compress the assembly slightly until the circlip can be removed. Over compression of the assembly will result in damage.

1. Remove the starter clutch (page 97).
2. Place the assembly in a soft jaw vice and compress slightly using the special tool (1).

**TOOL :** CM-506553  
Starter clutch compressor adapter

3. Remove the circlip (2).

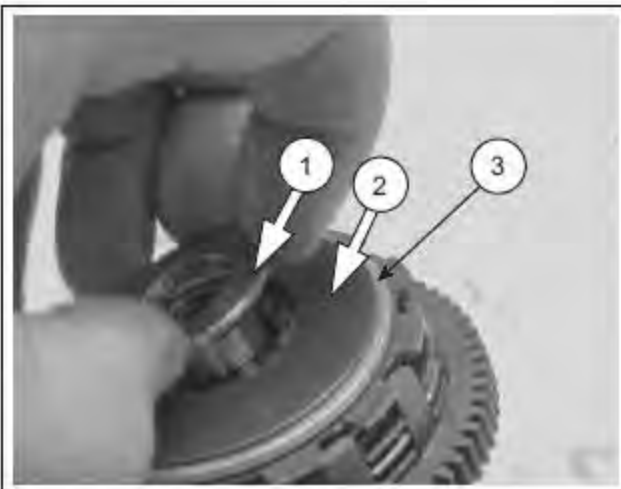


1. Special tool
2. Circlip

4. Remove the assembly and special tool from the vice.
5. Remove the spring washer (1), spring (2), and pressure plate (3).

**NOTE :**

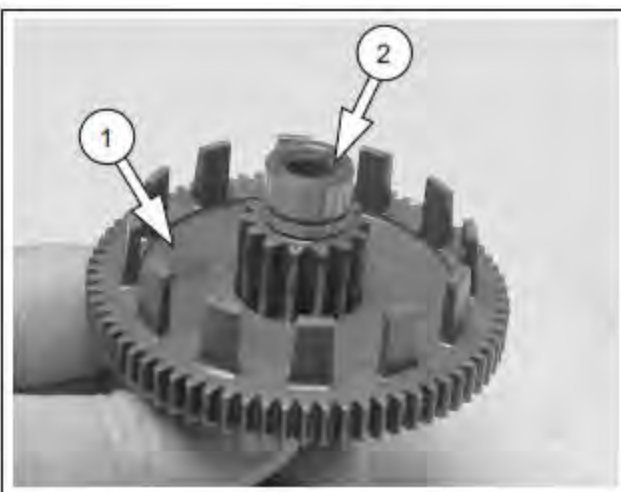
*Notice that the convex side of the spring faces up.*



- 1. Spring washer
- 2. Spring
- 3. Pressure plate

6. First, remove a metallic plate, then a friction plate. Alternate until the last (friction) plate is removed from the housing.

7. Remove the housing (1) from the shaft (2).



- 1. Housing
- 2. Shaft

8. Remove the spring.

**NOTE :**

*The inner spring washer is a press fit on the shaft.*



- 1. Washer
- 2. Shaft

9. Inspect the friction and metallic plates.



**Starter clutch friction plate thickness standard**

- (1)  $0.07873 \pm 0.001968$  in  
(2.00  $\pm$  0.05mm)
- (2)  $0.059 \pm 0.001968$   
(1.50  $\pm$  0.05mm)

**limit**

- (1) 0.0728 in (1.85mm)
- (2) 0.0531 in (1.35mm)

**Starter clutch metallic plate thickness**

- standard -  $0.03937 \pm 0.000984$  in  
(1.000  $\pm$  0.025mm)
- limit - 0.0374 in (0.950mm)

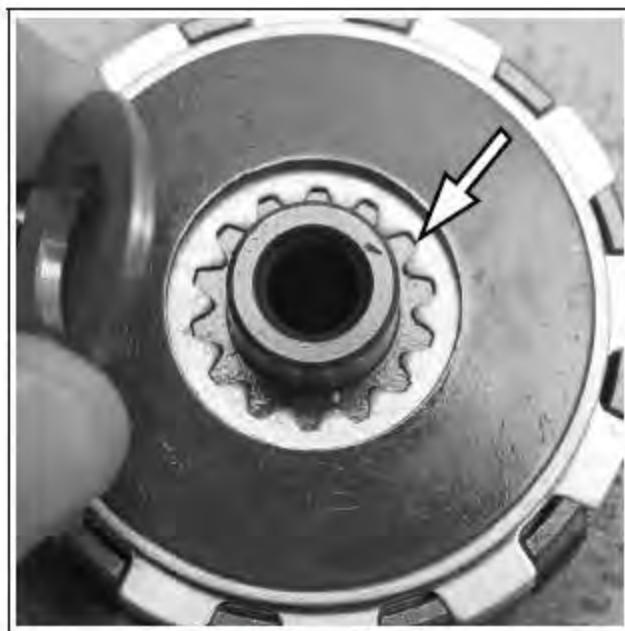
## STARTER CLUTCH, ASSEMBLE

1. Install the spring washer onto the shaft with the ridge facing up.
2. Install the spring convex side facing the shaft gear.
3. Install the clutch housing onto the shaft.
4. Install a friction plate into the housing, then install a metallic plate. Alternate the plates until all are installed in the housing.
5. Install the pressure plate with the friction material facing the last metallic plate installed.
6. Install the spring with the convex side up and spring washer so that the locating "ridge" of the washer is installed inward toward the spring.

### CAUTION

When compressing the assembly, be sure that the splines and teeth on the plates are aligned properly. Compressing the assembly with improper plate to shaft alignment will cause severe damage.

Only compress the assembly enough to install the circlip. Do not "squeeze" the assembly anymore than necessary; severe damage will result.



This photo shows how the teeth and splines align together.

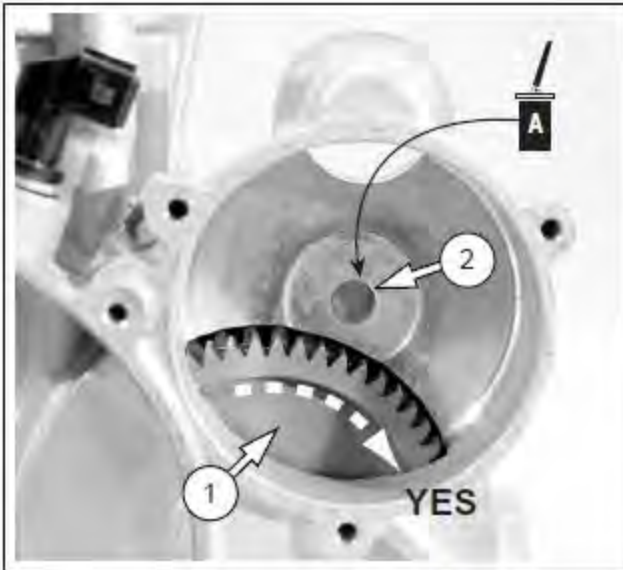
7. Using the special tool, place the assembly in a soft jaw vice. Compress the assembly slightly, and install the circlip.

**TOOL : CM-506553**



## STARTER CLUTCH, INSTALL

1. Test the balance shaft gear (1) for one-way rotation. It should move in the direction indicated in the photo but not the opposite direction. Apply assembly lube to the case shaft end (2).

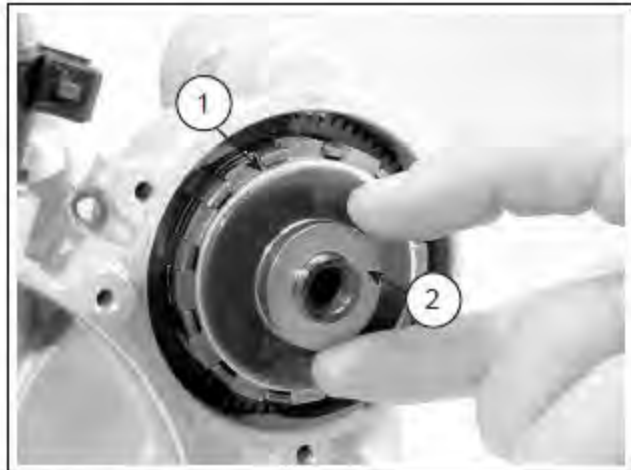


1. Balance shaft gear
2. Apply assembly lube

2. Insert the clutch assembly into the housing.

### NOTE :

*The assembly lube can create a "cushion or pillowing" effect when installed on both the assembly and cover. Move the assembly in and out slightly to aid in the release of any air trapped in the hole.*



1. Clutch Assembly
2. Flat washer

3. Install the clutch assembly and flat washer.
4. Apply assembly lube to the hole on the inside of the cover, and install the cover. Be sure to inspect the O-ring and replace if damaged. When installing the cover, use O-ring lubricant on the O-ring. Then, install the cover bolts and tighten evenly to the specified torque.



1. O-ring
2. Cover



**Starter clutch cover bolts  
3.3 lbf·ft (4.5 N·m)**

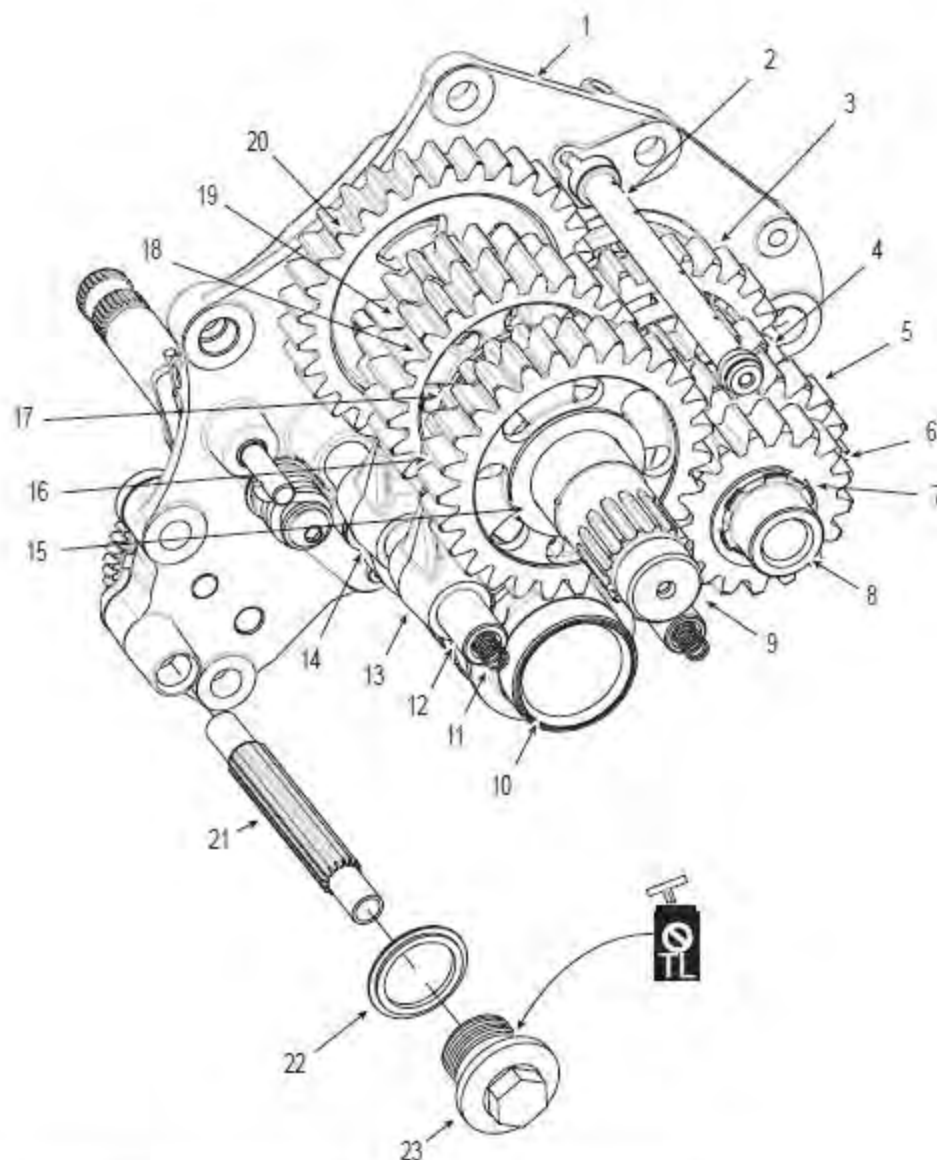


# Transmission cartridge plate

Unit: mm (in)

ITEM			STANDARD	SERVICE LIMIT
Shift forks ("L" and "R")	I.D.		12.02 - 12.06 (0.4732 - 0.4748)	12.10 (0.4764)
	Claw thickness (left)		4.70 - 4.90 (0.185 - 0.193)	4.20 (0.165)
	(right)		5.10 - 5.30 (0.20 - 0.209)	4.60 (0.22)
	Shaft O.D.		11.97 - 12.00 (0.471 - 0.472)	11.90 (0.469)
Shift fork ("O")	I.D.		11.02 - 11.06 (0.4338 - 0.4354)	11.10 (0.437)
	Claw thickness		4.70 - 4.90 (0.185 - 0.193)	4.20 (0.165)
	Shaft O.D.		10.97 - 11.00 (0.432 - 0.433)	10.90 (0.429)
Transmission	Mainshaft O.D.		24.95 - 24.97 (0.9822 - 0.983)	24.91 (0.9807)
	Countershaft O.D.	at C2	24.987 - 25.000 (0.9837 - 0.9842)	24.958 (0.9826)
		at C3	24.950 - 24.970 (0.9822 - 0.9830)	24.910 (0.98)
		at C1	19.962 - 19.975 (0.7859 - 0.7864)	19.920 (0.7842)
	Gear I.D.	M4	28.00 - 28.05 (1.102 - 1.104)	28.09 (1.105)
		M5	25.00 - 25.05 (0.9842 - 0.9862)	25.09 (0.9878)
		C1	22.92 - 22.97 (0.90235 - 0.9043)	23.01 (0.9059)
		C2	29.03 - 29.08 (1.14291 - 1.1448)	29.12 (1.1464)
		C3	25.00 - 25.05 (0.9842 - 0.9862)	25.09 (0.9878)
	Gear bushing O.D.	M4	27.95 - 27.97 (1.100 - 1.1011)	27.91 (1.0988)
		C1	22.85 - 22.87 (0.8996 - 0.9003)	22.81 (0.898)
		C2	28.88 - 28.90 (1.1370 - 1.1378)	28.83 (1.135)
	Gear-to-bushing clearance	C1	0.05 - 0.12 (0.001968 - 0.004724)	0.20 (0.007873)
		M4	0.03 - 0.10 (0.00118 - 0.003936)	0.18 (0.007086)
	Gear bushing I.D.	C1	20.025 - 20.075 (0.7883 - 0.7903)	20.125 (0.7923)
		C2	25.50 - 25.75 (1.00393 - 1.0137)	-
	Gear-to-shaft clearance		0.03 - 0.10 (0.00118 - 0.003936)	0.18 (0.007086)





**ASSEMBLY VIEW : Transmission cartridge plate (rear view, assembled)**

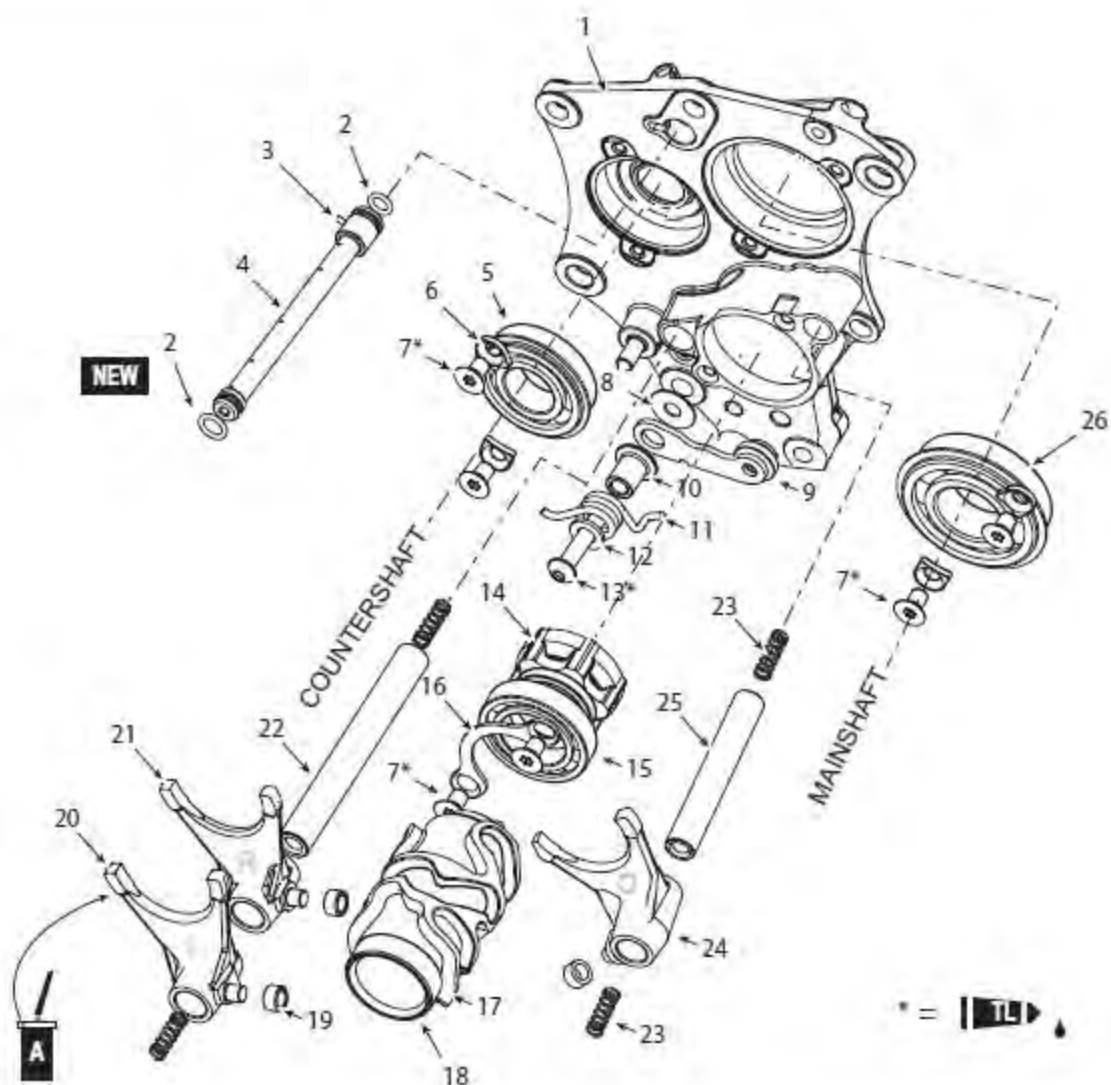
- 1. Plate
- 2. Spray bar
- 3. 5th gear
- 4. 3rd gear
- 5. 4th gear
- 6. 2nd gear
- 7. Ring clip
- 8. Mainshaft
- 9. Countershaft
- 10. Shift drum sleeve
- 11. Fork shaft spring

- 12. Fork shaft
- 13. Shift Fork "L"
- 14. Shift Fork "R"
- 15. Washer
- 16. 2nd gear (27T)
- 17. 4th gear (23T)
- 18. 3rd gear (25T)
- 19. 5th gear (20T)
- 20. 1st gear (30T)
- 21. Filter
- 22. Sealing washer

