**Note:**

This section outlines the procedure for installing a new camshaft and lifter set for test in the test cell. Technicians must make sure they follow all safety guidelines and lock out procedures specified by each laboratory before performing these procedures.

**Caution:**

All dynamometer operating systems must be locked out before performing these operations.

**Camshaft and Lifter Removal Procedure**

|  |  |
| --- | --- |
|  | Refer to Figure 1:   1. Ensure that the starting system has been disabled to prevent accidental cranking of engine. Lock out or disconnect starter electrical cable to engine (A). 2. Remove the safety guard (B) from around the front pulley to allow access to the front of the engine. |
| Figure 1 |  |
|  | Refer to Figure 2:   1. Remove the exhaust safety guard (A) from the exhaust system to allow access to the left side of the engine. |
| Figure 2 |  |
|  | Refer to Figure 3:   1. Using a marker, mark the four (4) ignition coil packs (A) with their respective positions. 2. Using a 5 mm Allen drive socket wrench, remove the bolts securing each of the four (4) coil packs. Keep the coil packs connected to the harness. The spaces between the intake manifold runners (B) are a good location to place the coil packs once removed. |
| Figure 3 |  |
|  | Refer to Figure 4:   1. Remove the crankcase pressure transducer line (A) and the crankcase ventilation line (B). |
| Figure 4 |  |
|  | Refer to Figure 5:   1. Remove the jacketed rocker cover (OHT p/n OHTIVB-002-1) and place the rocker cover assembly on the driveshaft guard. Do not disconnect the coolant hoses from the jacketed rocker cover. |
| Figure 5 |  |
|  | Refer to Figure 6:   1. Using a 16 mm spark plug socket wrench, remove the spark plugs from all cylinders. |
| Figure 6 |  |

|  |  |
| --- | --- |
|  | Refer to Figure 7:   1. Using a 19 mm socket wrench, rotate the crankshaft clockwise until the cylinder #1 piston is at top-dead-center (TDC) of the compression stroke, which can be confirmed with the following visual cues. The directions noted in the following description are valid when viewing the engine from the front.    1. Cylinder 1 intake cam lobes (A) are pointed towards the left (see Figure 8).    2. Cylinder 1 exhaust cam lobes (B) are pointed towards the right (see Figure 8).    3. Rectangular marks (C) on the camshaft sprockets are positioned vertically (see Figure 8).    4. TDC mark (D) on the crankshaft pulley is aligned with the TDC mark inscribed on the front cover (see Figure 9) |
| Figure 7 |  |
|  |  |
| Figure 8 | Figure 9 |
|  | Refer to Figure 10:   1. Using a marker, mark the chain link that is aligned with the rectangular marks on the camshaft sprockets.   **Note: Unlike conventional timing alignment procedures, it is not necessary to align the gold links on the timing chain.** |
| Figure 10 |  |
|  | Refer to Figure 11:   1. If not already present, scribe permanent reference marks on the camshaft sprockets and crankshaft pulley to ensure proper alignment during reassembly. |
| Figure 11 |  |
|  | Refer to Figure 12:   1. Remove the timing chain access cover (OHT p/n IVB003-3) and gasket (OHT p/n IVB003-4) from the OHT front cover (OHT p/n OHTIVB-003-1). Insert a wedge (A) between the chain tensioner arm (B) and chain tensioner guide. Push the wedge down, making sure that it is firmly in place, preventing the chain tensioner arm from collapsing onto the guide. |
| Figure 12 |  |

