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ENGINE MECHANICAL

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PRECAUTION

PRECAUTIONS

Precaution for Supplemental Restraint System (SRS) "AIR BAG" and "SEAT BELT PRE-TENSIONER"

INFOID:0000000014418462

The Supplemental Restraint System such as “AIR BAG” and “SEAT BELT PRE-TENSIONER”, used along with a front seat belt, helps to reduce the risk or severity of injury to the driver and front passenger for certain types of collision. Information necessary to service the system safely is included in the SR and SB section of this Service Manual.

WARNING:

- **To avoid rendering the SRS inoperative, which could increase the risk of personal injury or death in the event of a collision which would result in air bag inflation, it is recommended that all maintenance and repair be performed by an authorized NISSAN/INFINITI dealer.**
- **Improper repair, including incorrect removal and installation of the SRS, can lead to personal injury caused by unintentional activation of the system. For removal of Spiral Cable and Air Bag Module, see the SR section.**
- **Do not use electrical test equipment on any circuit related to the SRS unless instructed to in this Service Manual. SRS wiring harnesses can be identified by yellow and/or orange harnesses or harness connectors.**

PRECAUTIONS WHEN USING POWER TOOLS (AIR OR ELECTRIC) AND HAMMERS

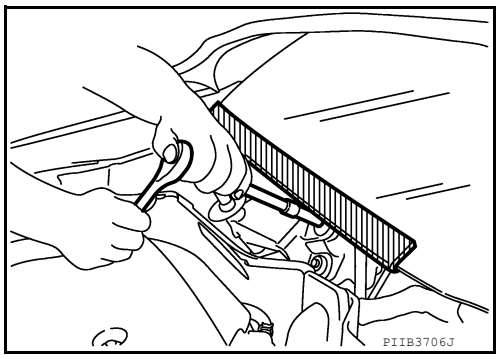
WARNING:

- **When working near the Air Bag Diagnosis Sensor Unit or other Air Bag System sensors with the Ignition ON or engine running, DO NOT use air or electric power tools or strike near the sensor(s) with a hammer. Heavy vibration could activate the sensor(s) and deploy the air bag(s), possibly causing serious injury.**
- **When using air or electric power tools or hammers, always switch the Ignition OFF, disconnect the battery or batteries, and wait at least three minutes before performing any service.**

Precaution for Procedure without Cowl Top Cover

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When performing the procedure after removing cowl top cover, cover the lower end of windshield with urethane, etc.



Precaution for Handling High Pressure Fuel System

INFOID:0000000014418464

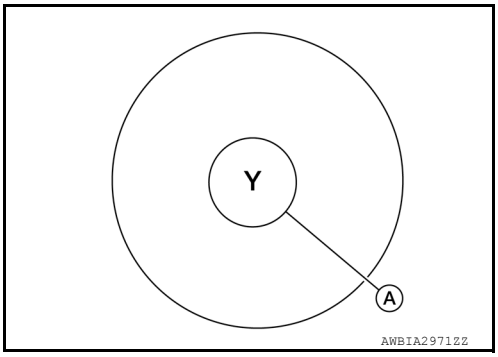
- High pressure fuel system components are between high pressure fuel pump and fuel injector.
- Always release fuel pressure and never start the engine when performing removal and installation.
- When removing or installing parts without releasing fuel pressure, fuel may be splashed and, if fuel contacts skin or eyes, it may cause inflammation.

Special Cautions to Ensure the Safe Disposal of Sodium-filled Exhaust Valves

INFOID:0000000014418465

Handling and disposal of sodium-filled exhaust valves requires special care and consideration. Under conditions such as breakage with subsequent contact with water, metal sodium which lines the inner portion of exhaust valve will react violently, forming sodium hydroxide and hydrogen which may result in an explosion. Sodium-filled exhaust valve is identified on the top of its stem as shown in illustration.