- 23. Drain bolt

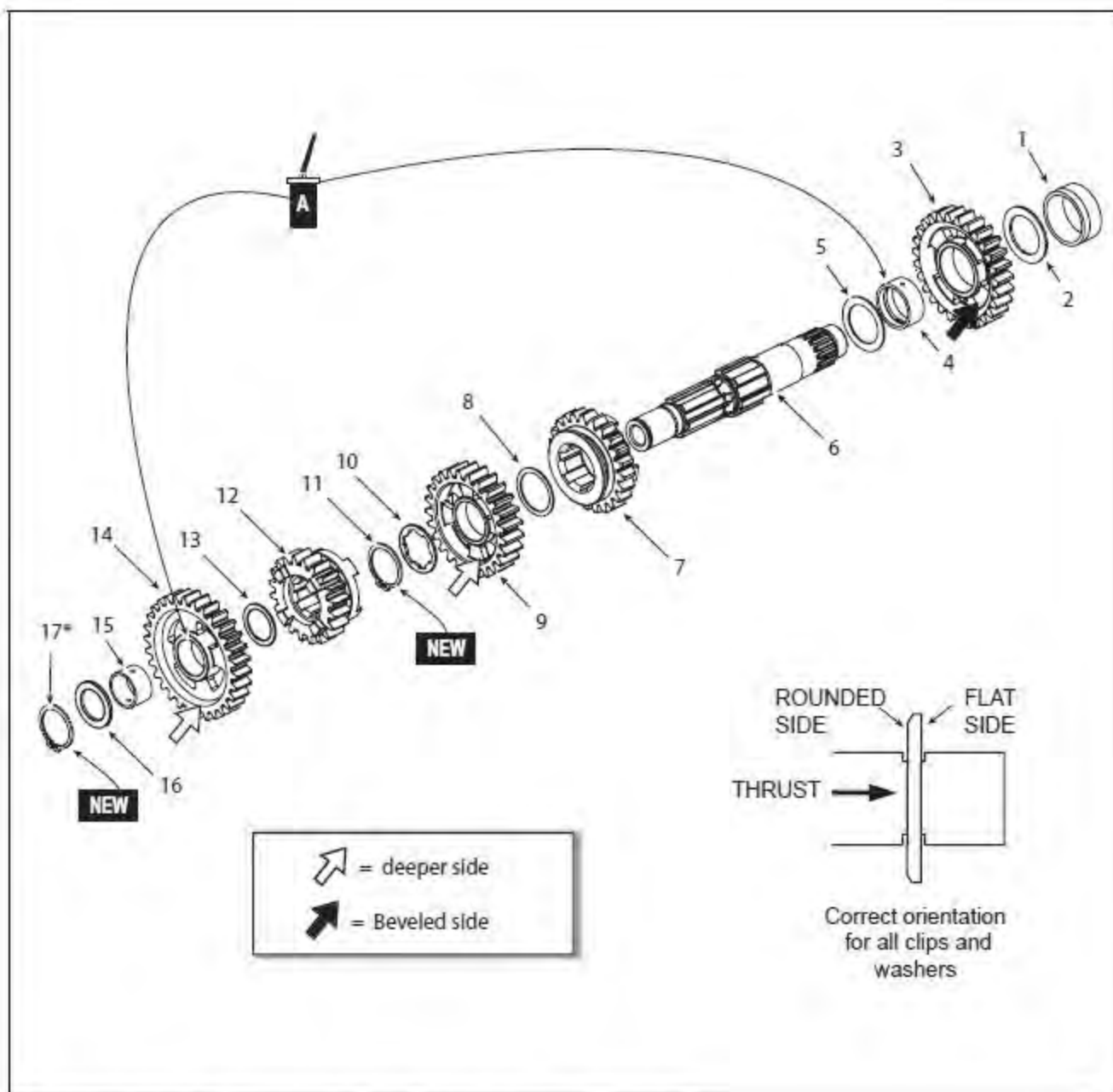
**NOTE :**

*A bearing race is installed on the countershaft before installation into the case. That race is not illustrated in the assembly above.*



ASSEMBLY VIEW : Transmission cartridge plate rear view, exploded)

- |                                       |                                 |                                     |
|---------------------------------------|---------------------------------|-------------------------------------|
| 1. Plate                              | 12. Washer                      | 23. Fork shaft springs (4)          |
| 2. O-ring (2)                         | 13. Bolt                        | 24. Shift fork "O"                  |
| 3. Pin                                | 14. Capstain                    | 25. Fork shaft (mainshaft)          |
| 4. Spray bar                          | 15. Ratchet drum bearing (8905) | 26. Mainshaft plate bearing (205KG) |
| 5. Countershaft plate bearing (8004Z) | 16. Shift drum bearing retainer |                                     |
| 6. Retainer                           | 17. Shift drum                  |                                     |
| 7. Screw                              | 18. Sleeve                      |                                     |
| 8. Washer                             | 19. Roller bushing (3)          |                                     |
| 9. Ratchet roller arm                 | 20. Shift fork "L"              |                                     |
| 10. Sleeve                            | 21. Shift fork "R"              |                                     |
| 11. Spring                            | 22. Fork shaft (countershaft)   |                                     |

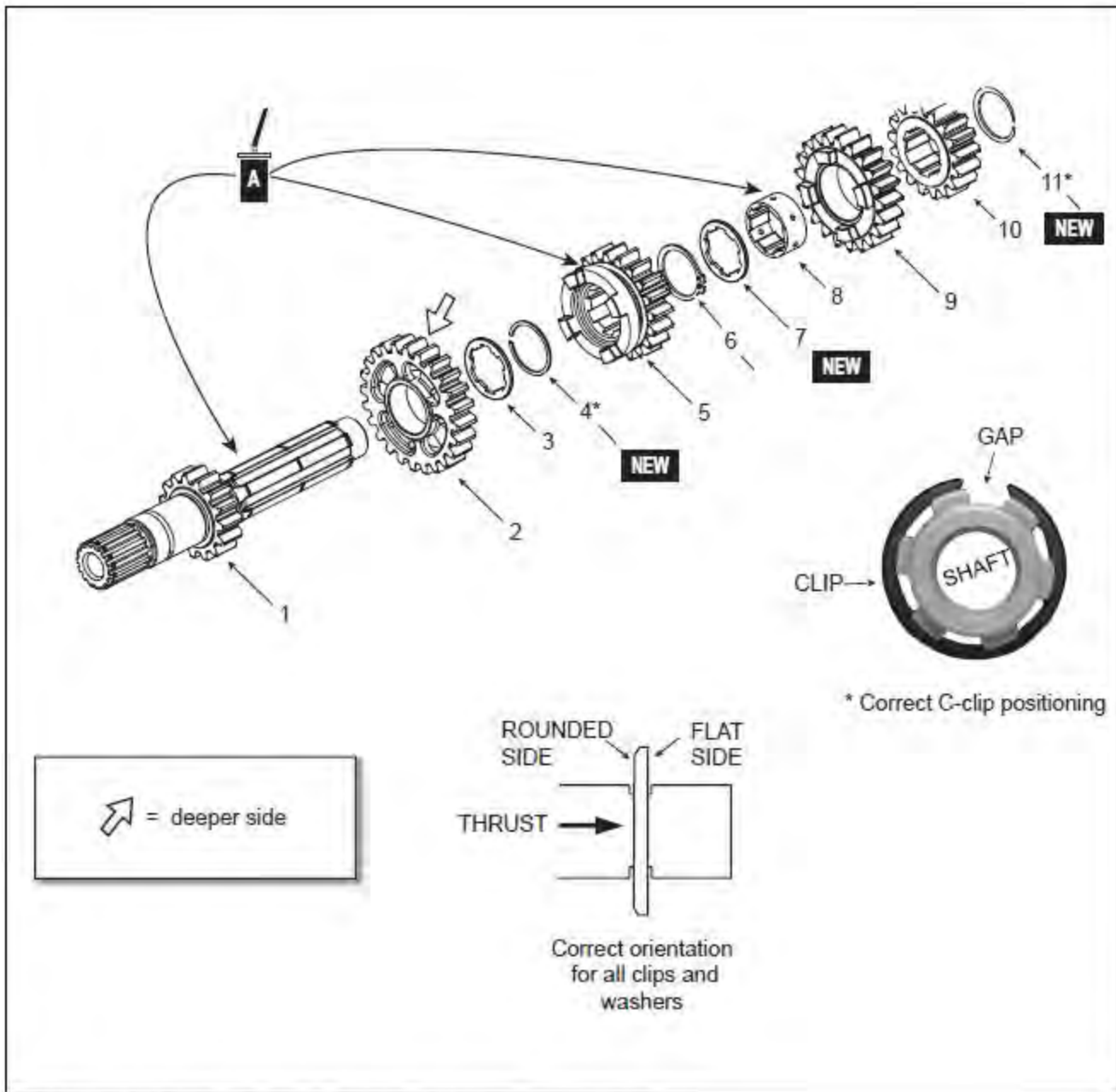


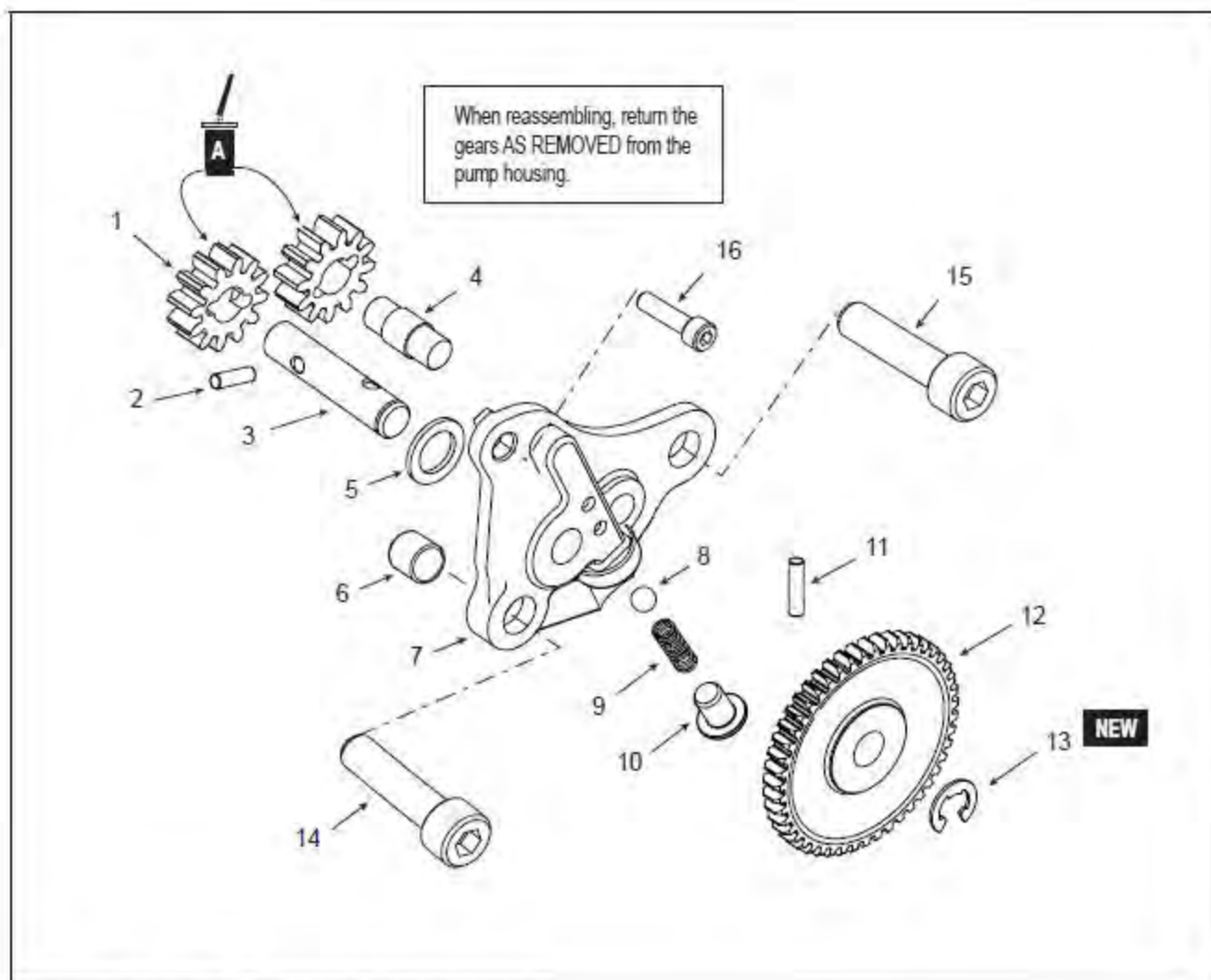
1. Bearing race
2. Washer
3. 2nd gear (27T)
4. Bushing
5. Washer
6. Countershaft
7. 4th gear (23T)

8. Washer
9. 3rd gear (25T)
10. Splined washer
11. Circlip
12. 5th gear (20T)
13. Washer
14. 1st gear (30T)

15. Bushing
16. Washer
17. Circlip (\* install after shaft is positioned in cartridge plate)

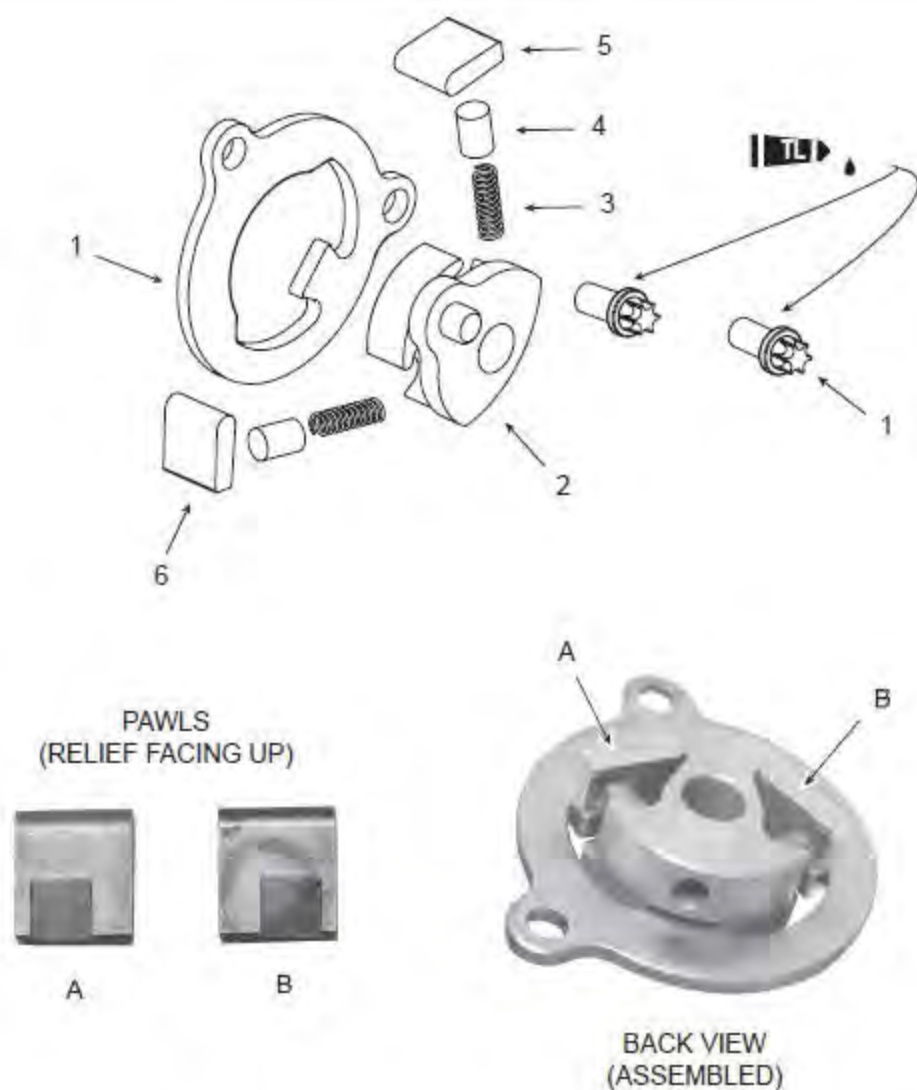






**ASSEMBLY VIEW : Transmission oil pump**

- |                     |                            |                             |
|---------------------|----------------------------|-----------------------------|
| 1. Pump gears       | 8. Check ball              | 15. Plate bolt (M8 x 30mm)  |
| 2. Driven shaft pin | 9. Spring                  | 16. Cover bolt (M5 x 16 mm) |
| 3. Driven shaft     | 10. Cap screw              |                             |
| 4. Idler shaft      | 11. Driven shaft pin       |                             |
| 5. Washer           | 12. Drive gear             |                             |
| 6. Hollow dowel     | 13. E-clip                 |                             |
| 7. Pump Cover       | 14. Plate bolt (M8 x 35mm) |                             |



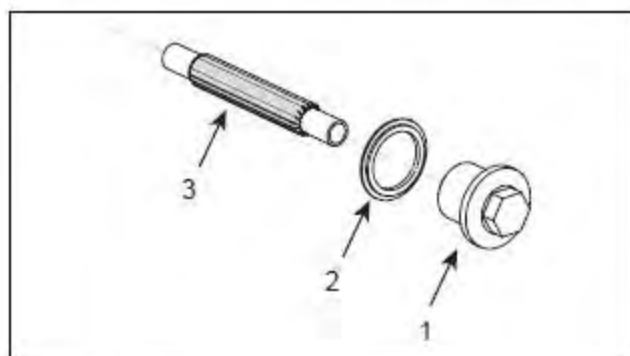
#### ASSEMBLY VIEW : Shift ratchet

- |               |                     |
|---------------|---------------------|
| 1. Plate      | 5. Ratchet Pawl "A" |
| 2. Ratchet    | 6. Ratchet Pawl "B" |
| 3. Spring(2)  |                     |
| 4. Spring cap |                     |



## TRANSMISSION CARTRIDGE PLATE, REMOVE

1. Remove the clutch assembly (page 163).
2. Remove the countershaft sprocket nut, splined washer, sprocket, and sprocket spacer from the countershaft.
3. Remove the transmission oil filter bolt (1), sealing washer (2), and filter (3) from the crankcase.



1. Filter bolt
2. Sealing washer
3. Filter (screen)

### NOTE :

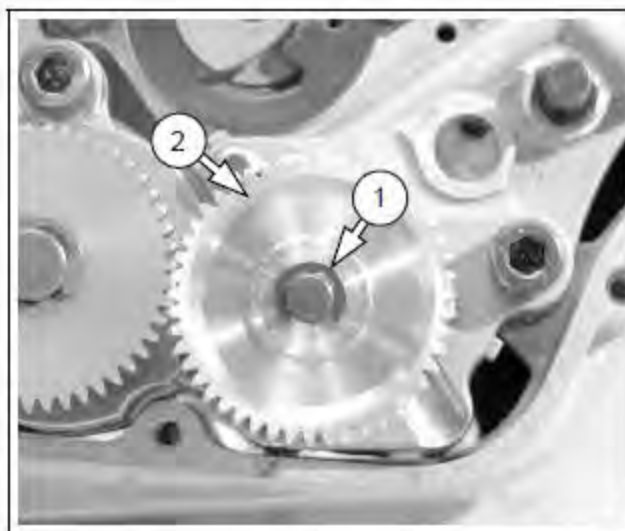
*Be sure to remove and keep the transmission oil pump drive shaft dowel pin in a safe place. Discard the circlip. Replace it with a new one.*

4. Remove the shift shaft (1) and top hat (2).



1. Shift shaft
2. Top hat

5. Remove the transmission oil pump circlip (1) and drive gear (2). Then, remove the shaft pin.



1. Drive gear
2. Circlip

6. Loosen each of the transmission cartridge plate bolt 1/4 turn first, and in a criss-cross pattern to avoid plate distortion. Then completely remove the bolts.



7. Support the mainshaft with your left hand, and use a rubber mallet with your right to carefully tap the countershaft end from the sprocket side of the crankcase until the plate can be removed from case cavity.

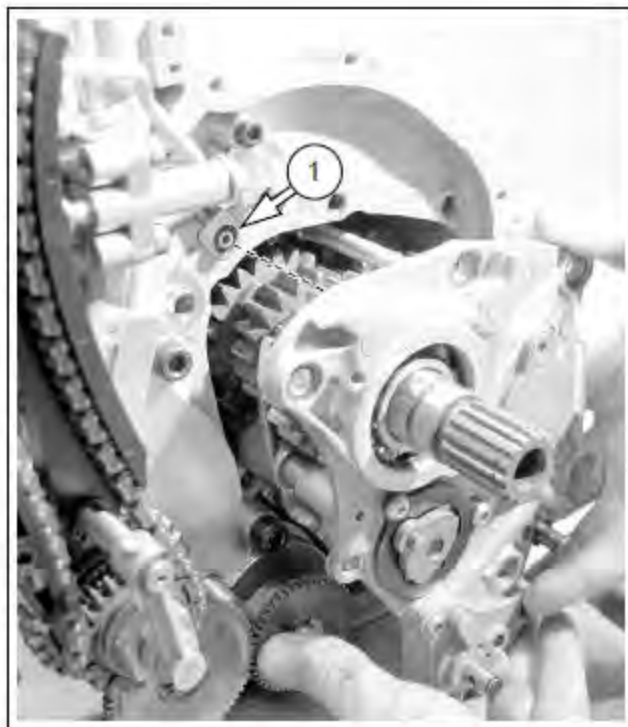
Remove the transmission cartridge plate (page 141).



#### NOTE :

The spray tube, fork tubes and or fork tube end springs may "stick" to the interior of the crankcase walls. Make sure all components are removed from the cavity.

The transmission oil tube adapter O-ring (1) can adhere to the transmission cartridge plate surface.