|  |  |
| --- | --- |
|  | **Removing exhaust camshaft sprocket bolts**  Refer to Figure 13:   1. Hold the camshaft in position with an adjustable wrench. Tighten the wrench jaws on the 20 mm wrench flats located in the middle of the camshaft (A).   **Note: Do not loosen or tighten camshaft sprocket bolts using only the timing chain to prevent the sprocket from rotating.**   1. While holding the use an open-ended wrench or a crow’s foot wrench attachment (B) to loosen the camshaft sprocket bolt. Take care not to damage the front cover sealing surfaces.   **Note: Do not remove camshaft sprocket bolts from the intake camshaft.** |
| Figure 13 |  |
|  | **Removing exhaust camshaft and bearing end caps**  Refer to Figure 14:   1. Carefully remove exhaust camshaft bolt and sprocket without dislodging the timing chain wedge. Carefully lay the chain into the timing cover. 2. Loosen front bearing end cap bolts with a 12 mm socket speed handle. Loosen remaining bearing end cap bolts with a 10 mm socket speed handle in the following order: E5, E2, E4, E3.   **Note: Only loosen bearing end cap bolts in ¼-turn increments.**   1. Remove exhaust camshaft and bearing end caps. |
| Figure 14 |  |
|  | **Removing intake camshaft and bearing end caps**  Refer to Figure 15:   1. Carefully remove the timing chain from the intake camshaft sprocket. Carefully lay the chain into the timing cover. 2. Loosen bearing end cap bolts with a 10 mm socket speed handle in the following order: I5, I2, I4, I3.   **Note: Only loosen bearing end cap bolts in ¼-turn increments.**   1. Remove intake camshaft and bearing end caps. |
| Figure 15 |  |
|  | Refer to Figure 16:   1. Place the intake camshaft on a non-marring surface. Have a secondary technician hold the intake camshaft in place with an adjustable wrench at the 20 mm wrench flats. The primary technician uses a 14 mm socket wrench to loosen and remove the camshaft sprocket and bolt. |
| Figure 16 |  |
|  | Refer to Figure 17:   1. Keep all lifters in order and record lifter size and position on the appropriate form for reassembly of new parts. An example of the form used for recording lifter size information is shown in Table 1, below. The lifter size is found on the underside of the lifter. This information is used to predict the lifter sizes of the next set of lifters to be installed in the engine. 2. If break-in parts are removed, store the parts in the appropriate area for reuse in the next break-in procedure. If test parts are removed, deliver the parts to metrology for post-test measurements |
| Figure 17 |  |
| Table 1: Example form used to record lifter sizes   |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Front of Engine |  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | Intake |  |  |  |  |  |  |  |  | | Exhaust |  |  |  |  |  |  |  |  | | |
|  |  |
|  | Refer to Figure 18:   1. Clean the OHT jacketed rocker cover of oil residue by spraying with degreasing solvent. Wipe oil residue off with lint-free terry towels. Air-dry with clean, dry compressed air. |
| Figure 18 |  |
|  | Refer to Figure 19:   1. Remove oil in the cylinder head valve deck using a vacuum cart or syringe. Suction as much oil from the valve deck as possible. |
| Figure 19 |  |

