001-088 Engine Base Timing

General Information

Front Gear Assembly Configuration

This procedure describes the removal, inspection, and installation of the gear train.

The illustration shown is from left to right and top to bottom.

- Valve camshaft gear
- Camshaft idler gear (adjustable)
- Upper idler gear
- Lower idler scissor gear
- Accessory drive gear
- Fuel pump idler gear
- Fuel pump gear.

Scissor Gear Definitions
**WARNING**

Do not attempt to remove any gears before reading scissor gear definitions. Serious personal injury or engine damage can result if instructions are not followed.

The following terms describe the conditions of the scissor gears for removal, installation, and operation.

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**Unloaded**

- The gear will be unloaded when removing, installing, and setting gear backlash.
- Unload the gear by backing out two gear adjusting screws until the gear teeth align.
- The idler scissor gear is loaded after the gear backlash is set.

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**Loaded**

- The gear teeth are loaded (functional) and are spread between the mating gear teeth.
- The gear is loaded by tightening all of the adjusting screws.

**Torque Value:** 29  n.m  [21 ft-lb]

- The gear teeth will be spread and no movement will be felt against the crankshaft gear. The gear will be in the loaded condition for engine operation.
Preparatory Steps

**CAUTION**

The timing pin and wedge must be installed before any gears are removed and must remain in place until all gears are fully installed and tightened. Failure to install the timing pin and wedge can lead to improper timing of the engine, resulting in severe engine damage or engine failure.

Rotate the crankshaft **clockwise** until the “insert pin” mark on the outside diameter of the engine vibration damper is aligned with the mark on the gear housing. Refer to Procedure 000-017 in Section 0.

Remove the plug from the timing pin boss.

Insert the crankshaft locking pin, Part Number 3163020, into the timing pin boss hole.

The green band on the timing pin will be lined up with the surface of the timing pin boss of the block.

The pin is **not** correctly seated in the crank notch if the green band is either completely visible outside the block or is **not** visible at all.

The crankshaft will be locked in place when the pin is properly seated.
• Remove the exhaust gas recirculation (EGR) crossover tube. Refer to Procedure 011-070 in Section 11.
• Remove the rocker lever cover and gasket. Refer to Procedure 003-011 in Section 3.

The timing code is located on the engine dataplate.

**WARNING**

Do not drive the wedge into place. Engine damage can occur.

Insert the correct timing wedge to lock the valve camshaft. Lightly tap the top of the timing wedge with a mallet to be sure it is properly seated.

Make sure the wedge with the proper angle is used and that the wedge is properly seated in its installed position.
- Remove the camshaft position sensor. Refer to Procedure 019-363 in Section 19.
- Remove the upper gear cover. Refer to Procedure 001-079 in Section 1.
- Remove the crankshaft position sensor. Refer to Procedure 019-365 in Section 19.
- Remove the lower gear cover, if needed. Refer to Procedure 001-080 in Section 1.

Valve Camshaft Gear

The lower idler scissor gear must be unloaded during removal of the valve camshaft gear. To unload the gear, two of the gear adjusting screws must be backed out far enough to allow the teeth on the scissor gear to be aligned.

Unload the lower idler scissor gear.

Remove the valve camshaft gear mounting capscrew and the camshaft tone wheel.

**NOTE:** Do not disassemble the camshaft tone wheel.
Install the gear puller, Part Number 3163069.

Install the valve camshaft gear mounting capscrew completely.

Loosen the capscrew two turns.

Use the gear puller to remove the valve camshaft gear from the camshaft nose.

Remove the puller.

_Do not_ completely remove the camshaft gear mounting capscrew when the three-jaw puller is used. The capscrew serves as a safety catch by preventing the gear from slipping off of the camshaft's tapered nose.

Remove the valve camshaft gear mounting capscrew, spacer, and valve camshaft gear.

**Camshaft Idler Gear (Adjustable)**

The lower idler scissor gear **must** be unloaded during removal of any gears. To unload the gear, two of the gear adjusting screws **must** be backed out far enough to allow the teeth on the scissor gear to be aligned.

Unload the lower idler scissor gear.
The camshaft idler gear shaft can fall out and be damaged when the camshaft idler gear is removed.

Remove the retainer capscrews, retainer, camshaft idler gear, and idler gear shaft.

**Upper Idler Gear**

The lower idler scissor gear **must** be unloaded during removal of any gears. To unload the gear, two of the gear adjusting screws **must** be backed out far enough to allow the teeth on the scissor gear to be aligned.