1. O-ring

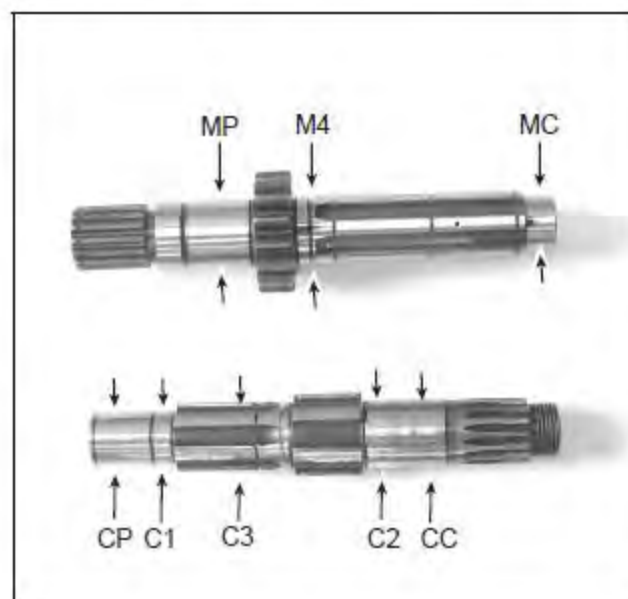
## TRANSMISSION CARTRIDGE PLATE, INSPECT

Consult the table at the beginning of this section for service specifications of the following items.

1. Disassemble the main shaft and countershaft.
2. Check the mainshaft and countershaft for scarring, abnormal wear or signs of insufficient lubrication.

Measure the mainshaft O.D. at MC, M4, and MP.

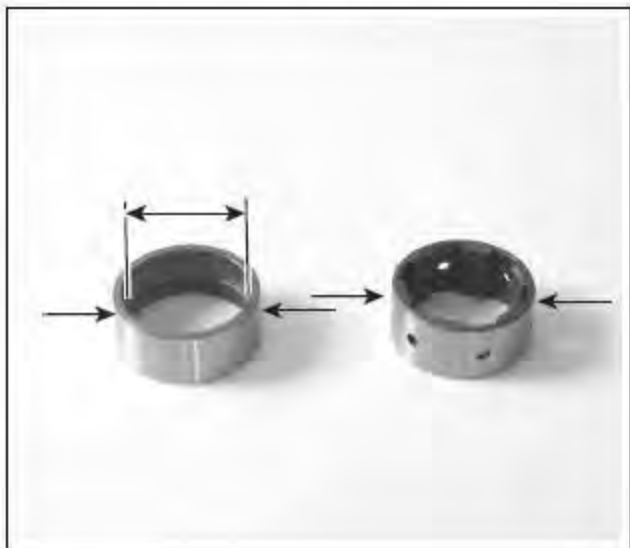
Measure the countershaft O.D. at BC, C2,C3,C1, and CP.



3. Measure the gear bushing O.D. of M4,M5, C1, and C2.
4. Measure the runout of the shafts.



5. Calculate the bushing-to-shaft clearance.



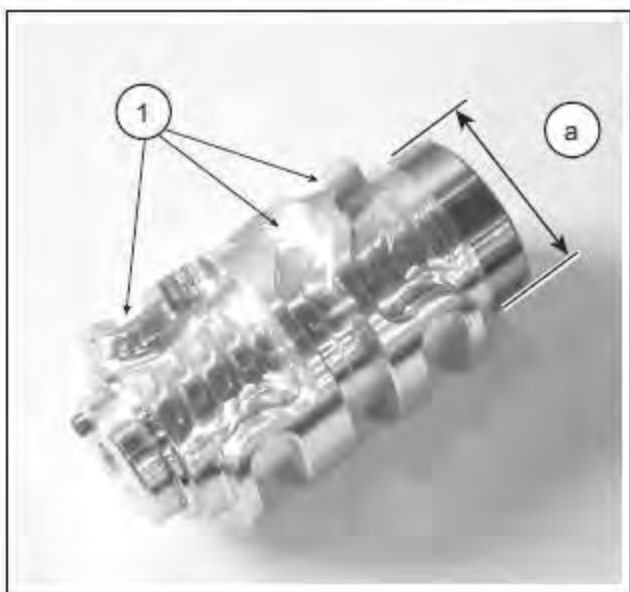
8. Measure the shaft(s) O.D.



- 1. Mainshaft fork shaft
- 2. Countershaft fork shaft

6. Check the shift drum grooves for excessive wear, deep scratches, or abnormal wear.

Check the shift drum bearing sleeve O.D.



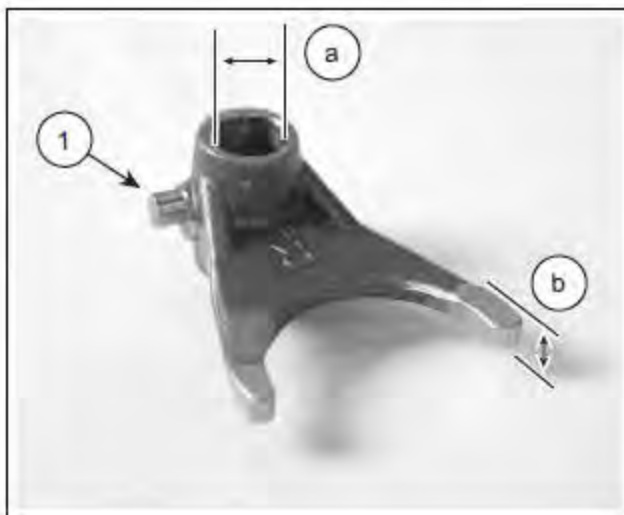
- 1. Shift drum grooves
- a. Sleeve O.D.

7. Check the shift fork shafts for bending or damage.

9. Measure the shift fork claw thickness).

Inspect the guide pins for unusual wear or damage.

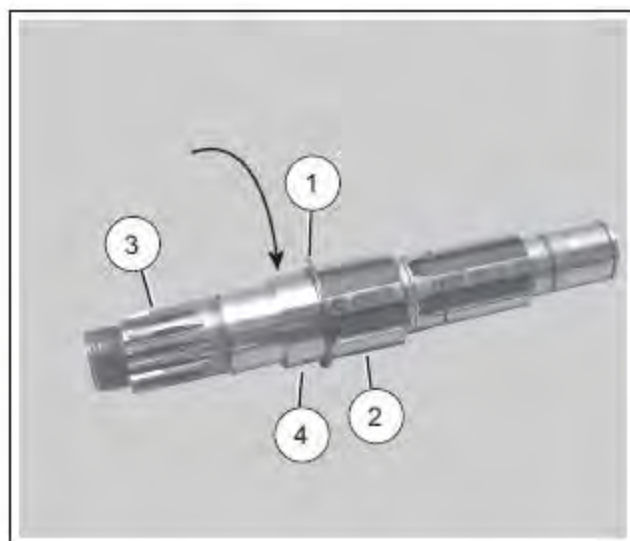
Measure the shaft I.D. of each fork.



- 1. Guide pin
- a. Shaft I.D.
- b. Claw thickness

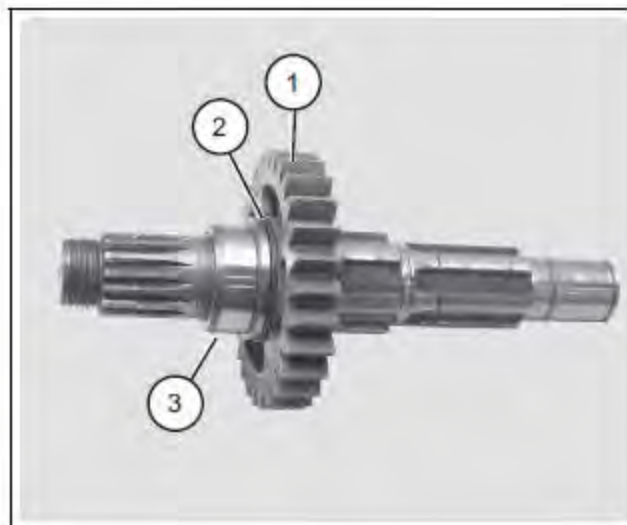
## COUNTERSHAFT, ASSEMBLE

1. Install the washer (1) onto the countershaft (3) with the flat side facing away from the countershaft drive sprocket splines (3). Then, apply assembly lube to the shaft, and install the bushing (4) onto the countershaft.



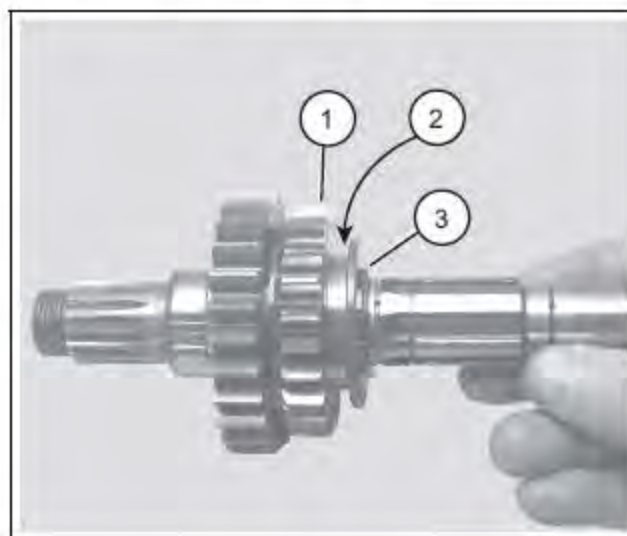
1. Washer
2. Mainshaft
3. Sprocket splines
4. Bushing

2. Install 2nd gear (1) with the deeper or beveled side of the gear facing away from the drive sprocket splines. Then, install the washer (2) with the flat side facing the gear. Use a suitable driver to install the bearing race (3) onto the shaft.



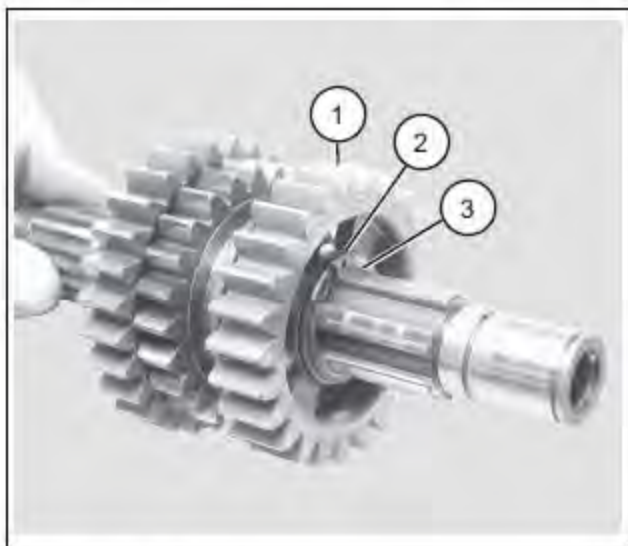
1. 2nd gear (27T)
2. Washer
3. Bearing race

3. Install 4th gear (1) onto the shaft with the fork groove (2) facing away from the sprocket splines. Then, install the washer (3).



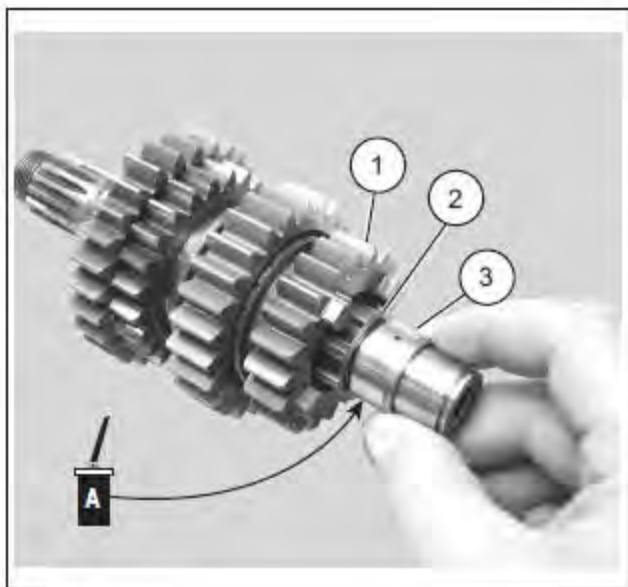
1. 4th gear (23T)
2. Fork groove
3. Washer

4. Install 3rd gear (1) with the deeper side facing away from the sprocket splines. Then, install the splined washer (2) and circlip (3).



1. 3rd gear (25T)
2. Splined washer
3. Circlip

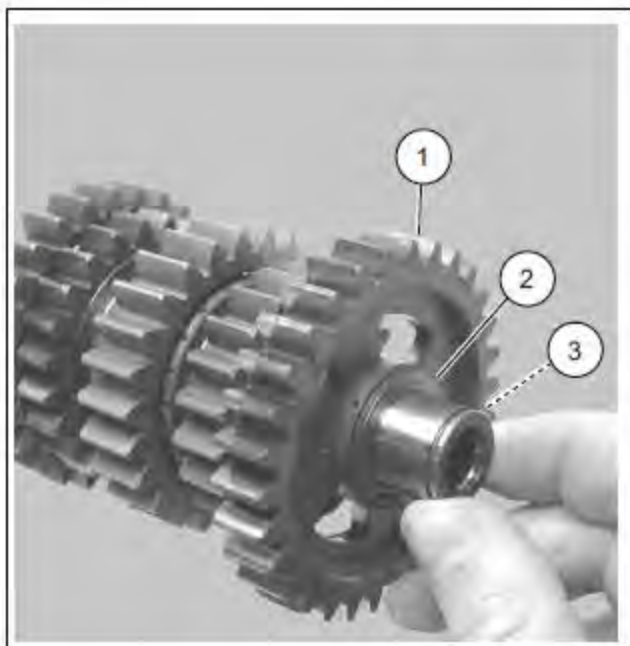
5. Install 5th gear (1), washer (2), and the bushing (3).



1. 5th gear (20T)
2. Washer (thinner)
3. Bushing.

6. Install 1st gear onto the bushing with the deeper side of the gear facing the circlip groove. Then install the thicker washer onto the shaft.

Temporarily install the circlip onto the end of the shaft.



1. 1st gear (30T)
2. Washer (thicker)
3. Circlip (temporarily)

#### NOTE :

*After the shaft is installed into the transmission cartridge plate, a washer and circlip are installed on the shaft end. Refer to "Transmission cartridge plate, assemble" starting on page 149.*

*Install the washer and circlip now, temporarily, to prevent the assembly from "disassembling" accidentally.*

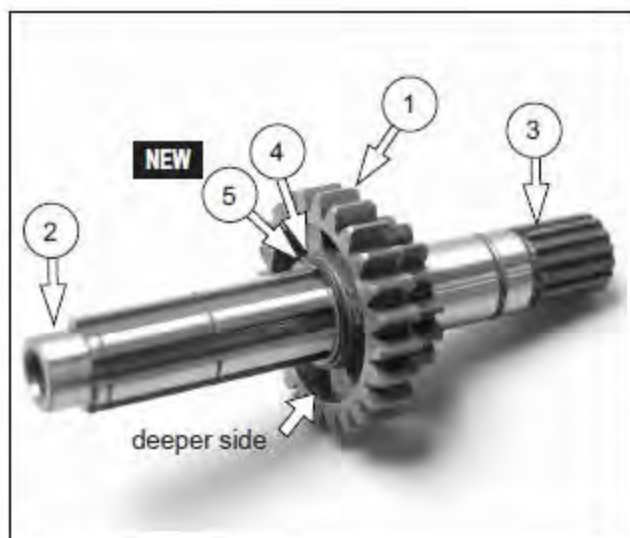
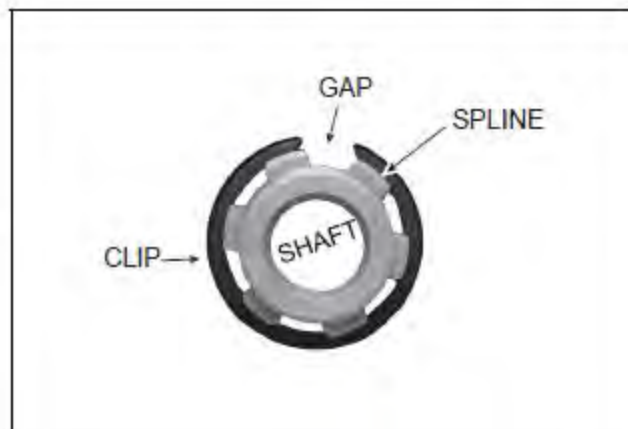


## MAINSHAFT, ASSEMBLE

1. Install 5th gear (1) onto the mainshaft (2) with the deeper end facing away from the clutch hub splines (3).

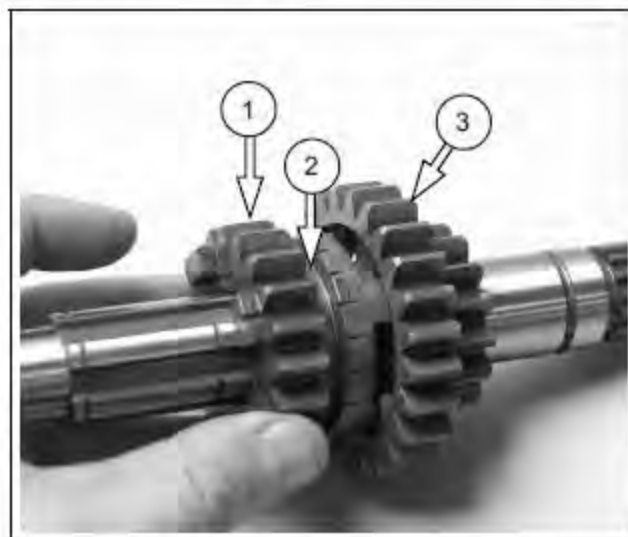
Then, install the splined washer (4) onto the mainshaft with the flatter side of the washer facing away from 5th gear.

Then, install a new ring clip (5) onto the mainshaft - flat side facing 5th gear. Make sure the gap of the ring clip is positioned between shaft splines.



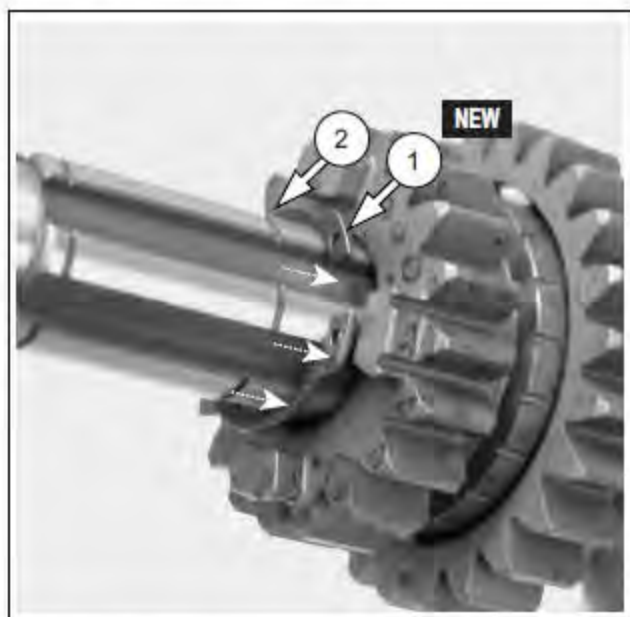
1. 5th gear
2. Mainshaft
3. Clutch hub splines
4. Splined washer
5. Ring clip

2. Install 3rd gear (1) with the fork groove (2) facing toward 5th gear (3).



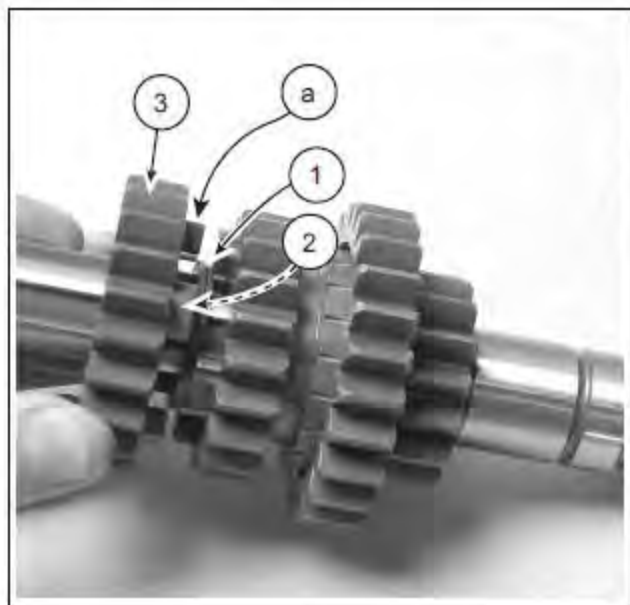
1. 3rd gear
2. Fork groove
3. 5th gear

3. Install the circlip (1) onto the mainshaft - flat side facing 3rd gear, and position it back behind its groove (2) in the shaft.