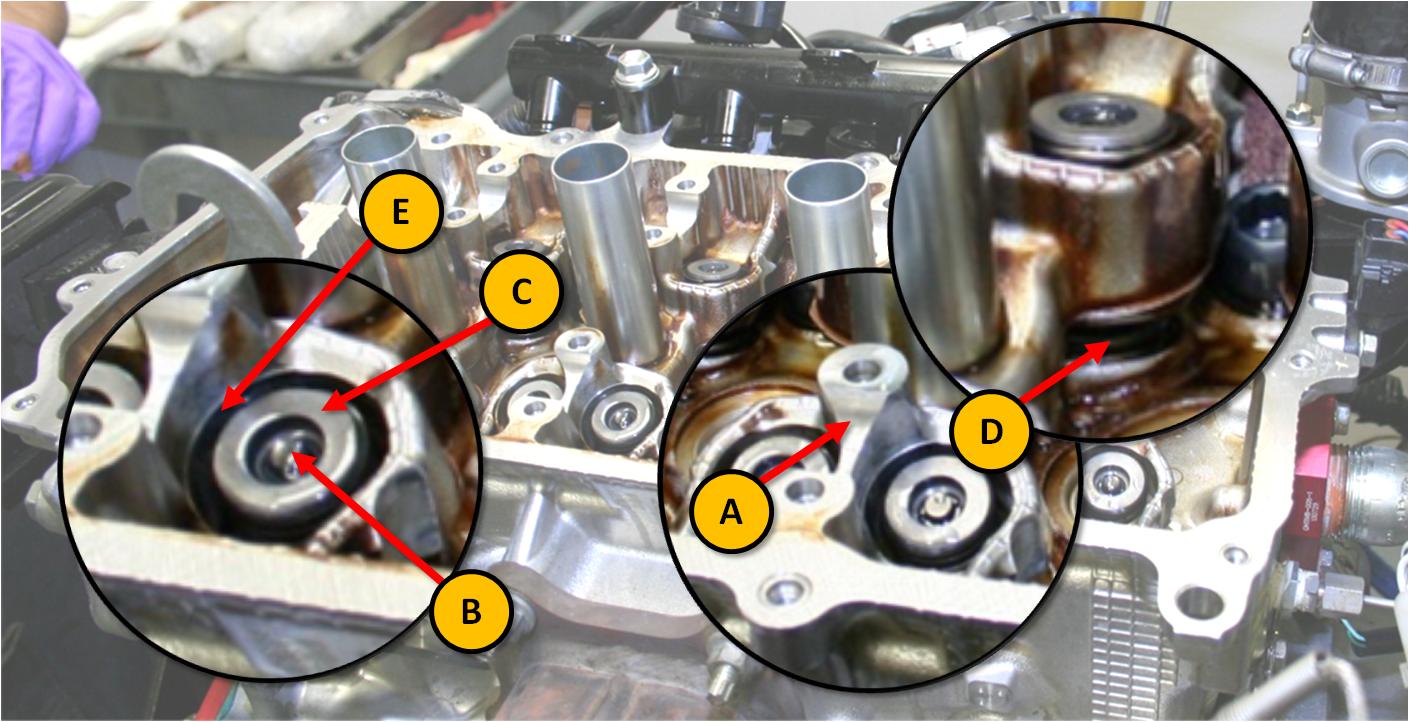


Figure 20

Refer to Figure 20:

1. Visually inspect the following areas:
   1. Camshaft bearing surfaces
   2. Valve stem tips
   3. Valve retainers and keepers
   4. Valve springs
   5. Lifter bore areas
2. Report any visual defects to the appropriate engineer for further instruction.

**THIS COMPLETES THE IN-TEST CELL DISASSEMBLY AND PREPARATION FOR REASSEMBLY.**

**Pre-Test Measurement Procedure**

|  |  |
| --- | --- |
|  | 1. Clean camshafts to be installed using degreasing solvent. Air dry with clean, dry shop air. 2. Clean camshaft bearing surfaces in the valve deck and camshaft bearing end caps with lint-free terry towels and degreasing solvent. Wipe dry with clean, dry terry towels.   Refer to Figure 20:   1. Place camshafts to be installed onto the bearing surfaces without lifters in the neutral, unloaded position. |
| Figure 20 |  |
|  | **Measuring camshaft end play**  Refer to Figure 21:   1. Install the bearing end caps on intake and exhaust camshafts. Ensure the front marks (arrows) and position numbers stamped on the bearing end caps are in the order shown.   **Note: Front bearing end cap is not labeled.**   1. Apply a light coat of EF-411 assembly fluid to the threads and under the heads of the bearing end cap bolts. 2. Fasten bearing end cap bolts and snug lightly with 10 mm socket speed handle in the following order for both intake and exhaust camshafts: 3, 4, 2, 5. Fasten front bearing end cap bolts and snug lightly with 12 mm socket speed handle. |
| Figure 21 |  |
|  | Refer to Figure 22:   1. Using 10 mm socket torque wrench, torque bearing end cap screws to the target torque in the sequence shown. Use a 12 mm socket torque wrench for the front bearing end cap bolts. The target torques for each bolt in Table 2.   Table 2: Target torques for bearing end cap bolts   |  |  |  |  | | --- | --- | --- | --- | | Item | Length  [mm (in)] | Thread Diameter  [mm (in)] | Target Torque  [N-m (ft-lbf)] | | Black | 40 (1.57) | 6 (0.236) | 13 (9) | | White | 40 (1.57) | 8 (0.315) | 21 (15) | |