(A) : Identification mark of sodium-filled exhaust valve



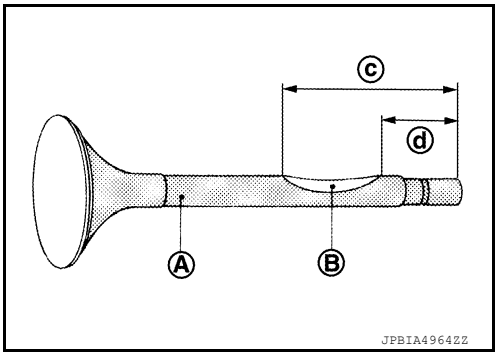
DEALER DISPOSAL INSTRUCTIONS

CAUTION:

- **Use approved shatter-resistant eye protection when performing this procedure.**
- **Perform this and all subsequent disposal work procedures in an open room, away from flammable liquids. Keep a fire extinguisher, rated at least 10 ABC, in close proximity to the work area.**
- **Be sure to wear rubber gloves when performing the following operations.**
- **Make sure the resultant (high alkalinity) waste water does not contact your skin. If the waste water does contact you, wash the contacted area immediately with large quantities of water.**
- **Dealers should check their respective state and local regulations concerning any chemical treatment or waste water discharge permits which may be required to dispose of the resultant (high alkalinity) waste water.**

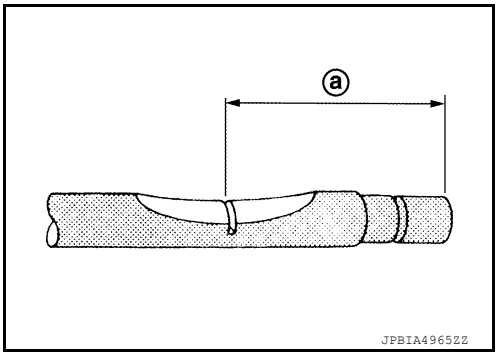
1. Clamp valve stem in a vice.
2. The valve has a specially-hardened surface. To cut through it, first remove a half-round section, approximately 30 mm (1.18 in) long using air-powered grinder until black color is removed and silver color appears.

(A) : Black color
(B) : Silver color
(c) : 47 mm (1.85 in)
(d) : 17 mm (0.67 in)

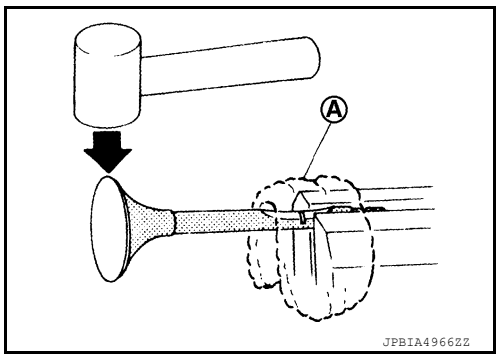


3. Use hacksaw to cut through approximately half the diameter of valve stem. Make the serration at a point 40 mm (1.57 in) from the end of valve stem.

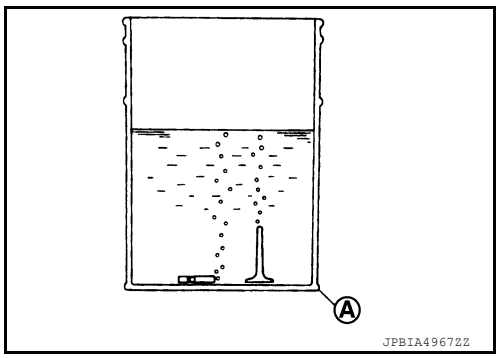
(a) : 40 mm (1.57 in)



4. Cover the serrated end of the valve with a large shop towel (A). Strike the valve face end with a hammer, separating it into two pieces.
5. Fill a bucket, such as a 20 ℓ (5-1/4 US gal, 4-3/8 Imp gal) oil can, with at least 10 ℓ (2-5/8 US gal, 2-1/4 Imp gal) of water. Carefully place the already cut (serrated) valves into the water one-at-a-time using a set of large tweezers and quickly move away at least 2.7 m (9 ft).



6. The valves should be placed in a standing position as shown in the illustration to allow complete reaction. After the bubbling action has subsided, additional valves can be placed into the bucket allowing each subsequent chemical reaction to subside. However, no more than eight valves should be placed in the same 10 ℓ (2-5/8 US gal, 2-1/4 Imp gal) amount of water. The complete chemical reaction may take as long as four to five hours. Remove the valves using a set of large tweezers after the chemical reaction has stopped. Afterwards, valves can be disposed as ordinary scrap.



(A) : Bucket [Such as 20 ℓ (5-1/4 US gal, 4-3/8 Imp gal) oil can]

Precautions For Engine Service

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DISCONNECTING FUEL PIPING

- Before starting work, check no fire or spark producing items are in the work area.
- Release fuel pressure before disconnecting and disassembly.
- After disconnecting pipes, plug openings to stop fuel leakage.

DRAINING ENGINE COOLANT

Drain engine coolant and engine oil when the engine is cooled.