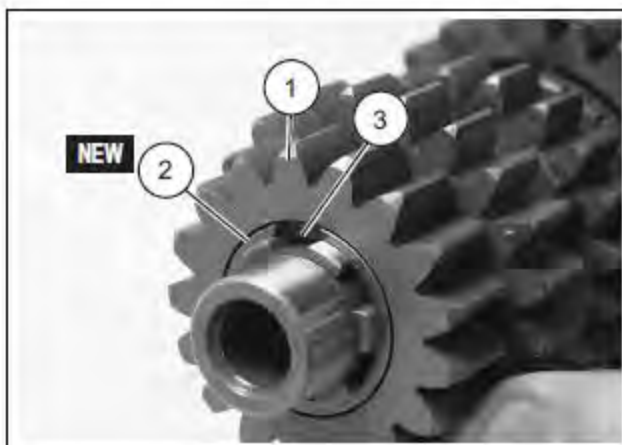
1. Mainshaft
2. Groove

4. Install the splined washer (1), splined bushing (2), and 4th gear (3) with the dogs (a) facing 3rd gear.



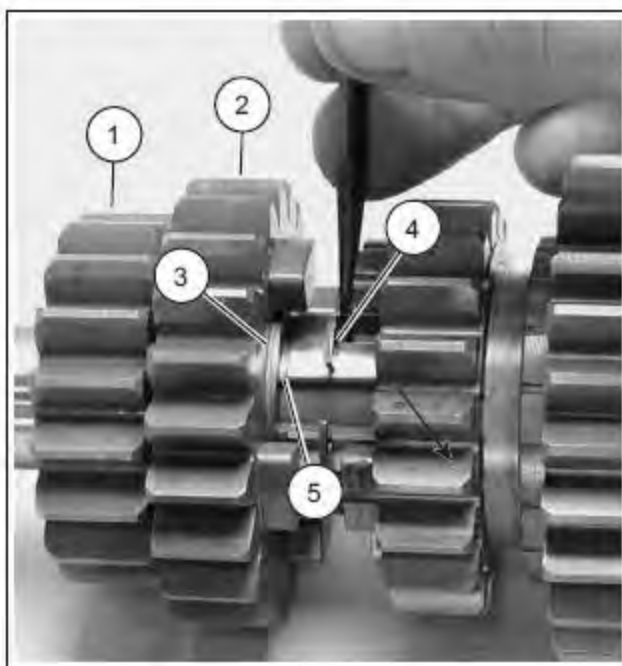
1. Splined washer
2. Splined bushing
3. 4th gear
- a. Dogs

5. Install 2nd gear (1) with the ring clip relief facing away from 4th gear.  
Then, install the ring clip (2) and position the gap (3) between shaft splines.



1. 2nd gear
2. Ring clip
3. Gap

6. Slide 2nd and 4th gear to the end of the shaft and then the splined washer. Carefully move the circlip into its groove using a thin blade screw driver.



1. 2nd gear
2. 4th gear
3. Splined washer
4. Circlip
5. Groove

## TRANSMISSION CARTRIDGE PLATE, ASSEMBLE

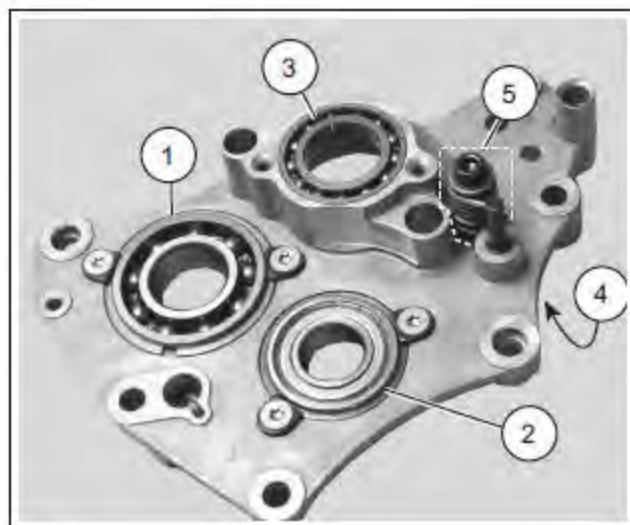
### **⚠ WARNING**

Use insulated gloves when handling heated components. Failure to use insulated gloves will result in serious burns.

1. Heat the bare transmission cartridge plate for 15-20 minutes at 100C / 212F.
2. Install the plate bearings and bearing retainers using an appropriate bearing installer. Use Loctite #242 on the bearing retainer screws and be sure to position the bearing ring gaps so they are not directly under the retainer clips.

Install the detent lever assembly. Use Loctite #242 on the lever bolt threads. See exploded view for assembly order.

Then, apply Loctite #242 to the threads and install the shift pin stop into the front of the plate.



1. Mainshaft bearing
2. Countershaft bearing
3. Shift drum bearing
4. Shift pin stop (install from plate front)
5. Detent lever assembly



Transmission, cartridge plate,  
bearing retainer screws  
3.3 lbf·ft (4.5 N·m)

Transmission, cartridge plate,  
detent lever bolt  
7.4 lbf·ft (10.0 N·m)

Transmission, cartridge plate, shift  
pin stop  
16.2 lbf·ft (22.0 N·m)

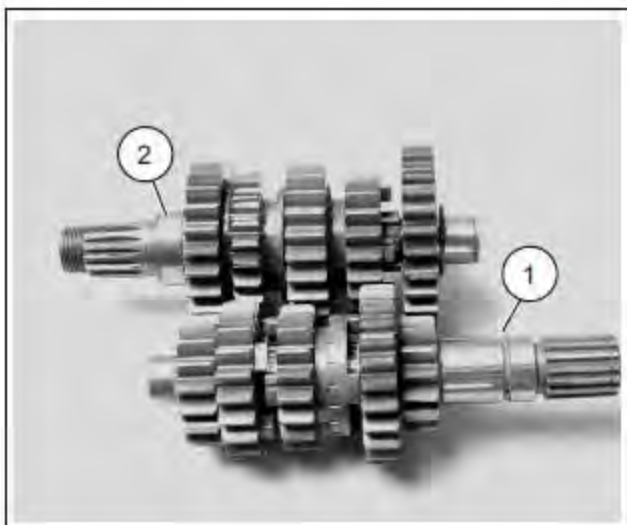
3. Insert the shift drum into the bearing, and install the retaining clip and screws. Use Loctite #242 on the threads.



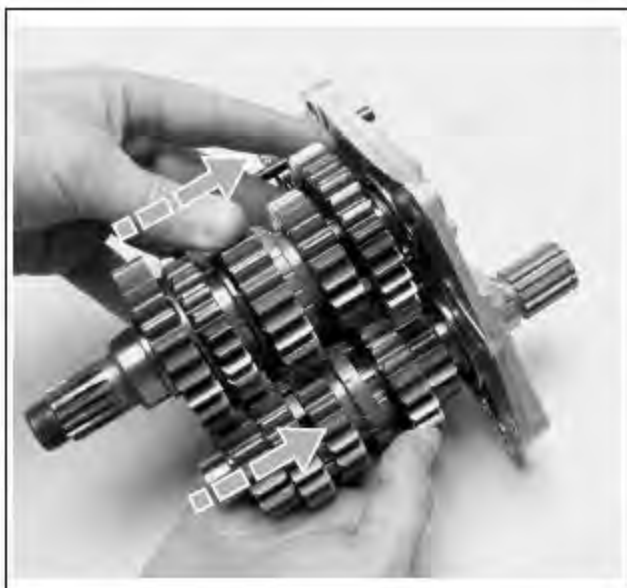
1. Shift drum
2. Retaining clip



4. Position the mainshaft (1) and countershaft (2) together as shown, and install into the plate together.



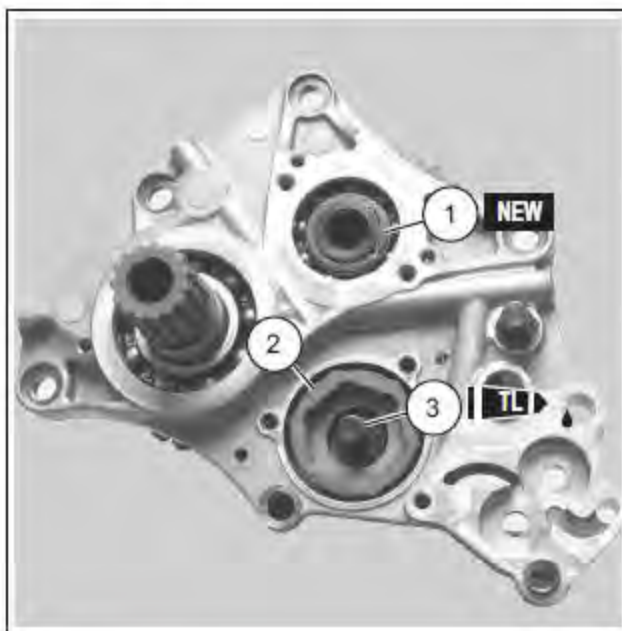
1. Mainshaft  
2. Countershaft



5. Install the countershaft washer (1) and new circlip (2) onto the countershaft at the front of the plate.

Install the capstain (3) into the front of the plate making sure the capstain groove locates on the shift drum pin.

Then apply Loctite #242 to the threads and install the shift pin (4). Tighten to the specified torque.



1. Circlip  
2. Capstain  
3. Shift pin



**Transmission, cartridge plate, shift pin**  
**16.2 lbf·ft (22.0 N·m)**

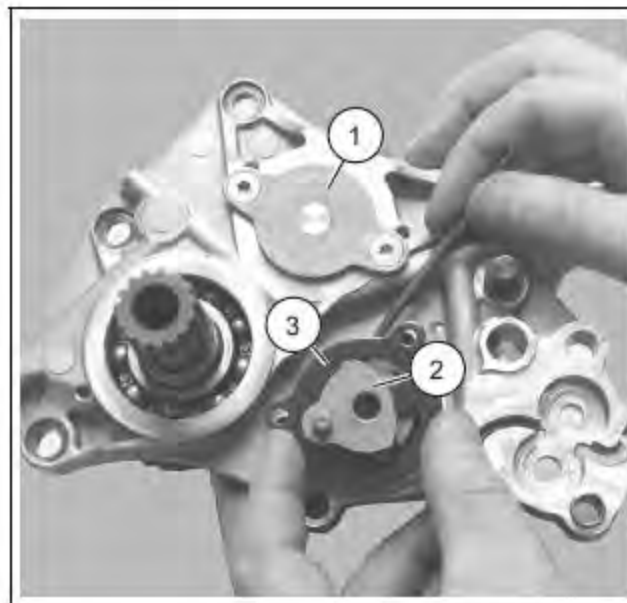
6. Install the O-ring onto the countershaft end cap, and apply some O-ring lubricant to it. Then, install the cap into the plate.



7. Install the ratchet assembly into the capstain. Then, apply Loctite #242 to the threads, and install the ratchet plate bolts and tighten to the specified torque.

**NOTE :**

*Use a small thin blade screw driver or blunted pick to compress the pawls while inserting the assembly into the capstain.*



- 1. Countershaft cover
- 2. Shift drum ratchet assembly.
- 3. Ratchet plate



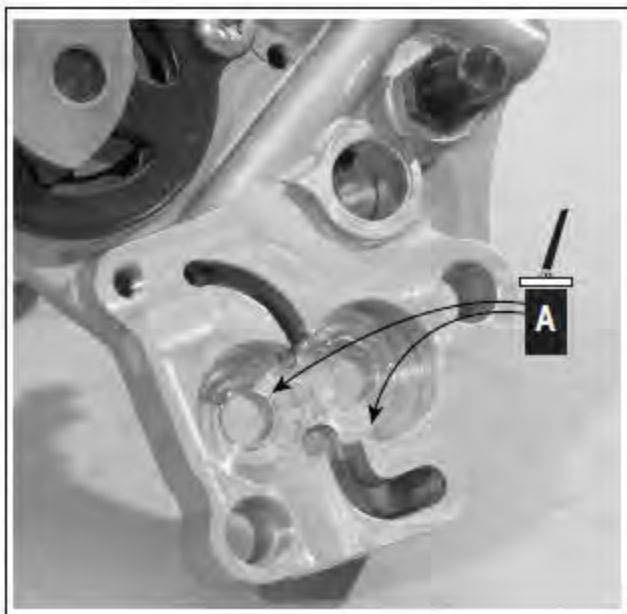
**Transmission, cartridge plate,  
countershaft cap cover screws**  
3.3 lbf·ft (4.5 N·m)

**Transmission, shift drum ratchet  
plate bolts**  
3.3 lbf·ft (4.5 N·m)

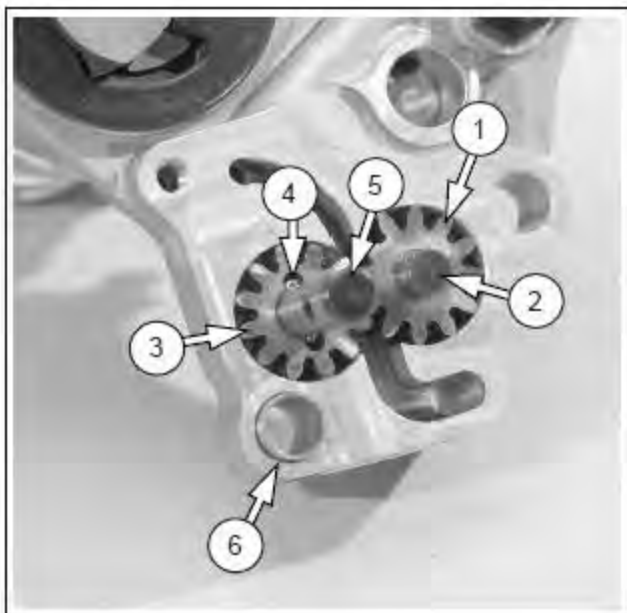
**CAUTION**

**Be sure to return the transmission pump gears to original position and plate orientation.**

8. Apply assembly lube to the interior of the oil pump housing.



9. Install the right gear (1) and shaft (2), left gear (3) pin (4) and shaft (5), and hollow dowel (6) into the plate.

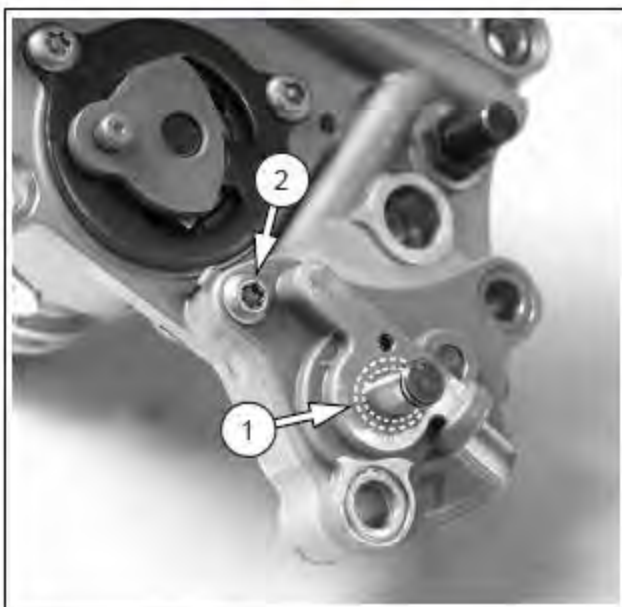


1. Right gear
2. Idler shaft (shorter)
3. Left gear (pin groove faces up)
4. Shaft pin
5. Driven shaft (longer)
6. Hollow dowel

10. Install the washer (1) into the pump cover, and install the cover onto the plate. Finger tighten the cover screw (2). Tighten it to the specified torque after the plate bolts are torqued.



**Transmission, oil pump, cover screw**  
**3.3 lbf·ft (4.5 N·m)**

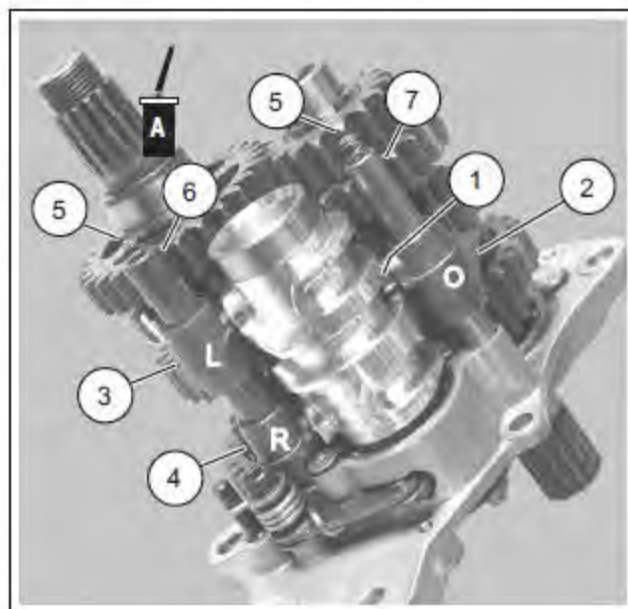


1. Cover washer (located on inner cover surface)
2. Cover screw



11. Apply some assembly lube to the roller bushings, and install them onto the shift fork pins. Then, insert the forks into fork grooves of the gears.

Apply some assembly lube to the ends of the fork shafts, and insert a spring in each end. Then, install through the forks into the plate.

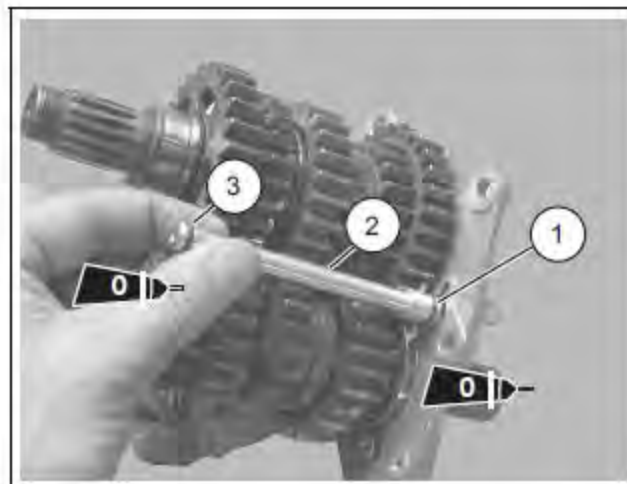


1. Roller bushing (all forks)
2. Fork "O"
3. Fork "L"
4. Fork "R"
5. Shaft spring (each end both shafts)
6. Countershaft fork shaft
7. Mainshaft fork shaft

12. Apply some o-ring lube onto the spray bar O-ring, and insert into the plate.

#### NOTE :

*Be sure to use the correct size O-ring. The wrong O-ring will prevent the bar from seating properly impeding or lessening the flow of oil through the bar.*



1. O-ring
2. Spray bar
3. O-ring

## TRANSMISSION CARTRIDGE PLATE, INSTALL

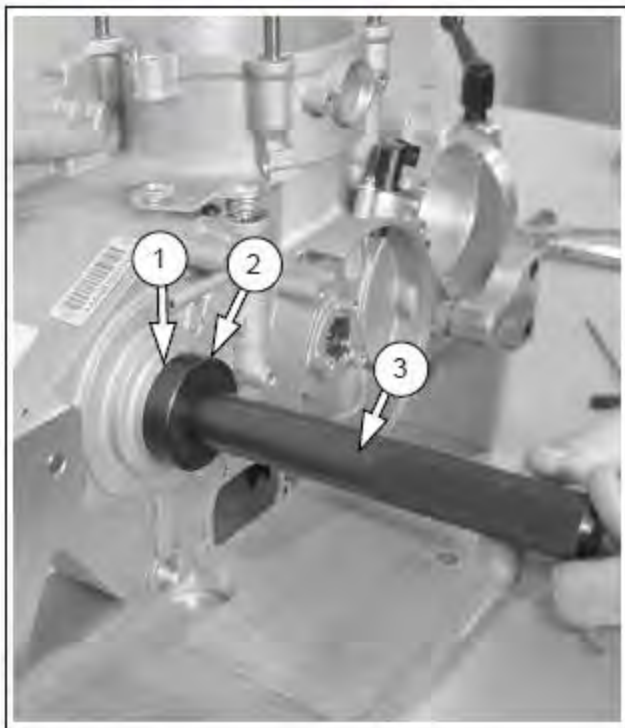
### CAUTION

Do not install transmission oil filter until after transmission cartridge plate has been installed.