| Figure 22 |  |
|  | **Measuring camshaft end play**  Refer to Figure 23:   1. Using a rubber mallet, tap the rear of the camshaft until the rear surface of the front bearing end cap is stopped against the rear flange of the first journal. 2. Using a feeler gage, measure the clearance between the front flange of the first journal and the front surface of the front bearing end cap. This is the camshaft end play.   **Note: Minimum camshaft end play = 0.038 mm (0.0015 in). Notify test engineer of any deviation.**     1. Record the intake and exhaust camshaft end play in the Engine Build Data file. |
| Figure 23 |  |
|  | **Measuring camshaft bearing clearance**   1. Remove front bearing end cap bolts using 12 mm socket wrench. Remove the remaining bearing end cap bolts using 10 mm socket wrench in the following order: E5, E2, E4, E3. Remove all camshaft bearing end caps.   Refer to Figure 24:   1. Clean journal surfaces, and apply strips of Plastigage along the centerline of each camshaft journal. 2. Repeats steps 4-7 above to install camshaft bearing end caps. **DO NOT ROTATE CAMSHAFTS!** 3. Remove front bearing end cap bolts using 12 mm socket wrench. Remove all remaining bearing end cap bolts using 10 mm socket wrench in the following order: E5, E2, E4, E3. Remove all camshaft bearing end caps. |
| Figure 24 |  |
|  | Refer to Figure 25:   1. Measure the bearing clearance of each journal by measuring the width of each deformed Plastigage segment. Record all clearance data in the Engine Build Data file.   **Note: Standard oil clearance = 0.035 – 0.072 mm (0.001 – 0.003 in). Notify test engineer of any deviation.**   1. Remove intake and exhaust camshafts. Clean off all Plastigage residue from each camshaft and bearing end caps using clean degreasing solvent. Air dry with clean, dry shop air. |
| Figure 25 |  |