Unload the lower idler scissor gear.

Remove the retainer capscrews, retainer, upper idler gear, and spacer/shaft assembly.

**Accessory Drive Gear**

If equipped, remove the air compressor. Refer to Procedure 012-014 in Section 12.

**Fuel Pump Idler Gear**
The lower idler scissor gear must be unloaded during removal of any gears. To unload the gear, two of the gear adjusting screws must be backed out far enough to allow the teeth on the scissor gear to be aligned.

Unload the lower idler scissor gear.

Remove the retaining capscrews, shaft, fuel pump idler gear, and thrust bearing.

**Lower Idler Scissor Gear**

The lower idler scissor gear must be unloaded during removal of any gears. To unload the gear, two of the gear adjusting screws must be backed out far enough to allow the teeth on the scissor gear to be aligned.

Unload the lower idler scissor gear.

Remove the idler scissor gear capscrews.

Remove the retainer, lower idler scissor gear, shaft, and thrust bearing.

**Inspect for Reuse**

Inspect the gear teeth on all gears for pitting, heavy wear, or breakage.

Replace the suspect gear and inspect the mating gear for resulting damage.
Inspect the idler shafts for heavy wear.

Measure the idler shafts outside diameters.

**Lower Idler Shaft Outside Diameter**

<table>
<thead>
<tr>
<th>mm</th>
<th>in</th>
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</thead>
<tbody>
<tr>
<td>88.880</td>
<td>3.4992</td>
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<tr>
<td>88.894</td>
<td>3.4998</td>
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</tbody>
</table>

**Upper Idler Shaft Outside Diameter**

<table>
<thead>
<tr>
<th>mm</th>
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<tbody>
<tr>
<td>88.880</td>
<td>3.4992</td>
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<tr>
<td>88.894</td>
<td>3.4998</td>
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**Camshaft Idler Gear Shaft Outside Diameter**

<table>
<thead>
<tr>
<th>mm</th>
<th>in</th>
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<tbody>
<tr>
<td>95.343</td>
<td>3.7537</td>
</tr>
<tr>
<td>95.357</td>
<td>3.7542</td>
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**Fuel Pump Idler Shaft Outside Diameter**

<table>
<thead>
<tr>
<th>mm</th>
<th>in</th>
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<tbody>
<tr>
<td>78.344</td>
<td>3.0844</td>
</tr>
<tr>
<td>78.358</td>
<td>3.0850</td>
</tr>
</tbody>
</table>

Inspect the idler gear bores for heavy wear or pitting.

Measure the inside diameter of the lower idler gear, adjustable idler gear, camshaft idler gear, and fuel pump idler gear bores.

**Lower Idler Gear Bore Inside Diameter**

<table>
<thead>
<tr>
<th>mm</th>
<th>in</th>
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<tbody>
<tr>
<td>88.963</td>
<td>3.5025</td>
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<tr>
<td>88.989</td>
<td>3.5035</td>
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</tbody>
</table>
### Adjustable Idler Gear Bore Inside Diameter

<table>
<thead>
<tr>
<th>mm</th>
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<tbody>
<tr>
<td>88.963</td>
<td>3.5025</td>
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<tr>
<td>88.989</td>
<td>3.5035</td>
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</tbody>
</table>

### Camshaft Idler Gear Bore Inside Diameter

<table>
<thead>
<tr>
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<th>in</th>
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<tbody>
<tr>
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<td>3.7569</td>
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<tr>
<td>95.452</td>
<td>3.7580</td>
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</tbody>
</table>

### Fuel Pump Idler Gear Bore Inside Diameter

<table>
<thead>
<tr>
<th>mm</th>
<th>in</th>
</tr>
</thead>
<tbody>
<tr>
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<td>3.0876</td>
</tr>
<tr>
<td>78.452</td>
<td>3.0887</td>
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</tbody>
</table>

Inspect the thrust bearing(s) for pitting, cracking, scratching, uneven wear, or other damage. Replace the thrust bearing(s) and inspect the corresponding gear if damage is found.

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**Install**

⚠️ **CAUTION** ⚠️

The timing pin and wedge must be installed before any gears are removed and must remain in place until all gears are fully installed and torqued. Failure to install the timing pin and wedge can lead to improper timing of the engine, resulting in severe engine damage or engine failure.
**CAUTION**

The gear train must be assembled in the same sequence as this procedure lists. Failure to follow this sequence may result in severe engine damage.