1. Install the countershaft oil seal with the seal markings facing out.

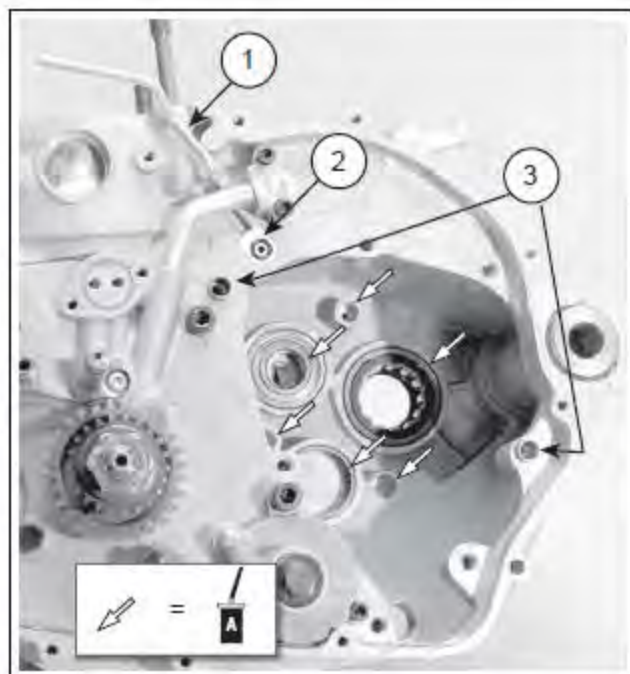
TOOL : CM-502462  
Driver handle

TOOL : CM502463,  
30mm oil seal installer



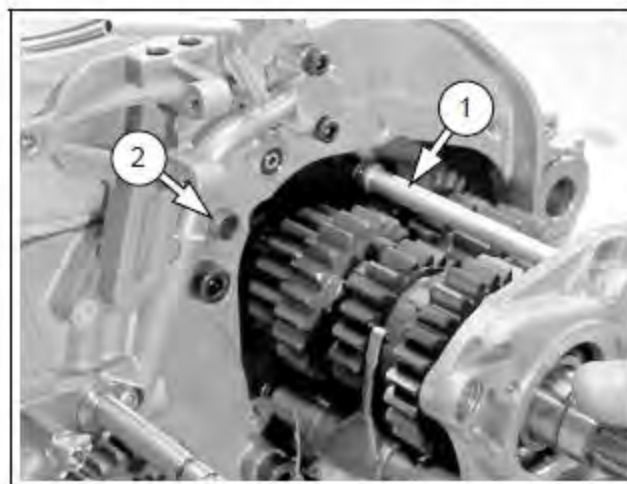
1. Seal
2. Attachment
3. Driver

3. Install the timing chain oil tube (1) and adapter block (2) with the O-ring facing out onto the crankcase. Be sure to inspect the condition of the adapter block O-rings. Replace if damaged. Apply assembly lube to the points shown in the photo, and make sure the hollow dowels (3) are in place.



1. Transmission oil tube (to timing chain)
2. Adapter
3. Dowels

4. Carefully align the plate so that the spray bar (1) will locate in the hole in the crankcase wall and align upper left transmission cartridge plate bolt hole with dowels (2).



1. Spray bar
2. Upper dowel

5. Install transmission cartridge plate into crankcase. (page 154).

6. Use a rubber mallet to carefully tap the plate into place - plate bolt holes are seated on case mating surface. See photo.





## CAUTION

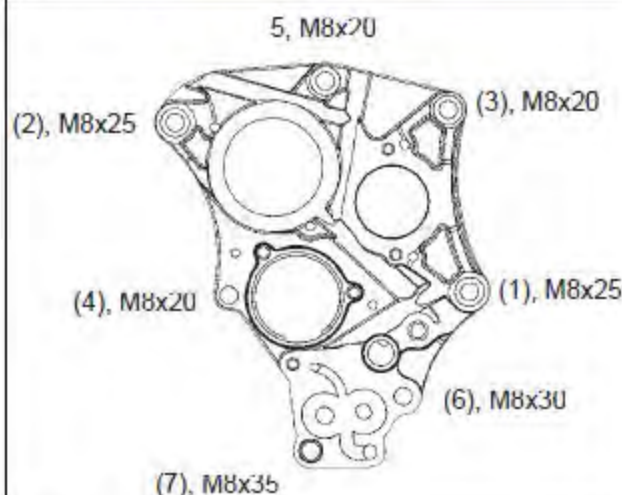
Do not use the plate bolts to draw the plate into the case. Damage to the plate can occur.

7. Clean the bolts with contact cleaner to remove any old thread locking compound.

Apply Loctite #242 to the threads and install each bolt until the head makes contact with cartridge plate. Tighten bolts to the specified torque in 2 stages and according to the pattern indicated..



**Transmission, cartridge plate,  
mounting bolts**  
stage1 - 8.9 lbf·ft (12.0 N·m)  
stage2 - 16.2 lbf·ft (22.0 N·m)



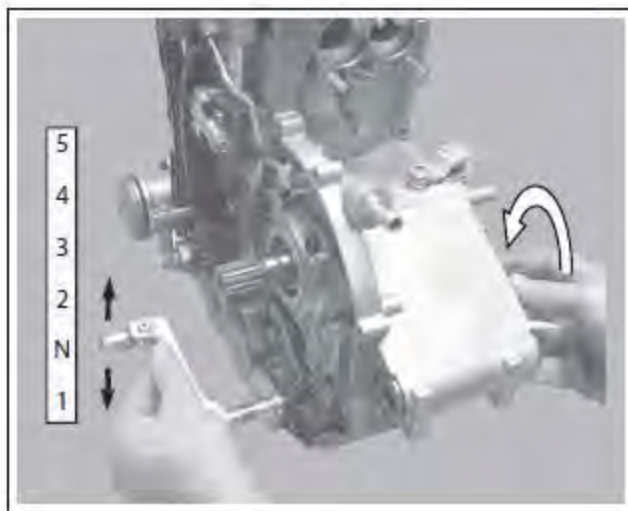
8. Install the transmission oil pump shaft pin, and the drive gear onto the shaft. Then, install a new circlip.

9. Install the spacer (1) with the smaller end facing out onto the shift drum ratchet (2).

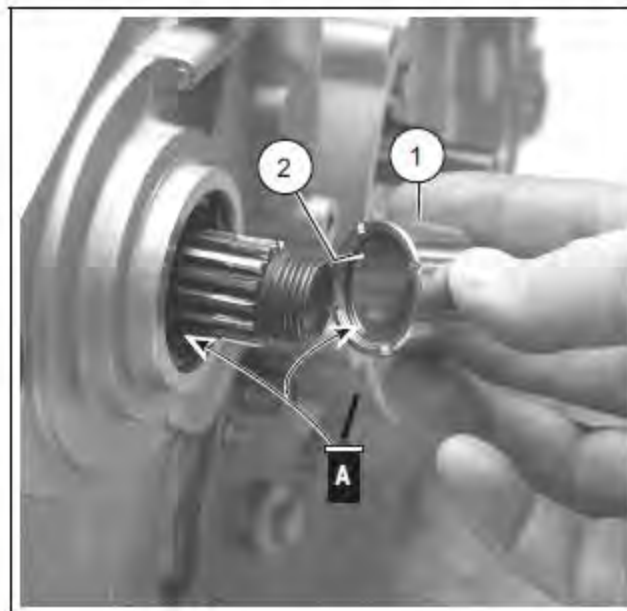


1. Spacer
2. Ratchet

10. Install the shift shaft (assembly) onto the cartridge plate. Then temporarily install the shift lever onto the shaft.
11. Test for proper shifting actions through all gears (1 down, NEUTRAL, and 4 up). Duplicate foot shifting with your left hand while turning the countershaft clockwise with your right hand. Quickly spin the countershaft to turn it. Be sure to hold the shift shaft properly as it would be supported if the crankcase cover was installed. This will prevent any slight binding that might make shifting with your hands difficult.

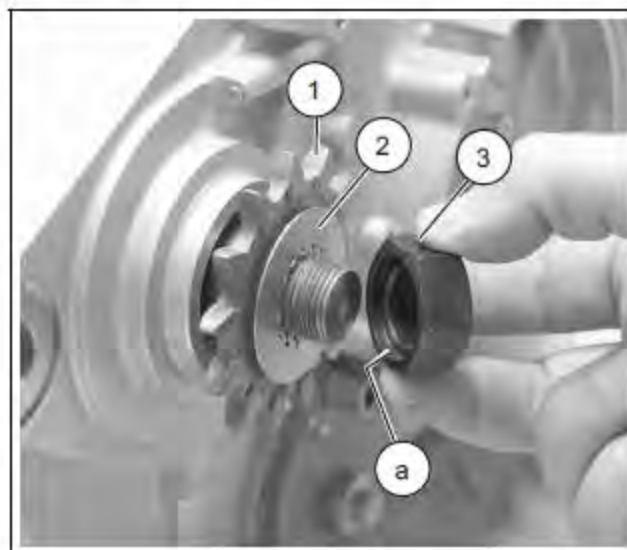


12. Apply assembly lube to the countershaft sprocket spacer (1) and to the lips of the seal, and install the spacer so that the internal o-ring (2) faces inward.



1. Countershaft spacer
2. O-ring

13. Install the countershaft sprocket (1)(13T), the splined lock washer (2), and countershaft sprocket nut (3) with the recess (a) of the nut facing inward toward the sprocket.



1. Sprocket
2. Splined lock washer
3. Nut
- a. Recess

14. Use a sprocket wrench to hold the sprocket and tighten the nut to the specified torque.

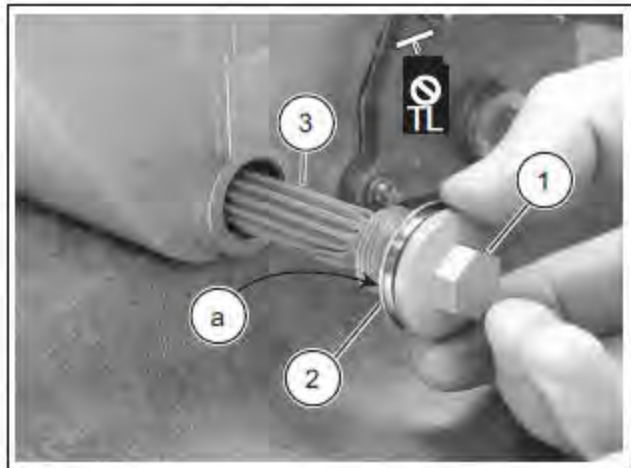


**Transmission, countershaft  
sprocket nut**  
29.5 lbf·ft (40.0 N·m)

15. Bend the splined lock washer over the nut.



16. Apply anti-seize compound to the threads of the transmission drain bolt (1). Then install the sealing washer (2) onto the bolt with the flat side (a) facing the case. Insert the filter into the bolt, and install into the case. Tighten the drain bolt to the specified torque.



- 1. Drain bolt
- 2. Sealing washer
- 3. Filter (screen)
- a. Sealing washer flat side



**Transmission drain bolt**  
6.0 lbf·ft (8.1 N·m)

**NOTE :**

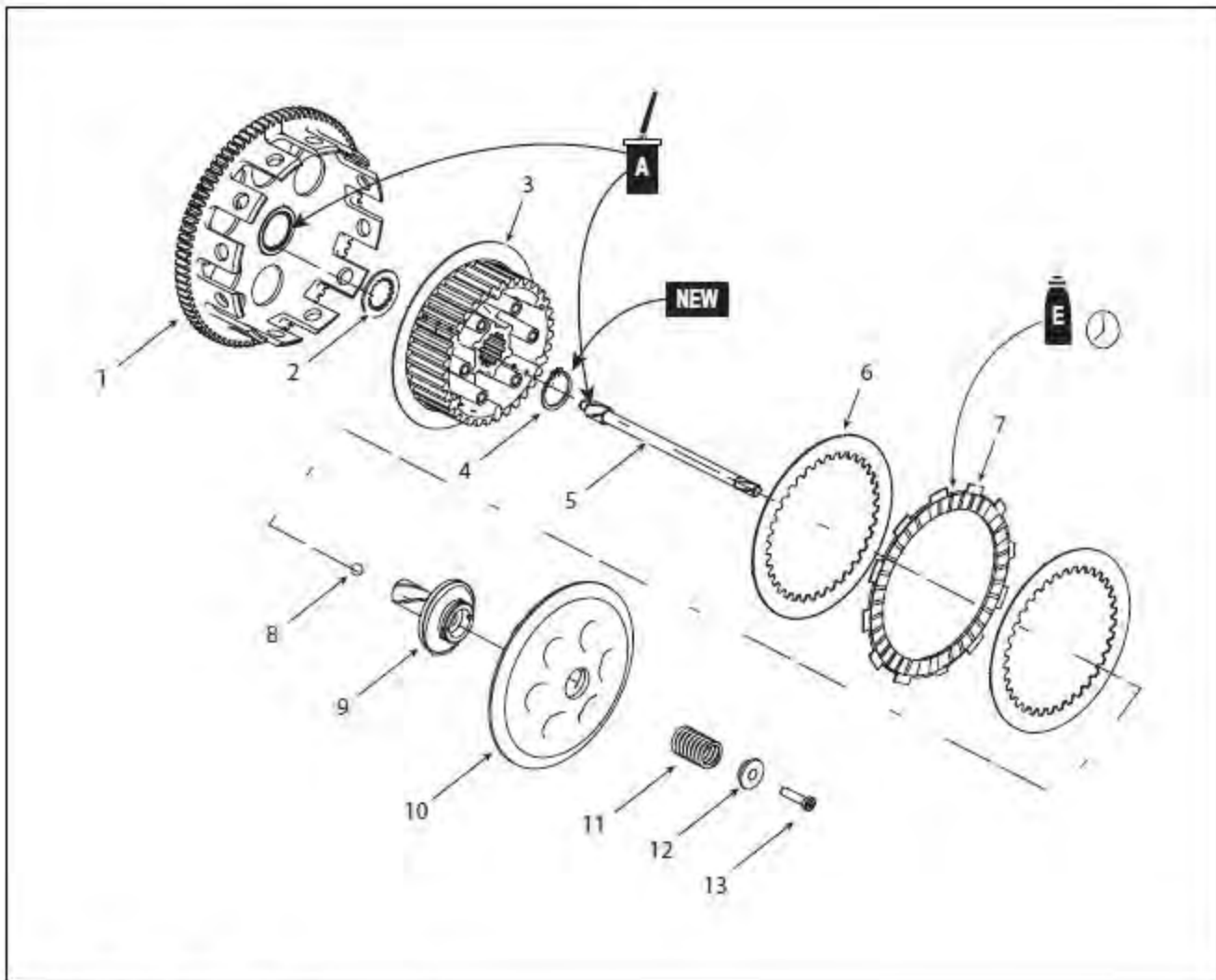
*Install the filter into the bolt and install together into the case. This is the recommended method to install the filter.*



# Clutch

Unit: mm (in)

ITEM			STANDARD	SERVICE LIMIT
Clutch	push rod runout limit		-	0.2 (0.007873)
	housing bushing	I.D.	-	25.15 (0.9901)
	friction plate	thickness	2.77 - 2.87 (0.1090 - 0.1129)	2.60 (0.1023)
	metallic plate	thickness	0.975 - 1.025 (0.03838 - 0.04035)	0.90 (0.03543)
		warpage	-	0.15 (0.005905)
	spring	free length	42.2 - 44.2 (1.6614 - 1.7401)	41.0 (1.6141)



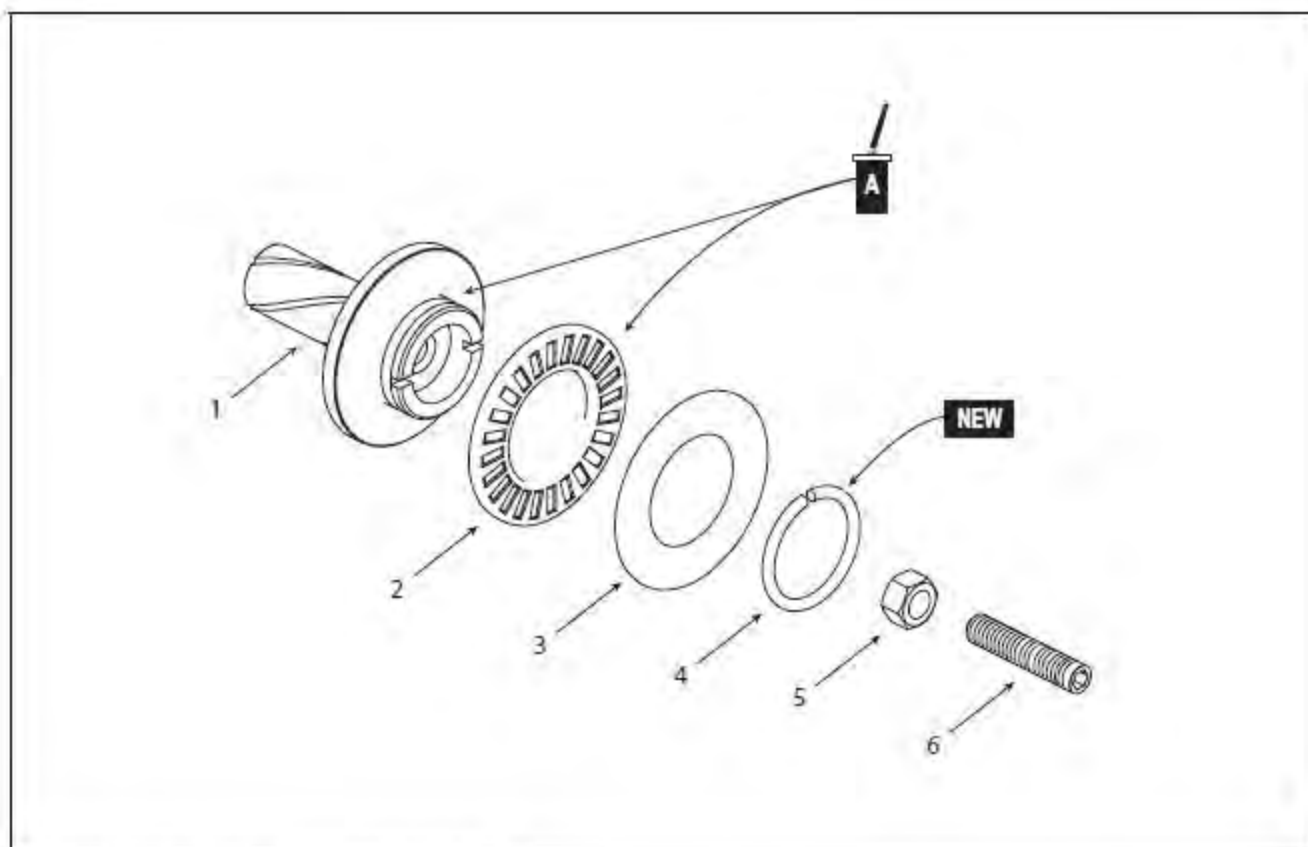
**ASSEMBLY VIEW : Clutch assembly**

- 1. Housing (Clutch basket)
- 2. Splined washer
- 3. Hub
- 4. Circlip
- 5. Push rod
- 6. Metallic plate (10)
- 7. Friction plate (9)
- 8. 8mm ball
- 9. Release collar assembly
- 10. Pressure plate

- 11. Spring (6)
- 12. Tophat (6)
- 13. Bolt (6)

**NOTE :**

*Always soak new friction plates overnight in clean transmission oil.*



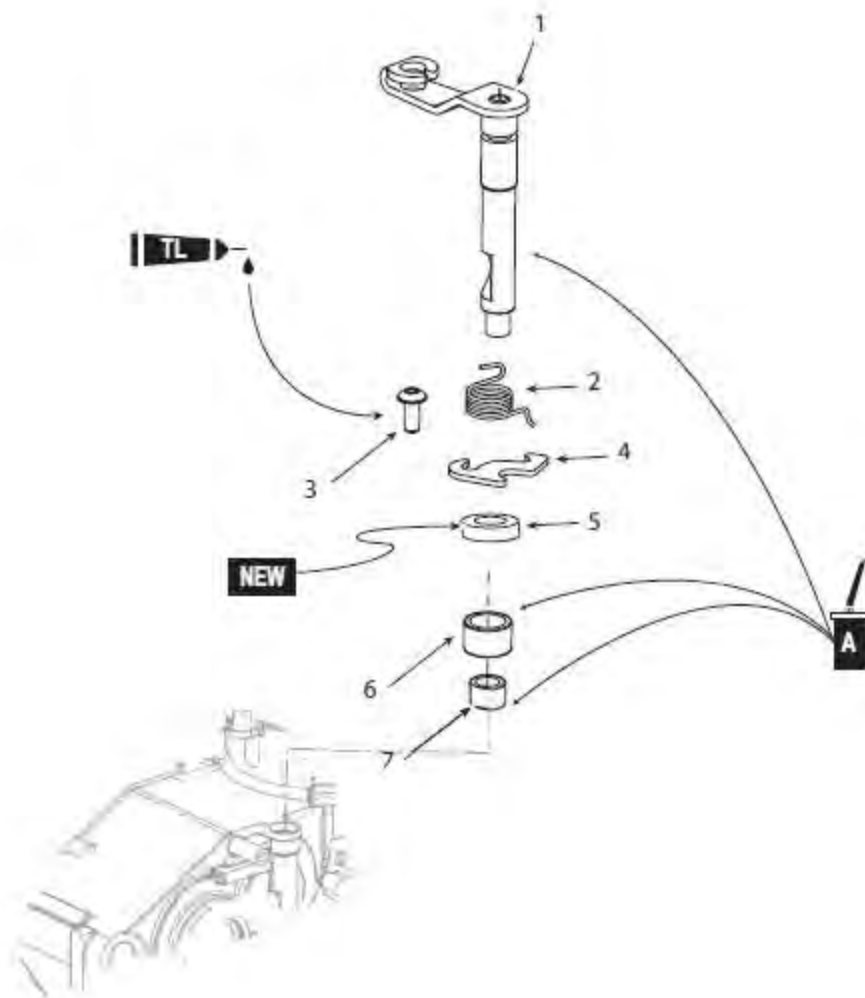
**ASSEMBLY VIEW : Clutch release collar**

1. Collar  
2. Bearing

3. Washer  
4. Clip

5. Locknut  
6. Adjuster



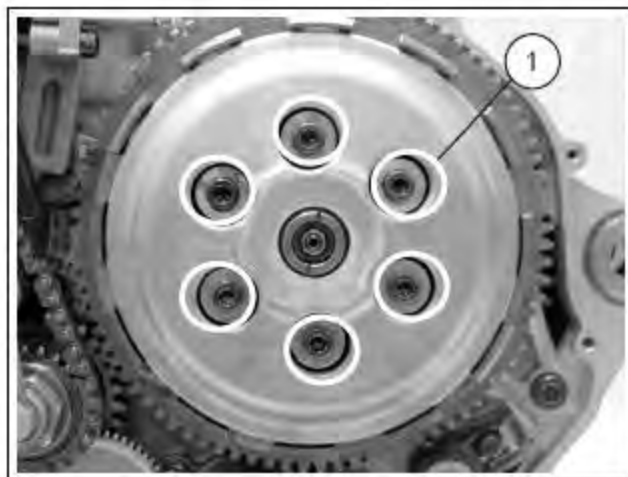


**ASSEMBLY VIEW : Clutch actuating arm**

- |             |                  |
|-------------|------------------|
| 1. Lever    | 5. Seal          |
| 2. Spring   | 6. Upper Bearing |
| 3. Bolt     | 7. Lower Bearing |
| 4. Retainer |                  |

## CLUTCH ASSEMBLY, REMOVE

1. Remove crankcase cover (page 21).
2. Remove the clutch pressure plate bolts (1), washers, and springs.



1. Pressure plate bolts

3. Remove the pressure, metallic, and friction plates.
4. Remove the release collar, 8mm ball, and push rod from the mainshaft.