|  |  |
| --- | --- |
|  | **Measuring camshaft sprocket diameter**  Refer to Figure 26:   1. If the current sprocket has completed its sixth (6th) test run, replace with a new sprocket (OHT p/n OHTIVB-13523-1). 2. Wrap a new timing chain around the circumference of camshaft sprocket. Pinch the chain as shown. 3. Use vernier caliper to measure the diameter of the entire assembly. Measure sprocket diameters of both intake and exhaust camshaft sprockets. Record sprocket diameters in the Engine Build Data file.   **Note: Minimum sprocket diameter with chain = 96.2 mm (3.79 in). Notify test engineer of any deviation.** |
| Figure 26 |  |

This completes the pre-test measurement of camshaft end play, bearing clearances, and sprocket diameters.

**Camshaft and Lifter Installation**

|  |  |
| --- | --- |
|  | Refer to Figure 27:   1. Record ID numbers of the lifters to be installed in the appropriate positions on the Engine Build Data file. An example of the form used for recording lifter ID numbers is shown in Table 3, below. The lifter ID number is inscribed on the underside of the lifter.   **Note: Lifter ID number is NOT the lifter size. It is a serial number that is assigned by the test lab to trace the lifters used each test.** |
| Figure 27 |  |
| Table 3: Example form used to record lifter ID numbers   |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Front of Engine |  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | Intake |  |  |  |  |  |  |  |  | | Exhaust |  |  |  |  |  |  |  |  | | |
|  |  |
|  | 1. Inspect all areas of the cylinder head for cleanliness, foreign objects, or debris from previous procedures. Pay close attention to the following areas for any defects:    1. Valve stem tips    2. Valve retainers    3. Valve springs    4. Lifter bores   Refer to Figure 28:   1. Apply a light coat of EF-411 assembly fluid to the valve stem tips, lifter bores, and camshaft journals. |
| Figure 28 |  |
|  | Refer to Figure 29:   1. Install lifters in the appropriate positions. |
| Figure 29 |  |
|  | Refer to Figure 30:   1. Coat lifter surface at each position with EF-411 assembly fluid. |
| Figure 30 |  |
|  | Refer to Figure 31:   1. On a clean, non-marring surface, install the intake camshaft sprocket, and finger-tighten the camshaft sprocket bolt. 2. Have a secondary technician hold the intake camshaft in place with an adjustable wrench at the 20 mm wrench flats. The primary technician uses a 14 mm torque wrench to carefully torque the camshaft sprocket bolt to 54 Nm (40 ft-lbf). 3. Carefully lift the timing chain from within the front cover without dislodging the timing chain wedge. |
| Figure 31 |  |
|  | Refer to Figure 32:   1. Install the timing chain onto the intake camshaft sprocket. Ensure that the chain link marked during camshaft removal coincides with the rectangular mark on the intake camshaft sprocket (A).   **Note: Do not install camshaft bearing end caps at this time. Camshaft must remain free-resting in cylinder head.**   1. Place the intake camshaft on the appropriate bearing surface. Rotate the camshaft until the rectangular mark (A) and the scribed mark (B) on the sprocket are in the 12 o’clock and 9 o’clock positions, respectively. 2. Install the timing chain onto the exhaust camshaft sprocket. Position the exhaust camshaft sprocket such that the rectangular mark (A) and the scribed mark (B) on the sprocket are in the 12 o’clock and 3 o’clock positions, respectively.   **Note: There should be eight (8) links between the marked chain links, including the marked chain links.**   1. Install the exhaust camshaft sprocket onto the exhaust camshaft. Finger-tighten the camshaft sprocket bolt only. |
| Figure 32 |  |
|  | Refer to Figure 33:   1. Lubricate the camshafts, journals, and lifters with EF-411 assembly fluid.   **Caution: Do not fill the threaded holes that receive the bearing end cap bolts with EF-411 assembly fluid. Hydraulic lock, false torque, or cracking of the cylinder head may occur.** |
| Figure 33 |  |
|  | Refer to Figure 34:   1. Lubricate camshaft bearing end caps with EF-411 assembly fluid. 2. Lubricate bearing end cap bolts with a light coat of EF-411 on the threads and underneath each bolt head. Lightly blot excess oil off the bolts. 3. Install camshaft bearing end caps. |
| Figure 34 |  |
|  | Refer to Figure 35:   1. Using 10 mm socket torque wrench, torque each bolt in the sequence to the target torque shown in Table 4, below. Slowly and uniformly tighten the bolts in ½-turn increments following the sequence shown. 2. Using 12 mm socket torque wrench, torque each bolt in the sequence to the target torque shown in Table 4, below. Slowly and uniformly tighten the bolts in ½-turn increments following the sequence shown.   Table 4: Target torques for bearing end cap bolts   |  |  |  |  | | --- | --- | --- | --- | | Item | Length  [mm (in)] | Thread Diameter  [mm (in)] | Target Torque  [N-m (ft-lbf)] | | Black | 40 (1.57) | 6 (0.236) | 13 (9) | | White | 40 (1.57) | 8 (0.315) | 21 (15) | |
| Figure 35 |  |
|  | Refer to Figure 36:   1. Utilizing the wrench flats on the intake camshaft, turn the intake camshaft counter-clockwise to take out the timing chain slack between the camshaft sprockets. Stop once the slack is removed.   **Note: Do not rotate the engine by force using the wrench flats on the camshafts.**   1. Verify cylinder 1 piston is in TDC position on the compression stroke using the visual cues described in sheet 3, step 9. If the timing marks are not properly aligned, remove the exhaust camshaft sprocket and reposition the valvetrain components to obtain proper alignment. |
| Figure 36 |  |
|  | Refer to Figure 37:   1. If the timing marks are properly aligned, hold the exhaust camshaft at the wrench flats with adjustable wrench (A). 2. Using 14 mm crow’s foot torque wrench (B), torque the exhaust camshaft sprocket bolt to 54 Nm (40 ft-lbf).   **Note: Do not use the timing chain to hold the sprocket while applying torque.** |
| Figure 37 |  |
|  | Refer to Figure 38:   1. Remove wedge holding the timing chain tensioners. Verify alignment of timing marks. 2. Using 19 mm socket wrench, slowly rotate the engine through two complete revolutions. Verify alignment of timing marks. |
| Figure 38 |  |
|  | Refer to Figure 39:   1. Install the OHT timing chain access cover (A) (OHT p/n IVB003-3) and gasket (OHT p/n IVB003-4). Using a 8 mm socket torque wrench, torque all bolts to 5 Nm (44 ft-lbf). |
| Figure 39 |  |

This completes the camshaft installation procedure.