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**Fuel Pump Idler Gear**

Be sure the fuel pump is timed correctly before installing the fuel pump idler gear. Refer to Procedure 005-037 in Section 5.

Apply Lubriplate™ to the thrust bearing, shaft, and fuel pump idler gear.

Install the thrust bearing, shaft, and fuel pump idler gear. The shaft must be installed with the alignment mark (1) (stamped on the gear retainer) pointed toward the center of the lower idler scissor gear.

Install the capscrews.

Tighten all capscrews evenly.

**Torque Value:**

1. 30 n.m  [22 ft-lb]
2. Rotate each capscrew an additional 60 degrees in the same sequence as above.

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**Lower Idler Scissor Gear**
The lower scissor idler gear must be unloaded during installation. To unload the gear, two of the gear adjusting screws must be backed out far enough to allow the teeth on the scissor gear to be aligned.

Apply Lubriplate™ to the thrust bearing, shaft, and lower scissor idler gear.

Install the thrust bearing, shaft, and lower scissor idler gear. The shaft must be installed with the word “TOP” (stamped on the end of the shaft) toward the top of the engine.

The slots in the gear retainer plate go toward the scissor gear.

Install the retainer and capscrews.

Tighten all capscrews in the alternating pattern shown in the illustration.

Torque Value:

1. 30 n.m  [22 ft-lb]
2. Rotate each capscrew an additional 60 degrees in the same alternating patterns.

NOTE: The lower idler scissor gear must not be loaded until all other gears are installed and tightened.

Accessory Drive Gear
If equipped, install the air compressor. Refer to Procedure 012-014 in Section 12.

Upper Idler Gear

Apply Lubriplate™ to the spacer plate/shaft assembly and the upper idler gear.

The spacer plate/shaft assembly is doweled to the block with two standard dowels.

Install the mounting spacer plate/shaft assembly and the upper idler gear.

The spacer plate/shaft assembly must be installed with the word “OIL PAN” (stamped on the front face of the shaft) oriented toward the oil pan.
The slots in the gear retainer plate go toward the upper idler gear

Install the retainer and capscrews.

Tighten all capscrews in the alternating pattern as shown in the illustration.

**Torque Value:**

1. 30 n.m  [22 ft-lb]
2. Rotate each capscrew an additional 60 degrees in the same alternating pattern.

**Camshaft Idler Gear (Adjustable)**

⚠️ **CAUTION** ⚠️

The camshaft idler gear retainer and shaft must be oriented with the part number facing outward, such that the oil drain from the head is not blocked. If blocked, engine operation will be affected.

Apply Lubriplate™ to the shaft and camshaft idler gear.

Install the shaft and the adjustable camshaft idler gear. The shaft must be installed with the words “OIL PAN” (1) and the arrow (stamped on the front face of the shaft) pointing toward the oil pan.
The slots in the gear retainer plate go toward the gear.

Install the retainer and capscrews. Hand-tighten the capscrews and then loosen by one “flat,” which is 60 degrees.

Be sure that the oil hole in the retainer plate and shaft (1) is in line with the oil drilling in the head.

**NOTE:** The camshaft idler gear is installed loosely, because it is moved into its final position later in the timing process.

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**Valve Camshaft Gear**

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⚠️ **WARNING** ⚠️

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer’s recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠️ **CAUTION** ⚠️

The valve camshaft nose and valve camshaft gear must be clean and dry prior to assembly. Wipe off the shaft surface and gear with a lint-free cloth and do not touch the surfaces after wiping. Engine damage can occur.

⚠️ **CAUTION** ⚠️

The camshaft gear retaining capscrew torque process must be completed within
Scrape off any Loctite™ residue from the bore of the valve camshaft gear.

Clean the valve camshaft and camshaft gear bore with Envirosol™ 655 solvent, or equivalent, and a lint-free cloth.

Do not spray solvent directly onto the camshaft nose. Spray solvent onto a clean, lint-free cloth, and then wipe the camshaft nose clean. No oil residue can remain and these surfaces are not to be touched once cleaned.

Apply a thin coat of Loctite™ 609, Part Number 3823718, to the camshaft nose and camshaft gear bore.

Install the valve camshaft gear loosely on the camshaft nose taper.

The valve camshaft gear needs to be fully engaged on the camshaft nose taper, yet loose enough so it can rotate on the camshaft nose.