### NOTE :

*Use a magnetic hand or tilt the engine slightly to remove the 8mm ball and push rod.*

5. Remove the clutch hub circlip and clutch hub from the mainshaft.

### CAUTION

**Do not drag the clutch housing (basket) bushing over the countershaft splines.**

6. Remove the splined washer and clutch housing (basket) from the countershaft.

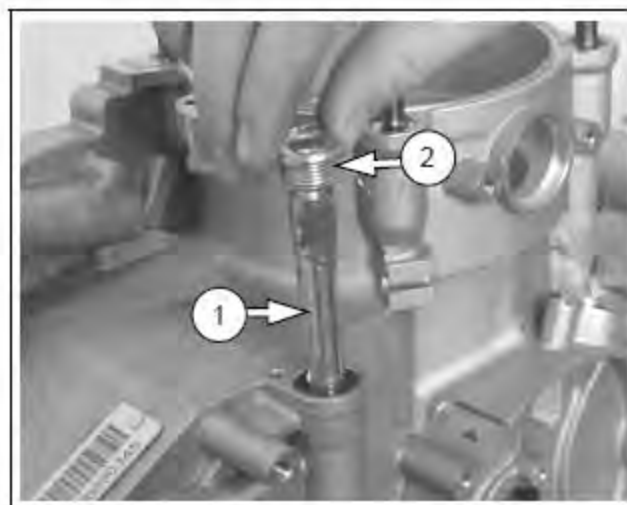
## CLUTCH ACTUATING ARM, REMOVE

1. Remove the clutch push rod. Refer to "Clutch assembly, remove" starting on page 163.
2. Remove the clutch actuating lever retaining clip bolt (1).



1. Bolts

3. Remove the retaining plate and lift out the lever (1) and spring (2).



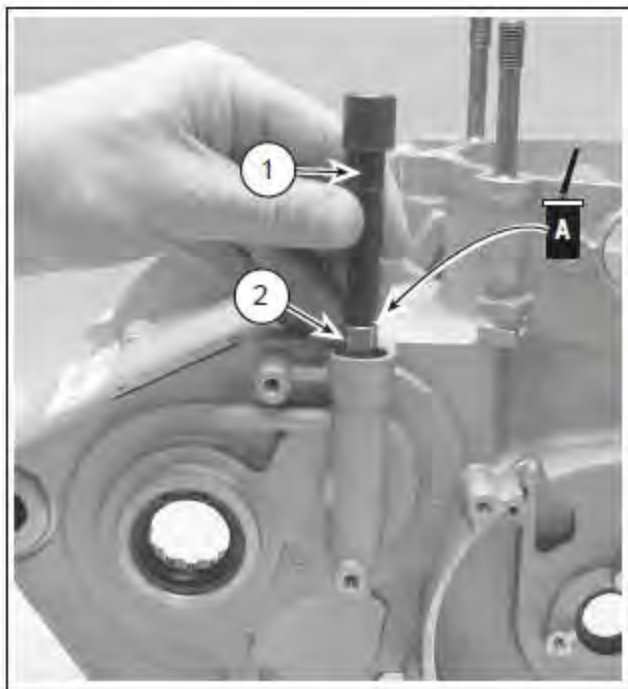
1. Lever  
2. Spring

## CLUTCH ACTUATING ARM, INSTALL

### CAUTION

The following procedure was completed on a bare crankcase - bearings not installed. If you are replacing the lever bearings, be sure to remove the existing ones first.

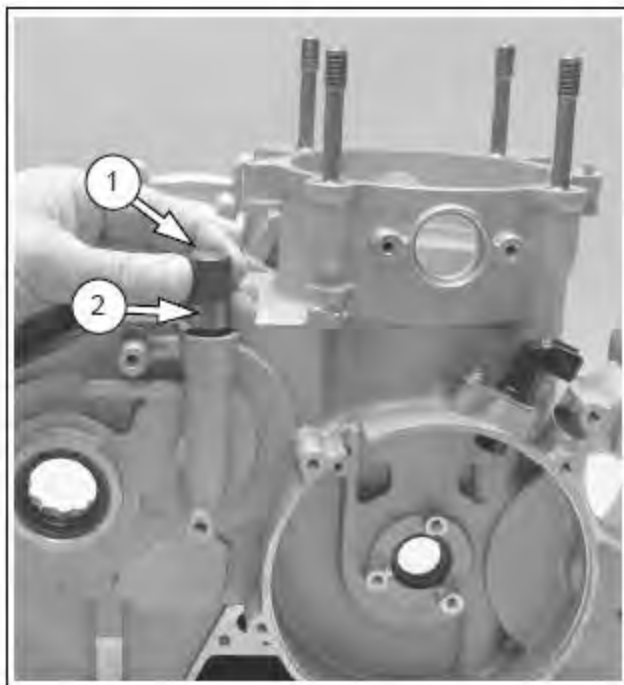
1. Apply assembly lube to the special tool tip, and install the lower clutch actuating arm bearing into the crankcase.



1. Tool
2. Lower bearing

**TOOL :** CM-503870  
Bearing installer

2. Install the upper clutch actuating arm bearing onto the special tool and insert into crankcase.



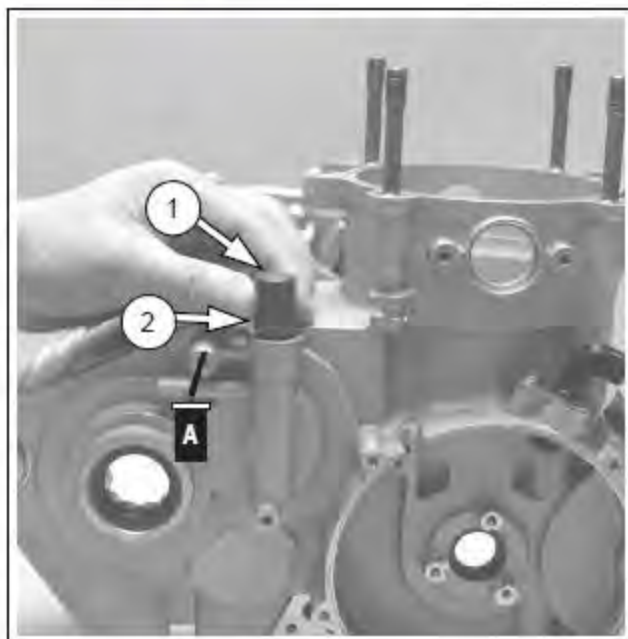
1. Tool
2. Upper bearing

**TOOL :** CM-503870  
Bearing installer

3. Apply some assembly lube to the seal lips, and install the oil seal (markings face up) onto the special tool. Then, install the seal into the crankcase.

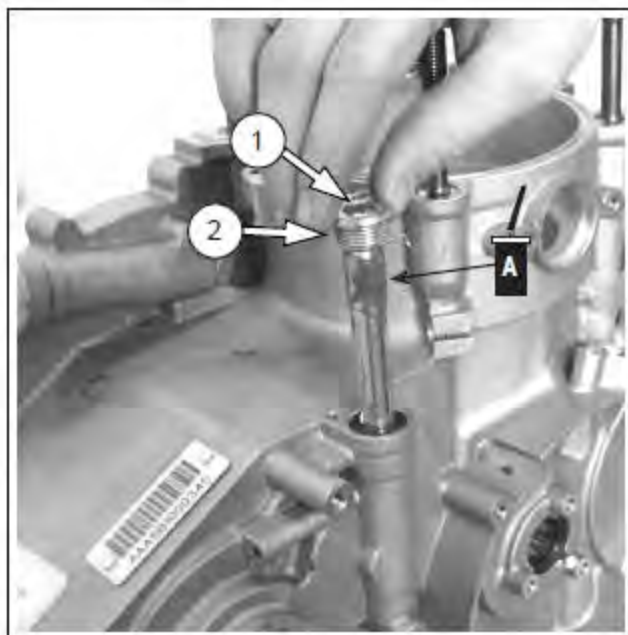


**TOOL : CM-503870**  
**Bearing installer**



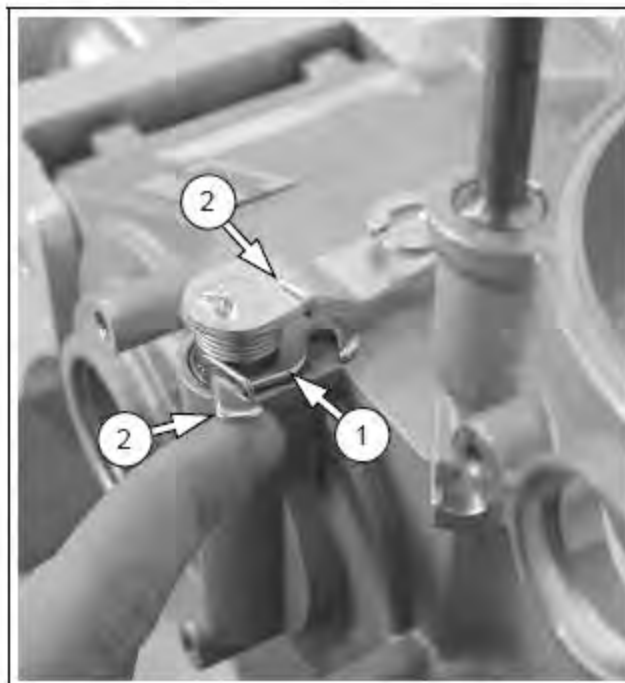
- 1. Tool
- 2. Oil seal

4. Install the spring onto the actuating arm. Then, apply assembly lube to the lever and insert into case.



- 1. Arm
- 2. Spring

5. Position retaining clip on the actuating arm, and position the spring ends.



- 1. Clip
- 2. Spring ends

6. Apply Loctite #242 to the threads and install the bolt.

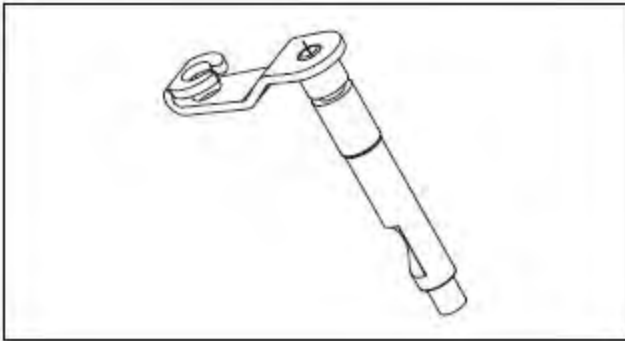


**Clutch actuating arm retaining clip  
 bolt**  
**3.3 lbf·ft (4.5 N·m)**

7. Test the actuating arm; push it toward the front of the engine and release. The actuating arm should return freely without binding or sticking.

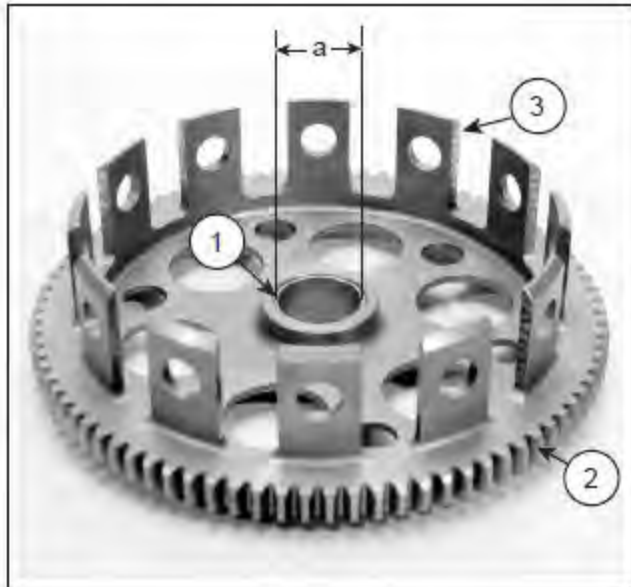
## CLUTCH ACTUATING ARM, INSPECT

Inspect the lever for wear or damage. Replace if necessary.



## CLUTCH HOUSING, INSPECT

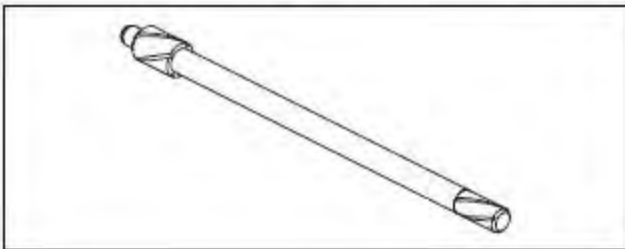
Measure bushing I.D. If out of specification - replace. Inspect fingers for pitting or wear. Deburr the fingers if possible or replace them.



- 1. Bushing
- 2. Primary driven gear.
- 3. Housing fingers
- a. Bushing I.D.

## CLUTCH PUSH ROD, INSPECT

Measure the runout limit. Replace if necessary.



### NOTE :

*Damage to the housing fingers will cause erratic clutch operation.*



**Clutch, housing, bushing I.D.  
limit - 0.9901 in (25.15mm)**

### NOTE :

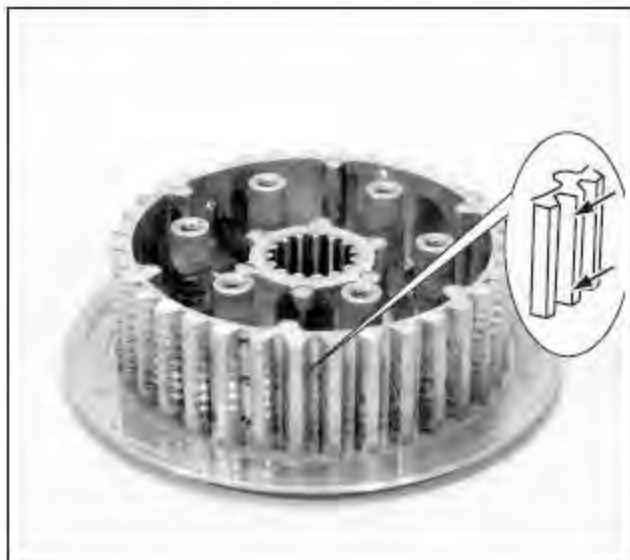
*Use V-Blocks and a dial gauge.*



**Clutch push rod runout limit  
0.008 in (0.2mm)**

## CLUTCH HUB, INSPECT

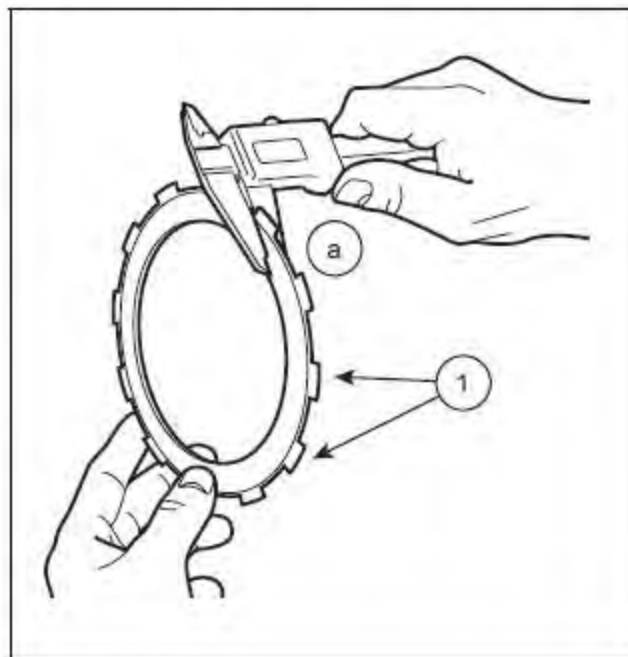
Inspect the hub splines for damage, pitting, or wear. Replace if damaged.



## CLUTCH FRICTION PLATES, INSPECT

The following procedure applies to all plates.

Inspect the tabs that contact the clutch housing for bending or damage. Measure friction plate thickness.



- 1. Tabs
- a. Thickness



**Clutch, plates, friction, thickness**  
**standard - 0.1090 - 0.1129 in**  
**(2.77 - 2.87mm)**  
**limit - 0.1023 in (2.60mm)**



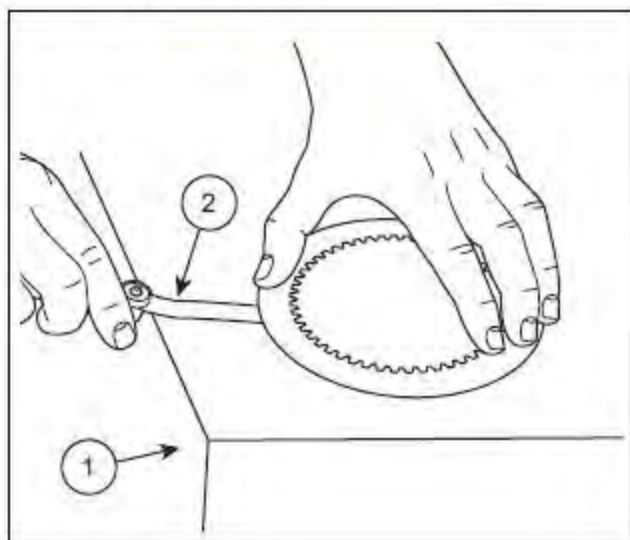
## CLUTCH METALLIC PLATES, INSPECT

Measure the plate thickness.

Measure all metallic plates' warpage using a surface plate and a feeler gauge.

Replace if out of specification.