INSPECTION, REPAIR AND REPLACEMENT

Before repairing or replacing, thoroughly inspect parts. Inspect new replacement parts in the same way, and replace if necessary.

REMOVAL AND DISASSEMBLY

- When instructed to use SST, use specified tools. Always be careful to work safely, avoid forceful or uninstructed operations.
- Exercise maximum care to avoid damage to mating or sliding surfaces.
- Dowel pins are used for several parts alignment. When replacing and reassembling parts with dowel pins, check that dowel pins are installed in the original position.
- Must cover openings of engine system with a tape or equivalent, to seal out foreign materials.
- Mark and arrange disassembly parts in an organized way for easy troubleshooting and reassembly.
- When loosening nuts and bolts, as a basic rule, start with the one furthest outside, then the one diagonally opposite, and so on. If the order of loosening is specified, do exactly as specified. Power tools may be used in the step.

ASSEMBLY AND INSTALLATION

- Use torque wrench to tighten bolts or nuts to specification.
- When tightening nuts and bolts, as a basic rule, equally tighten in several different steps starting with the ones in center, then ones on inside and outside diagonally in this order. If the order of tightening is specified, do exactly as specified.
- Replace with new gasket, packing, oil seal or O-ring.

- Thoroughly wash, clean, and air-blow each part. Carefully check engine oil or engine coolant passages for any restriction and blockage.
- Avoid damaging sliding or mating surfaces. Completely remove foreign materials such as cloth lint or dust. Before assembly, oil sliding surfaces well.
- After disassembling, or exposing any internal engine parts, change engine oil and replace oil filter with a new one.
- Release air within route when refilling after draining engine coolant.
- After repairing, start the engine and increase engine speed to check engine coolant, fuel, engine oil, and exhaust gases for leakage.

Parts Requiring Angle Tightening

INFOID:0000000014418467

- Use angle wrench [SST: KV10112100 (BT8653-A)] for the final tightening of the following engine parts:

- Cylinder head bolts
- Main bearing cap bolts
- Main bearing cap sub bolts
- Connecting rod cap bolts
- Crankshaft pulley bolt (No angle wrench is required as the bolt flange is provided with notches for angle tightening)

Tool : KV10112100 (BT8653-A)

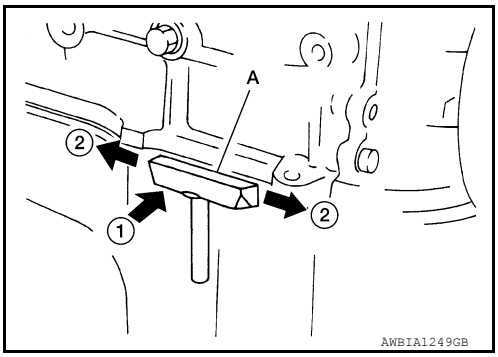
- Ensure thread and seat surfaces are clean and coated with engine oil.

Precaution for Liquid Gasket

INFOID:0000000014418468

REMOVAL OF LIQUID GASKET SEALING

- After removing the bolts and nuts, separate the mating surface and remove the liquid gasket using Tool (A).



Tool Number : KV10111100 (J-37228)

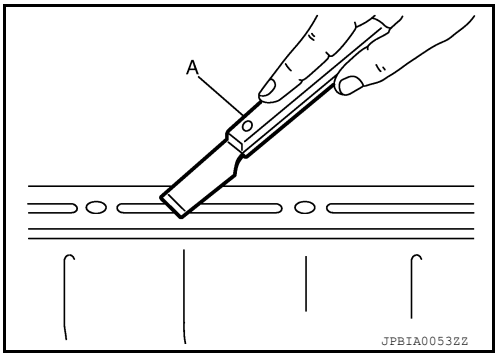
CAUTION:
Be careful not to damage the mating surfaces.

- In areas where the cutter is difficult to use, use a plastic hammer to lightly tap (1) the cutter where the liquid gasket is applied. Use a plastic hammer to slide (2) the cutter by tapping on the side.

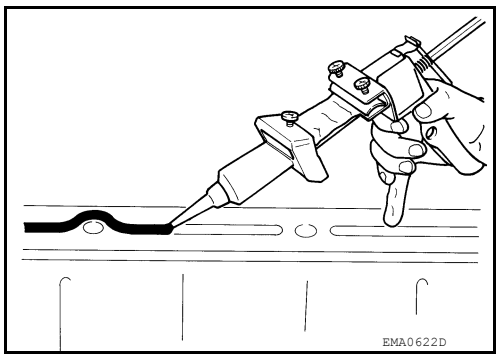
CAUTION:
Do not damage the mating surfaces.