**Valve Clearance Measurement**

|  |  |
| --- | --- |
|  | Refer to Figure 40:   1. Verify cylinder 1 piston is in TDC position on the compression stroke using the visual cues described in sheet 2, step 9. While the engine is in this orientation, the highlighted cam lobes can be measured for valve clearance. |
| Figure 40 |  |
|  | Refer to Figure 41:   1. Using a feeler gage, measure the clearance between the lifter and cam lobe base circle. The standard valve clearances (cold) are shown in Table 5, below.   Table 5: Upper and lower limits of valve clearances   |  |  |  | | --- | --- | --- | | Item | Lower Limit  [mm (in)] | Upper Limit  [mm (in)] | | Intake | 0.145 (0.00571) | 0.235 (0.00925) | | Exhaust | 0.275 (0.0108) | 0.365 (0.0144) | |
| Figure 41 |  |
|  | Refer to Figure 42:   1. Using 19 mm socket wrench, rotate the crankshaft one complete rotation to set cylinder 4 to TDC on the compression stroke. While the engine is in this orientation, the highlighted cam lobes can be measured for valve clearance. 2. Repeat step 2 to measure valve clearance for the highlighted cam lobes. |
| Figure 42 |  |

1. Record valve clearance measurements in the appropriate Engine Build Data form. An example form is shown in Table 6, below. If any positions are out-of-specification, contact the project engineer for instructions.

Table 6: Valve clearance measurements

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Intake |  |  |  |  |  |  |  |  |
| Exhaust |  |  |  |  |  |  |  |  |

Intake Valve Clearance Cold: 0.145 to 0.235 mm (0.00571 to 0.00925 in)

Exhaust Valve Clearance Cold: 0.275 to 0.365 mm (0.0108 to 0.0144 in)

This completes the valve clearance measurement procedure.

**Miscellaneous Engine Preparation Procedure**

|  |  |
| --- | --- |
|  | Refer to Figure 43:   1. Using 16 mm spark plug socket wrench, remove and inspect spark plugs (OHT p/n OHTIVB-01258-1). Look for defects, and check spark plug gap. If any defects are noted and/or gap exceeds 1.1 mm (0.043 in), replace with new spark plug, and notify project engineer. 2. To install spark plugs, use 16 mm spark plug socket torque wrench to torque each spark plug to 18 Nm (13 ft-lbf). |
| Figure 43 |  |
|  | Refer to Figure 44:   1. Inspect OHT jacketed rocker cover and O-ring (OHT p/n OHTIVB-002-1). Replace gasket if it is damaged. |
| Figure 44 |  |
|  | Refer to Figure 45:   1. Apply a small dab of RTV sealant at the mating areas indicated between the front cover and the cylinder head.   **Note: The applied sealant should take up no larger than an area of 2.0 x 5.0mm (0.079 x 0.197in).** |
| Figure 45 |  |
|  | Refer to Figure 46:   1. Carefully install the OHT jacketed rocker cover. Ensure the spark plug tube seals properly fit over the spark plug tubes. |
| Figure 46 |  |
|  | Refer to Figure 47:   1. Carefully align and hand-tighten the OHT jacketed rocker cover bolts. 2. Using 10 mm socket torque wrench, torque the fasteners in the sequence shown to 10 Nm (88 ft-lbf). Slowly and uniformly tighten the bolts in ½-turn increments. |
| Figure 47 |  |
|  | Refer to Figure 48:   1. Install the four (4) coil packs. Using 5 mm Allen drive torque wrench, torque coil pack fasteners to 5 Nm (44 ft-lbf). |
| Figure 48 |  |
|  | Refer to Figure 49:   1. Using a 14 mm socket wrench, remove the oil drain plug to allow any excess EF-411 assembly fluid to drain from the engine. 2. Contact project engineer for the proper oil assignment and follow procedural guidelines for oil charging and test initiation. 3. Re-enable the engine starter and all required test stand systems and follow procedures for test start. |
| Figure 49 |  |

This completes the camshaft and lifter removal and reinstallation procedure. The engine is currently ready for testing. Please refer to Engine Operations Manual, Section E for instructions on conducting the Sequence IVB test.