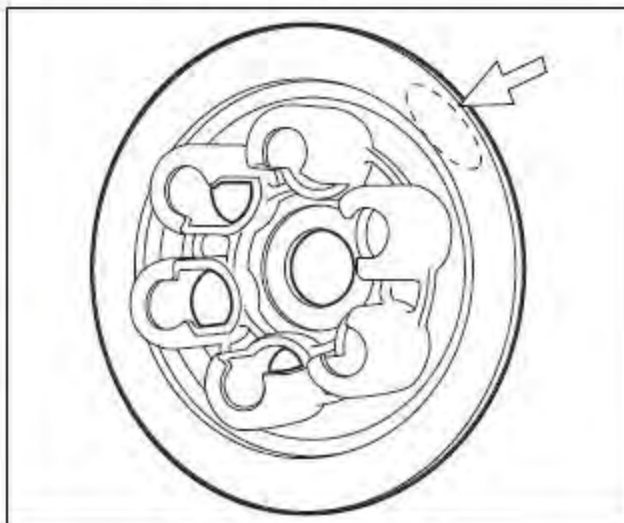
	<p>Clutch, plates, metallic, thickness standard - 0.03838 - 0.04035 in (0.975 - 1.025mm) limit - 0.03543 in (0.90mm)</p> <p>Clutch plate, metallic warpage limit 0.006 in (0.15mm)</p>
---	--



1. Surface plate
2. Thickness gauge

## CLUTCH PRESSURE PLATE, INSPECT

Inspect the clutch pressure plate for scoring, wear, or scratches. Replace if damaged.



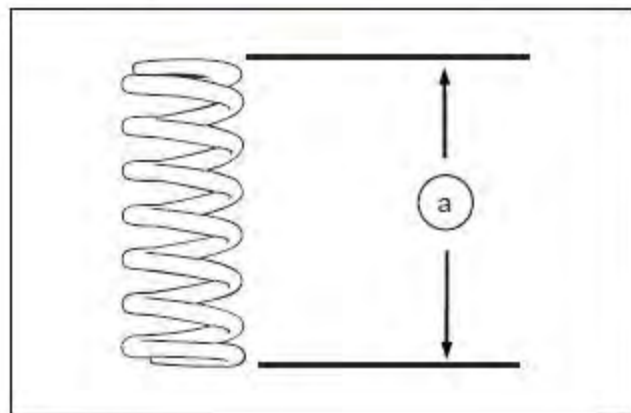
## CLUTCH SPRINGS, INSPECT

Measure the clutch spring's free length (a).

Measure each spring.

Replace with a new spring set if out of specification.

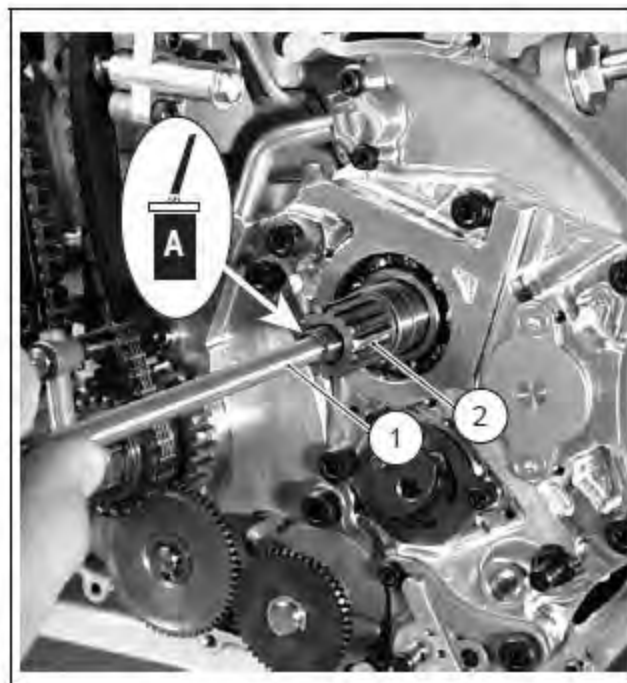
	<b>Clutch spring free length standard</b> standard - 1.6614 - 1.7401 in (42.2 - 44.2mm) limit - 1.6141 in (41.0mm)
---	---



a. Free length

## CLUTCH ASSEMBLY, INSTALL

1. Install the clutch actuating arm (if removed) (page 164).
2. Make sure the shift shaft is installed properly with the top hat installed correctly on the shift drum ratchet.
3. Apply assembly lube to ends of the push rod, and install the larger end into the mainshaft.



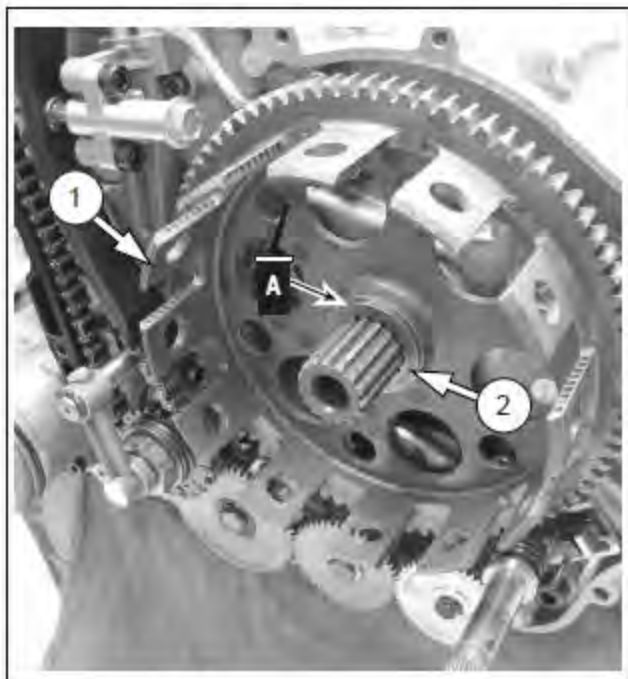
1. Push rod
2. Mainshaft

### CAUTION

When installing the clutch housing (basket) onto the mainshaft, be careful not to damage (gouge, scar, etc.) the housing bearing with the splines of the shaft.

4. Apply assembly lube to clutch housing (basket) bushing (1), and install the housing onto the mainshaft.

Then, install the splined washer (2).

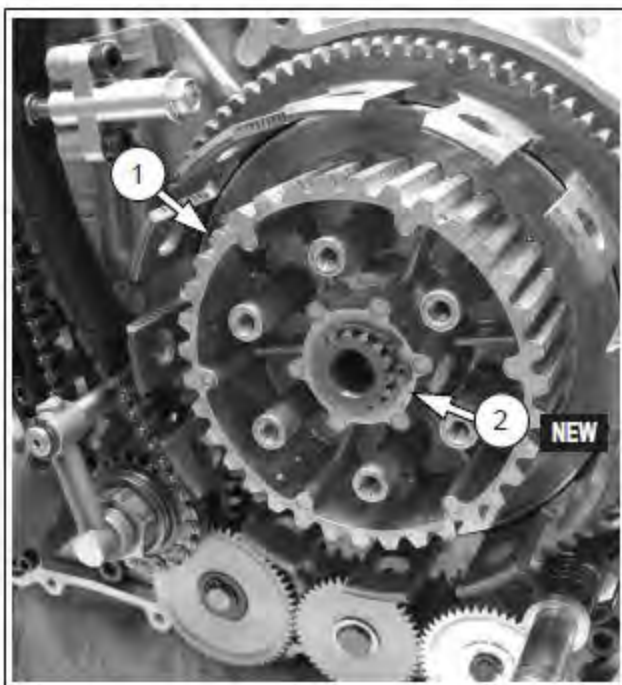


1. Housing (basket)
2. Splined washer

5. Install the clutch hub (1) and a new circlip (2). Be sure that the circlip is seated entirely in the groove with the flatter side facing out.

#### NOTE:

*Rotate the clip in the groove to confirm that it is installed correctly.*



1. Hub
2. Circlip

#### CAUTION

Replace clutch plates and springs as a set. Failure to replace as a set will accelerate plate wear or spring failure.

6. Now, install a metallic plate onto the hub. Then, install a friction disc.

Alternate plates until all plates are installed onto hub. The last plate installed before the pressure plate goes on will be a metallic plate.



Clutch, plate, metallic count  
10

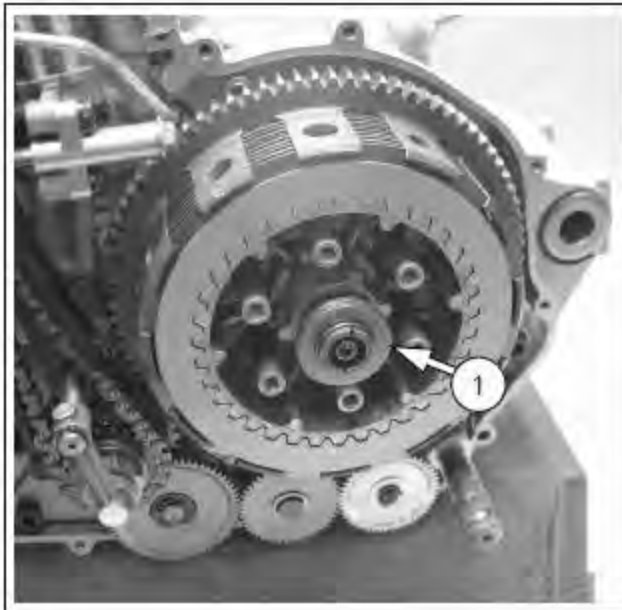
Clutch, plate, friction count  
9



**NOTE :**

*Use a little assembly lube inside the release collar to help keep the ball in place during assembly.*

7. Install the 8mm ball into the release collar then install the collar assembly (1) into the mainshaft.

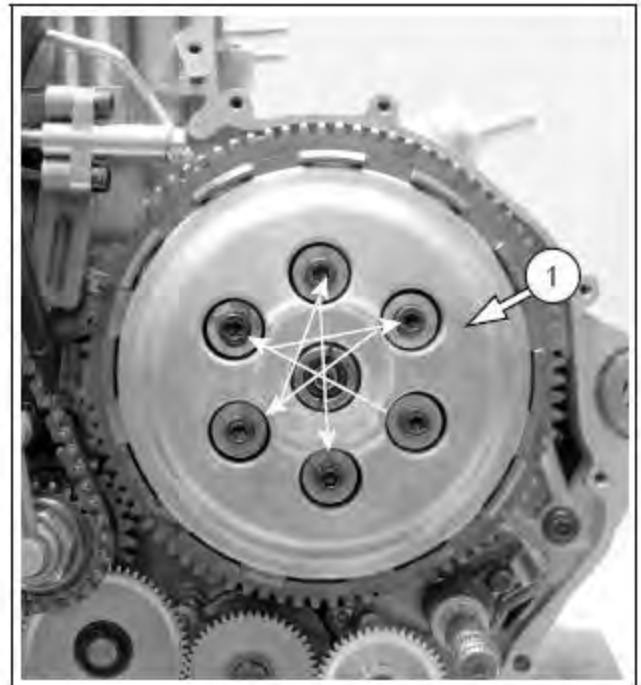


1. Release collar

8. Install the pressure plate onto the hub.
9. Install the springs and tophats, with smaller ends facing into the spring, into the pressure plate.

10. Install the bolts. Tighten to the specified torque.

When tightening, use a criss-cross pattern.

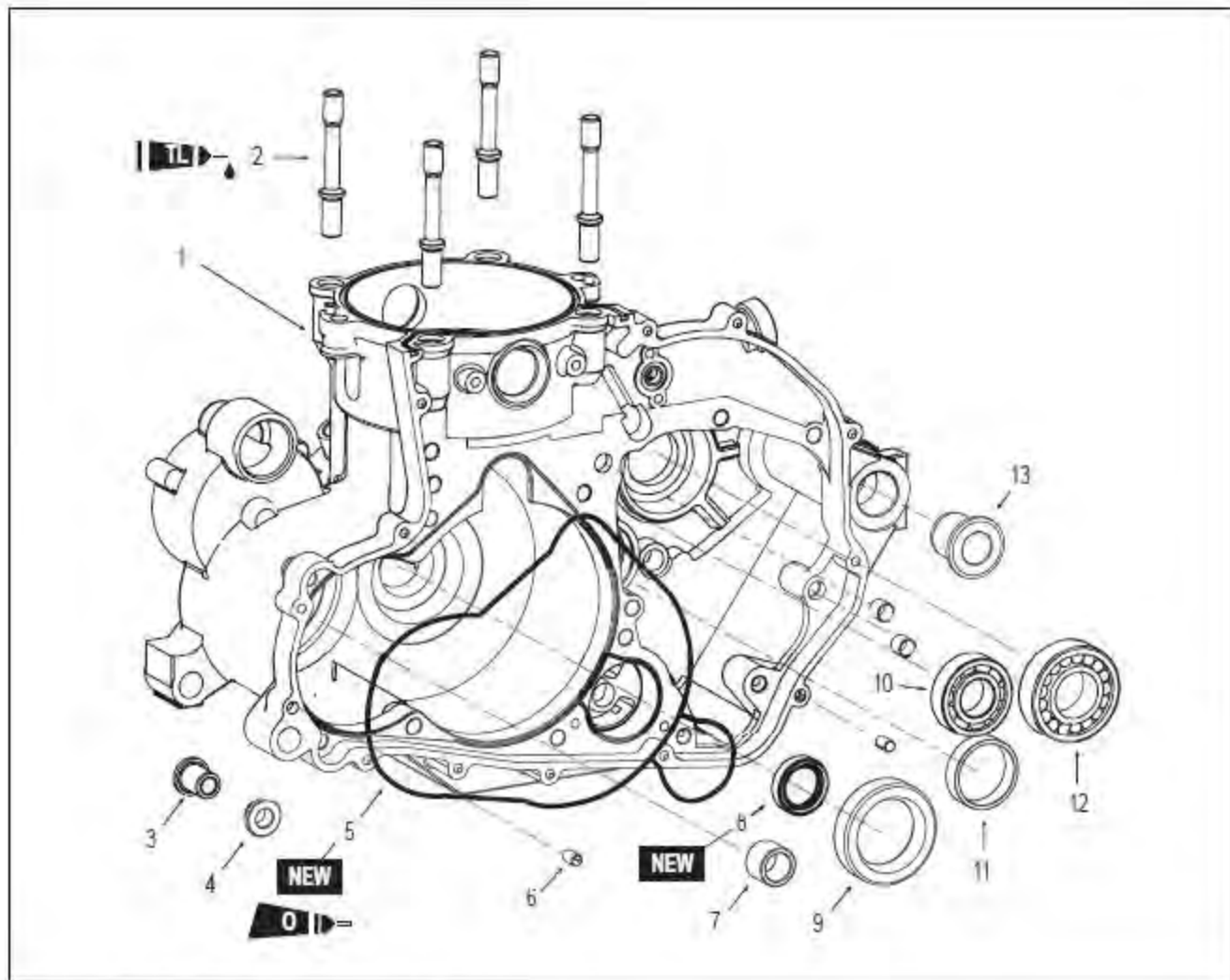


1. Pressure plate



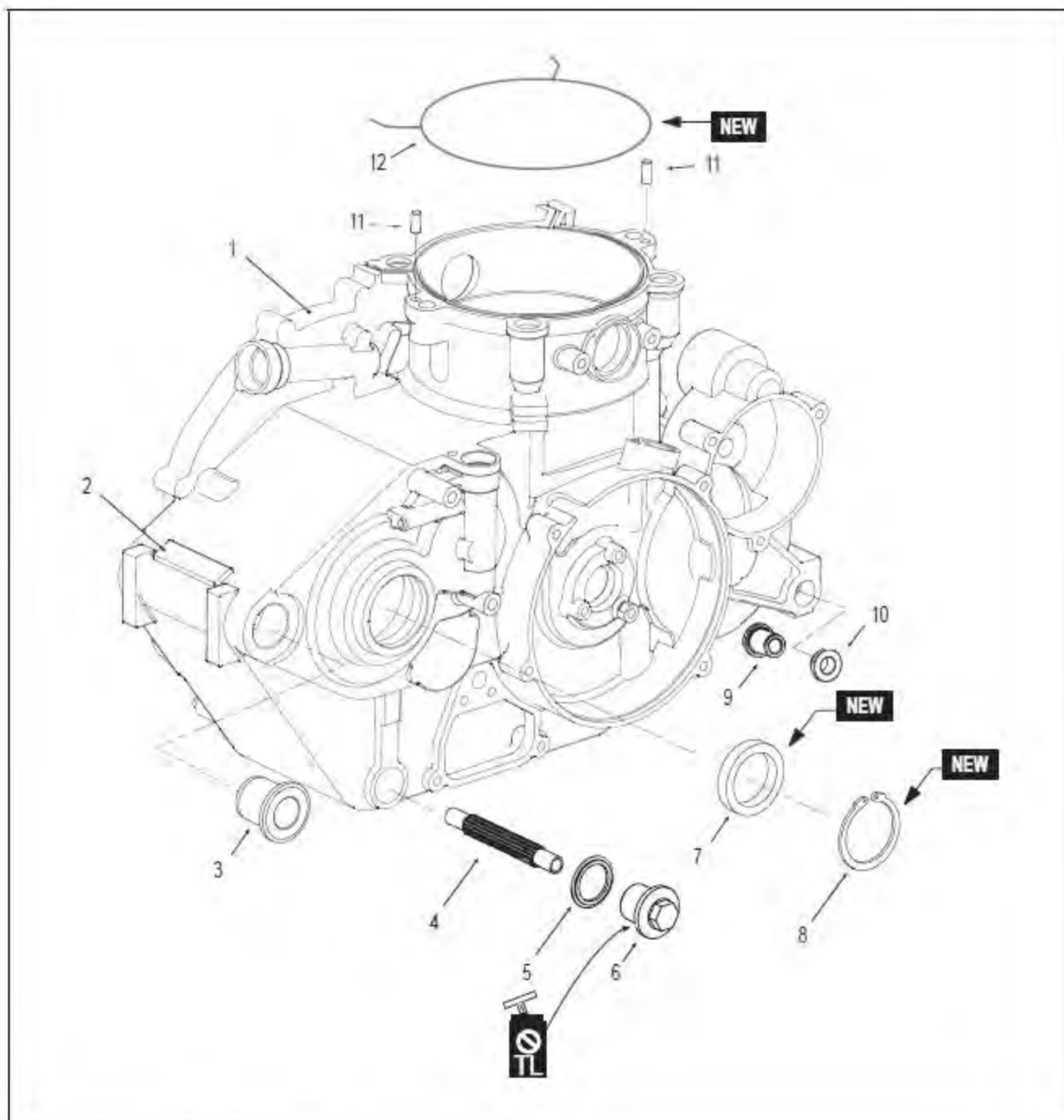
**Clutch pressure plate bolts**  
**3.3 lbf·ft (4.5 N·m)**

# Crankcase



**ASSEMBLY VIEW : Crankcase, Left**

- |                                    |                                    |                        |
|------------------------------------|------------------------------------|------------------------|
| 1. Crankcase                       | 7. Balance shaft bearing (right)   | 13. Pivot shaft insert |
| 2. Cylinder head studs             | 8. Crankshaft oil seal (right)     |                        |
| 3. Inner engine mount insert       | 9. Crankshaft main bearing (right) |                        |
| 4. Outer engine mount insert       | 10. Mainshaft bearing (right)      |                        |
| 5. Crankshaft cartridge plate seal | 11. Shift drum bearing (right)     |                        |
| 6. Crankcase cover locating dowel  | 12. Countershaft bearing (right)   |                        |



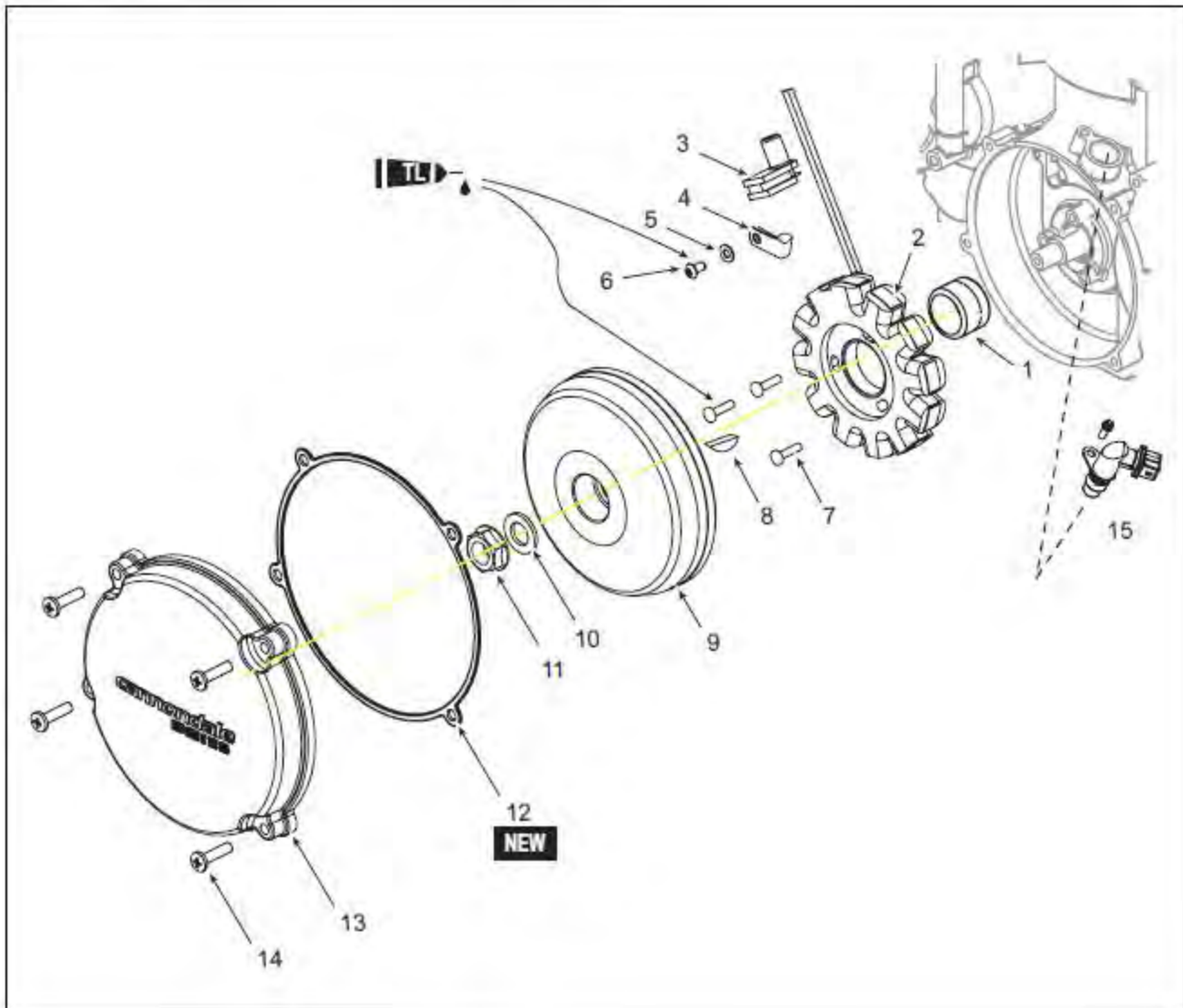
**ASSEMBLY VIEW : Crankcase, Right**

- |                                 |                                       |
|---------------------------------|---------------------------------------|
| 1. Crankcase                    | 7. Countershaft oil seal              |
| 2. Engine Serial Number         | 8. Circlip                            |
| 3. Pivot shaft insert           | 9. Inner engine mount insert          |
| 4. Transmission filter (screen) | 10. Outer engine mount insert         |
| 5. Sealing washer               | 11. Cylinder head locating dowels (2) |
| 6. Transmission drain bolt      | 12. Seal                              |



# Electrical

This section cover component removal and installation.  
Electrical diagnostics can be found in the vehicle's chassis manual.