LIQUID GASKET APPLICATION PROCEDURE

1. Using suitable tool (A), remove old liquid gasket adhering to the liquid gasket application surface and the mating surface.
   - Remove liquid gasket completely from the groove of the liquid gasket application surface, mounting bolts, and bolt holes.
2. Thoroughly clean the mating surfaces and remove adhering moisture, grease and foreign materials.

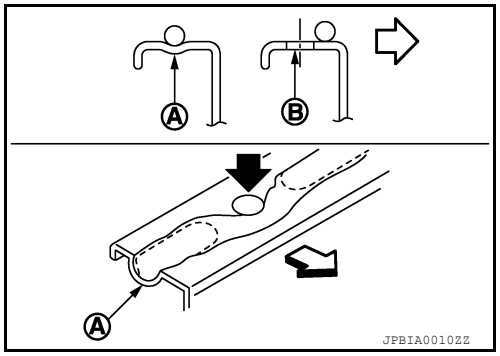


3. Attach liquid gasket tube to the suitable tool.
Use Genuine Silicone RTV Sealant, or equivalent. Refer to GI-22, "Recommended Chemical Products and Sealants".
4. Apply liquid gasket without gaps to the specified location according to the specified dimensions.
   - If there is a groove for liquid gasket application, apply liquid gasket to the groove.



   - As for bolt holes (B), normally apply liquid gasket inside the holes. Occasionally, it should be applied outside the holes. Check to read the text of this manual.

     (A) : Groove
     ⇦ : Inside



   - Within five minutes of liquid gasket application, install the mating component.
   - If liquid gasket protrudes, wipe it off immediately.
   - Do not retighten mounting bolts or nuts after the installation.
   - After 30 minutes or more have passed from the installation, fill engine oil and engine coolant. Refer to LU-10, "Refilling" and CO-11, "Changing Engine Coolant".

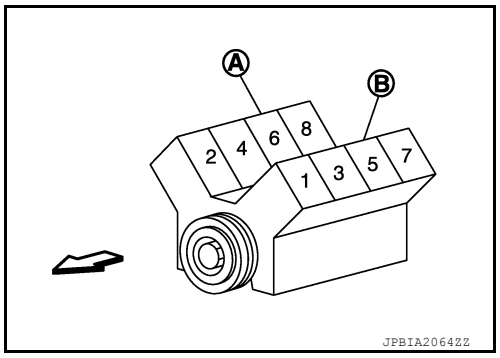
CAUTION:
If there are more specific instructions in the procedures contained in this manual concerning liquid gasket application, observe them.

Definitions of Bank Names

INFOID:0000000014418469

- In this manual, each bank name is defined as per the following:

  (A) : Bank 2 (The conventional right bank)
  (B) : Bank 1 (The conventional left bank)
  ⇦ : Engine front



- For cylinder numbers and bank layout, refer to the figure.

Bank 1 : The bank side including cylinder No. 1 (odd-numbered cylinder side)
Bank 2 : The other bank side of the above (even-numbered cylinder side)

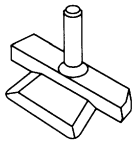
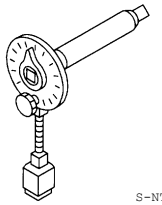
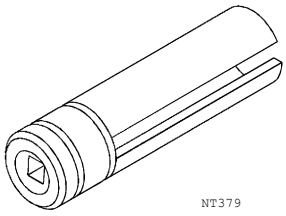
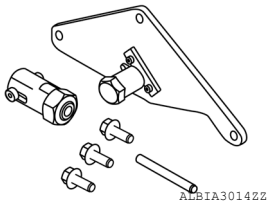
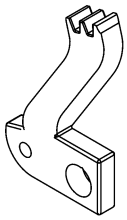
PREPARATION

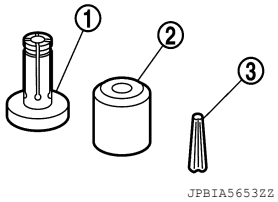
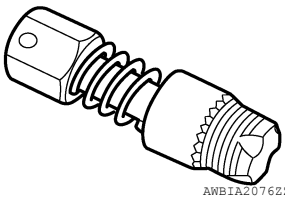
PREPARATION