Install the tone wheel and capscrew, making sure that the key on the tone wheel matches up properly with the keyed hole in the camshaft.

Hand-tighten the capscrew and then loosen by one “flat,” which is 60 degrees.

**NOTE:** The valve camshaft gear is still loose at this point to allow the adjustable idler gear to be properly positioned. Do not seat the gear.
The lower idler scissor gear must still be unloaded during this step. To unload the gear, two of the gear adjusting screws must be backed out far enough to allow the teeth on the scissor gear to be aligned.

Insert, as illustrated, a narrow shim (0.25 mm [0.010 in]) into the gear teeth mesh between the camshaft idler gear and the upper idler gear, as well as a narrow shim (0.25 mm [0.010 in]) into the mesh between the camshaft idler gear and the valve camshaft gear.

**NOTE:** Per the above adjustable idler gear install procedure, be sure that the oil hole in the retainer plate and the shaft are in line with the oil drilling in the head. Use the camshaft idler gear retainer markings to insert the feeler gauges in the correct teeth mesh. The triangles represent idler gear teeth. The lines represent the feeler gauge placement.

**Shim Tolerance**

<table>
<thead>
<tr>
<th>mm</th>
<th>in</th>
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<tbody>
<tr>
<td>0.225</td>
<td>MIN 0.009</td>
</tr>
<tr>
<td>0.275</td>
<td>MAX 0.011</td>
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</table>

Use hand pressure only, to move the camshaft idler gear toward the center of the engine and rotate the cam gear clockwise (into mesh), so there is no gap on either side of the shim.

A slight drag will be felt on the shims while
pulling the shims in and out. Do **not** remove the shims.

Hold the adjustable camshaft idler gear in position and tighten the capscrews. Use the alternating pattern shown in the illustration. Tighten all capscrews in an alternating pattern.

1. Tighten the camshaft idler gear mounting capscrews: **30 N•m [22 ft-lb]**.
2. Tighten the valve camshaft gear mounting cap screw: **30 N•m [22 ft-lb]**.
3. Rotate the camshaft idler gear mounting capscrews an additional 60 degrees.
4. Tighten the valve camshaft gear mounting cap screw: **148 N•m [109 ft-lb]**

Remove the shims.

A slight drag should be felt on the shims while pulling the shims out.

**CAUTION**

Make sure all the scissor gear screws are tightened to the proper torque so that they do not back out during engine operation. Severe engine damage can occur.

**NOTE:** If the fuel pump and air compressor have been removed, do not perform these last three steps until the fuel pump and air...
compressor have been installed.

The lower idler scissor gear must not be loaded until all other gears are installed and tightened.

Load the lower idler scissor gear by tightening all of the gear adjusting screws.

**Torque Value:** 29 n.m [21 ft-lb]

Coat the entire gear train with clean 15W-40 oil.

Remove the valve camshaft timing wedge.

A sudden jerking motion upward is the most effective way to remove the wedge.

Remove the crankshaft locking pin.

Install the plug into the timing pin boss hole.

**Torque Value:** 20 n.m [177 in-lb]

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Rotation Check
Rotate the crankshaft over 360 degrees.
Check the fuel pump idler gear capscrews.
Tighten the fuel pump idler gear capscrews.

**Torque Value:** 95 n.m [70 ft-lb]

If any of the capscrews rotate prior to achieving the above torque value:

- Loosen all three capscrews
- Tighten the capscrews. Use the method specified in the Install Step of this procedure for the fuel pump idler gear.

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**Finishing Steps**

- Install the camshaft position sensor. Refer to Procedure 019-363 in Section 19.
- Install the upper gear cover. Refer to Procedure 001-079 in Section 1.
- Install the crankshaft position sensor. Refer to Procedure 019-365 in Section 19.
- Install the lower gear cover. Refer to Procedure 001-080 in Section 1.
- Install the rocker lever cover and gasket. Refer to Procedure 003-011 in Section 3.
- Install the EGR crossover tube. Refer to Procedure 011-070 in Section 11.
- If coolant, oil, excessive fuel, or excessive black smoke has entered the exhaust system, the aftertreatment system must be inspected.
  - Use the following procedure to check the aftertreatment selective catalytic reduction. Refer to Procedure 014-015 in Section 14.
Use the following procedure to check the aftertreatment diesel particulate filter. Refer to Procedure 014-016 in Section 14.

- Operate the engine to normal operating temperature and check for leaks and proper operation.