**ASSEMBLY VIEW : Generator, generator cover, & flywheel**

- |                         |                 |                                |
|-------------------------|-----------------|--------------------------------|
| 1. Alignment collar     | 7. Bolts (3)    | 13. Cover                      |
| 2. Stator               | 8. Key          | 14. Bolts (4)                  |
| 3. Grommet              | 9. Flywheel     | 15. Crankshaft position sensor |
| 4. Clip (flat side out) | 10. Lock washer |                                |
| 5. Washer               | 11. Nut         |                                |
| 6. Screw                | 12. Gasket      |                                |

## STARTER

The starter motor is located on the front left side of the engine. The starter is not serviceable and should not be disassembled.

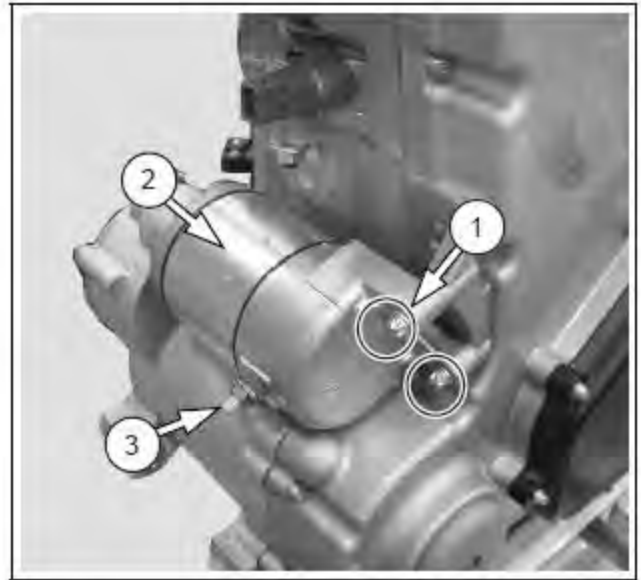
### **⚠ WARNING**

Always disconnect the negative battery lead from the negative battery terminal on the battery before servicing the starter motor. The starter motor could be engaged accidentally or electrical sparks can cause an accident where you can be seriously burned, injured, or even killed.

## STARTER, REMOVE - INSTALL

### NOTE :

*The engine has been removed in the procedures of this manual, consult the vehicle's chassis manual for any steps required to access the starter motor when the engine is installed in the vehicle.*



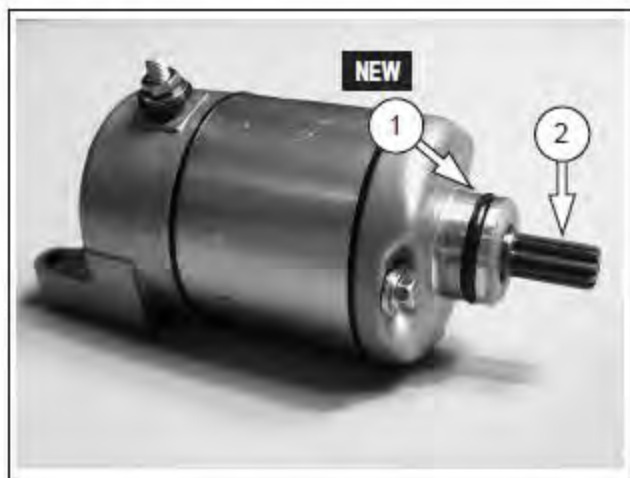
1. Bolts
2. Starter motor (installed)
3. Cable terminal (12v+ positive)

### NOTE :

*Note any shims between the crankcase cover and starter mounting base, and return as removed.*

1. Remove the starter motor mounting bolts (1) and remove the starter motor (2).
2. Inspect the starter body for a bent or corroded cable terminal, burn marks, signs of arcing, cracking, deep scratches, fraying, worn leads, or other damage.

3. Inspect the O-ring (1) and teeth (2) for signs of excessive wear or damage. Replace the starter if the teeth are cracked, chipped, or show signs of excessive wear.



1. O-ring
2. Teeth

4. To install the starter motor, apply a light coat of clean engine oil to the O-ring and carefully slide the starter motor into the crankcase.
5. Install the mounting bolts and any removed shims. Tighten the bolts to the specified torque.

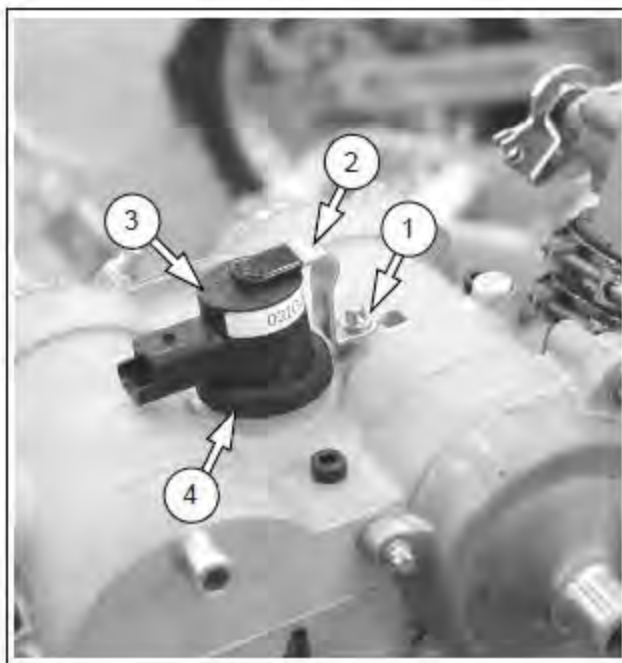


**Starter mounting bolts**  
7.4 lbf·ft (10.0 N·m)

**Starter terminal nut**  
4.4 lbf·ft (6.0 N·m)

## IGNITION COIL, REMOVE

1. Remove the bolt (1) and coil hold down bracket (2) and pull out the coil (3).



1. Bolt
2. Coil hold down bracket
3. Coil
4. Coil seal



## IGNITION COIL, INSTALL

1. Install the spark plug.
2. Inspect the condition of the coil seal. If undamaged, install onto cylinder head cover. Apply a light coat of O-ring lubricant to the inner lip of the seal.
3. Apply clean dielectric grease to the inner part of the rubber tip, and insert the coil into the cylinder head.
4. Install the retaining bracket and bolt. Tighten the bolt to the specified torque.



Ignition coil retaining clip bolt  
3.3 lbf·ft (4.5 N·m)

## GENERATOR COVER, REMOVE - INSTALL

### CAUTION

The generator cover seal is re-usable. However, inspect it carefully. A damaged seal will allow contaminants to enter and cause damage.

1. Remove the cover bolts, cover and seal.



1. Cover

2. To install, place the seal onto the cover and install cover. Tighten screws to the specified torque.



Generator cover screws  
0.8 lbf·ft (1.1 N·m)

## GENERATOR & FLYWHEEL, REMOVE - INSTALL

1. Remove the generator cover (page 177).
2. Use a flywheel holder to loosen and remove the flywheel nut and lock washer from the crankshaft end.

TOOL : Flywheel holder  
CM-506551

3. Install the special tool into the flywheel.

### NOTE :

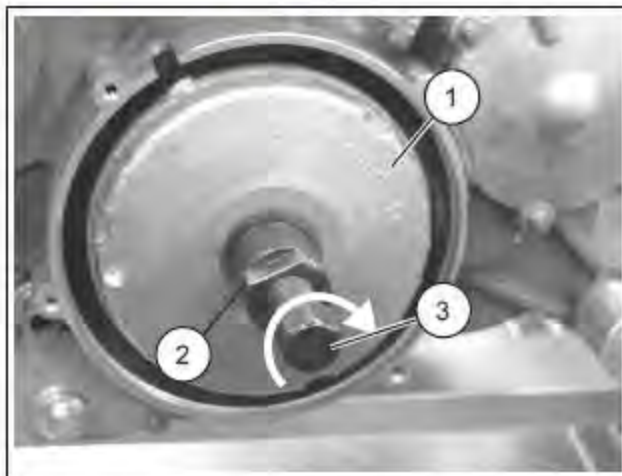
*Be certain to examine the surface for metal debris.*

4. Hold the tool (2) with an open end wrench and tighten the smaller bolt on the special tool (3) until the flywheel can be removed from the shaft.

### NOTE :

*Tapping the end of the flywheel puller lightly with hammer may aid in the removal process.*

TOOL : CM503877,  
Flywheel remover

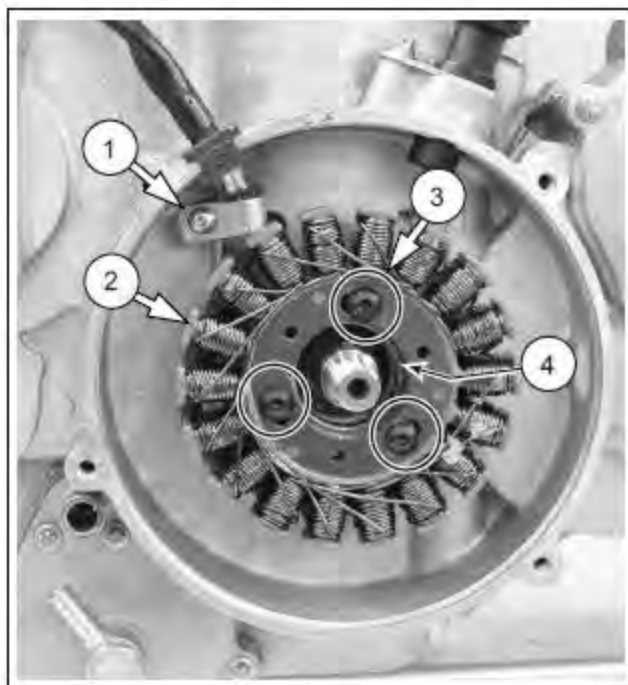


1. Flywheel
2. Special tool - large end (part that screws into the flywheel and keeps it secure)
3. Special tool - smaller bolt

### NOTE :

*The flat side of the clip faces outward to maintain clearance with the flywheel.*

5. Remove the harness clip screw (1). Remove the stator mounting bolts (2). Remove the stator (3) and sleeve (4) from the crankcase.



1. Harness clip screw
2. Stator
3. Mounting bolts
4. Sleeve

6. To install, make sure the sleeve is inserted into the crankcase side of the stator.
7. Install the stator and sleeve onto the crankcase. Tighten the bolts to the specified torque.



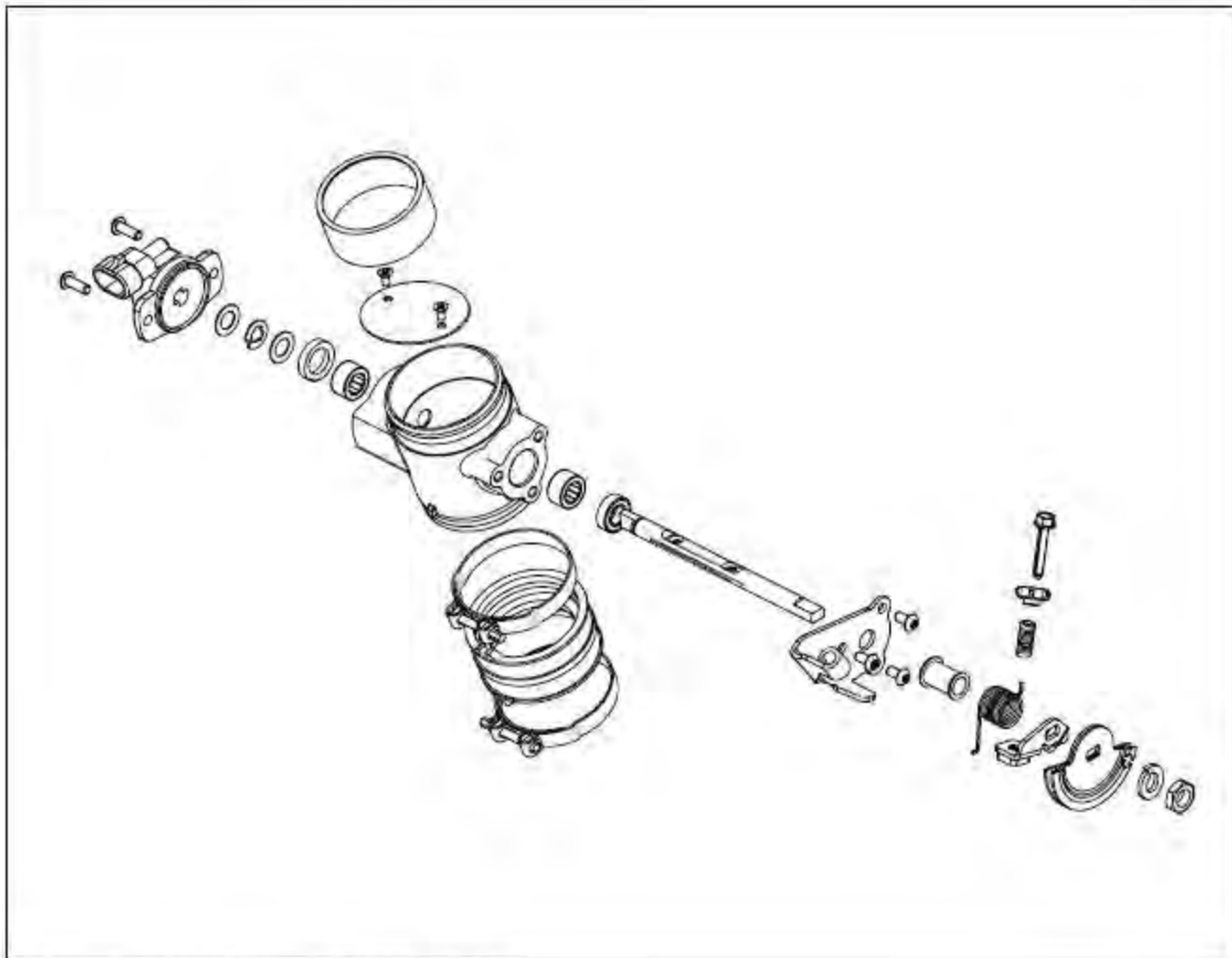
**Stator mounting bolts**  
3.3 lbf•ft (4.5 N•m)

**Stator clip screw**  
1.7 lbf•ft (2.3 N•m)

8. Apply thread lock to the screw, and install the harness clip with the flat side facing out. Tighten the screw to the specified torque.



# Throttle Body



ASSEMBLY VIEW : Throttle Body (MC500)







# VALVE CLEARANCE SHIM TABLES

## INTAKE

Installed Shim	190	195	200	205	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350			
Measured Clearance (Inches)																																				
.001-.003				190	195	200	205	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350
.003-.005			190	195	200	205	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350	
.005-.007		190	195	200	205	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350		
STANDARD CLEARANCE																																				
.007-.009																																				
.009-.011	195	200	205	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350				
.011-.013	200	205	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350					
.013-.015	205	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350						
.015-.017	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350							
.017-.019	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350								
.019-.021	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350									
.021-.023	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350										
.023-.025	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350											
.025-.027	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350												
.027-.029	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350													
.029-.031	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350														
.031-.033	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350															
.033-.035	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350																
.035-.037	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350																	
.037-.039	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350																		
.039-.041	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350																			
.043-.045	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350																				
.045-.047	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350																					
.047-.049	285	290	295	300	305	310	315	320	325	330	335	340	345	350																						
.049-.051	290	295	300	305	310	315	320	325	330	335	340	345	350																							
.051-.053	295	300	305	310	315	320	325	330	335	340	345	350																								
.053-.055	300	305	310	315	320	325	330	335	340	345	350																									
.055-.057	305	310	315	320	325	330	335	340	345	350																										
.057-.059	310	315	320	325	330	335	340	345	350																											
.059-.061	315	320	325	330	335	340	345	350																												

**STANDARD CLEARANCE**

1. Measure the current clearance (row)  
2. Select installed shim column (columns)  
3. Find intersection of current clearance and current installed shim; this is the new shim to install.

**Example**  
Measured valve clearance is .026in.  
Installed shim is 295 (2.95mm).  
The new shim 340 shim is required.

**CAUTION**  
Do not use shims sizes not found in this table. Using shims sizes out of the range specified will result in severe engine damage.



## EXHAUST

Shim Number	190	195	200	205	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350
Measured (inches)																																	
.000-.002																																	
.002-.004																																	
.004-.006																																	
.006-.008																																	
.008-.010																																	
.010-.012																																	
.012-.014																																	
.014-.016																																	
STANDARD CLEARANCE																																	
.016-.018	195	200	205	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350	
.018-.020	200	205	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350		
.020-.022	205	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350			
.022-.024	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350				
.024-.026	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350					
.026-.028	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350						
.028-.030	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350							
.030-.032	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350								
.032-.034	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350									
.034-.036	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350										
.036-.038	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350											
.038-.040	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350												
.040-.042	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350													
.042-.044	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350														
.044-.046	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350															
.046-.048	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350																
.048-.050	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350																	
.050-.052	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350																		
.052-.054	285	290	295	300	305	310	315	320	325	330	335	340	345	350																			
.054-.056	290	295	300	305	310	315	320	325	330	335	340	345	350																				
.056-.058	295	300	305	310	315	320	325	330	335	340	345	350																					
.058-.060	300	305	310	315	320	325	330	335	340	345	350																						
.060-.062	305	310	315	320	325	330	335	340	345	350																							

1. Measure the current clearance (row)

2. Select installed shim column (columns)

3. Find intersection of current clearance and current installed shim: this is the new shim to install.

Example

Measured valve clearance is .028in.

Installed shim is 250 (2.95mm).

The new shim 285 shim is required.

1. Measure the current clearance (row).  
2. Select installed shim column (columns).  
3. Find intersection of current clearance and current installed shim; this is the new shim to install.

### Example

Measured valve clearance is .028in.  
Installed shim is 250 (2.95mm).  
The new shim 285 shim is required.