Special Service Tool

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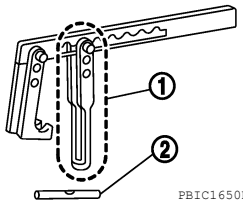
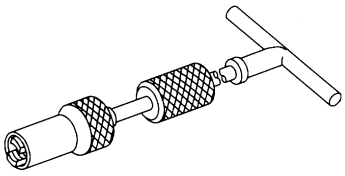
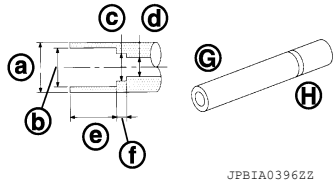
The actual shapes of TechMate tools may differ from those of special service tools illustrated here.

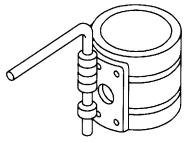
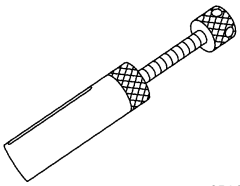
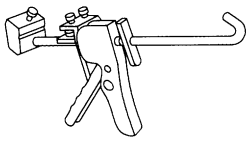
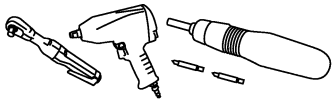
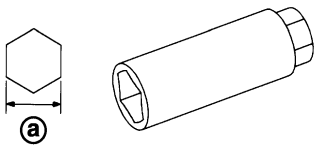
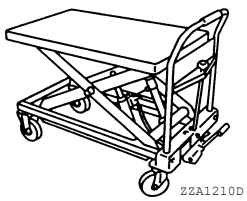
Tool number (TechMate No.) Tool name		Description
KV10111100 (J-37228) Seal cutter	 S-NT046	Removing steel oil pan and front cover
KV10112100 (BT8653-A) Angle wrench	 S-NT014	Tightening bolts for bearing cap, cylinder head, etc.
KV10117100 (J-44626) Heated oxygen sensor wrench	 NT379	Loosening or tightening air fuel ratio sensor 1 and exhaust temperature sensor **a: 22 mm (0.87 in)**
— (J-51269) Oil jet installer/remover • — (J-51269-1) Remover puller • — (J-51269-2) Alignment fixture	 ALBIA3014ZZ	Removing and installing oil jet (bank 2)
KV10120100 (J-47245) Ring gear stopper	 LBIA0451E	Removing and installing crankshaft pulley
— (J-45488) Quick connector release	 PBIC0198E	Removing fuel tube quick connectors in engine room (Available in SEC. 164 of PARTS CATALOG:Part No. 16441 6N210)

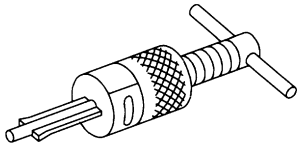
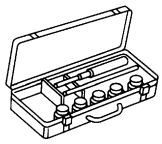
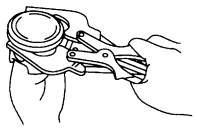
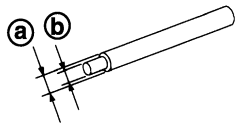
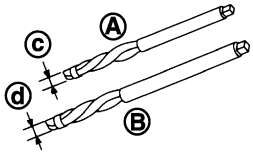
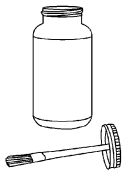
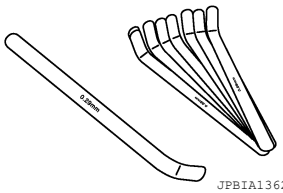
Tool number (TechMate No.) Tool name	Description
KV101197S0 (J-50364) Injector seal drift set 1. KV10119730 (—) Seal installer 2. KV10119710 (—) Drift 3. KV10119720 (—) Seal guide  JPBIA5653ZZ	Installing fuel injector seal ring
(J-43897-18) Oxygen sensor thread cleaner  AWBIA2076ZZ	Reconditioning the exhaust system threads before installing a new heated oxygen sensor (Use with anti-seize lubricant shown below.) **a: J-43897-18 (18 mm dia.) for zirconia heated oxygen sensor and air fuel ratio sensor**

Commercial Service Tool

INFOID:0000000014418471

(TechMate No.) Tool name	Description
KV10116200 (—) Valve spring compressor 1. KV10115900 (—) Attachment 2. KV10109220 (—) Adapter  PBIC1650E	Disassembling valve mechanism Part (1) is a component of KV10116200 but part (2) is not so.
KV10107902 (—) Valve oil seal puller  S-NT011	Removing valve oil seal
KV10115600 (—) Valve oil seal drift  JPBIA0396ZZ	Installing valve oil seal **Use side A (G)** **a: 20 (0.79) dia.** **d: 8 (0.31) dia.** **b: 13 (0.51) dia.** **e: 10.7 (0.421)** **c: 10.3 (0.406) dia.** **f: 5 (0.20)** **H: Side B** Unit: mm (in)

(TechMate No.) Tool name	Description
EM03470000 (—) Piston ring compressor  S-NT044	Installing piston assembly into cylinder bore
KV10119300 (—) Adapter and torque wrench assembly  JPBIA2623ZZ	Tightening rocker cover mounting bolts. (specified torque)
KV10119600 (—) Injector remover  JPBIA3746ZZ	Removing fuel injector
Tube presser  S-NT052	Pressing the tube of liquid gasket
Power tool  PIIB1407E	Loosening nuts, screws and bolts
Spark plug wrench  JPBIA0399ZZ	Removing and installing spark plug **a: 14 mm (0.55 in)**
Manual lift table caddy  ZZA1210D	Removing and installing engine

(TechMate No.) Tool name	Description
Pilot bushing puller  NT045	Removing pilot converter
Valve seat cutter set  S-NT048	Finishing valve seat (EXH) dimensions
Piston ring expander  S-NT030	Removing and installing piston ring
Valve guide drift  JPBIA0400ZZ	Removing and installing valve guide (EXH) **a: 9.5 mm (0.374 in) dia.** **b: 5.5 mm (0.217 in) dia.**
Valve guide reamer  JPBIA0401ZZ	(A): Reaming valve guide (EXH) inner hole (B): Reaming hole for oversize valve guide (EXH) **c: 6.0 mm (0.236 in) dia.** **d: 10.2 mm (0.402 in) dia.**
Anti-seize lubricant (Permatex 133AR or equivalent meeting MIL specification MIL-A-907)  AEM489	Lubricating oxygen sensor thread cleaning tool when reconditioning exhaust system threads
Feeler gauge  JPBIA1362ZZ	Inspection valve clearance (use a curved-tip gauge)

BASIC INSPECTION

CAMSHAFT VALVE CLEARANCE

Inspection

INFOID:0000000014418472

INSPECTION

Check valve clearance if applicable to the following cases:

Intake side:
- At the removal and installation of VVEL ladder assembly or valve-related parts, or at the occurrence of malfunction (poor starting, idle malfunction, unusual noise) due to aged deterioration in valve clearance.

CAUTION:
Valve clearance check on the intake side is not required when replacing the VVEL ladder assembly & cylinder head assembly with a new one. (Install new VVEL ladder assembly & cylinder head assembly in factory-shipped condition because it is factory-adjusted and inspected.)
NOTE:
VVEL ladder assembly cannot be replaced as a single part, because it is machined together with cylinder head assembly.

Exhaust side:
- At the removal, installation, and replacement of exhaust camshaft or valve-related parts, or at the occurrence of malfunction (poor starting, idle malfunction, unusual noise) due to aged deterioration in valve clearance.

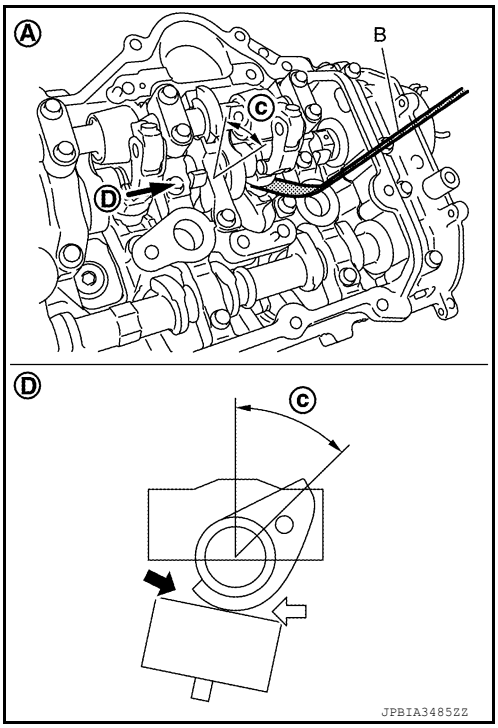
1. Remove VVEL actuator housing assembly. Refer to EM-41, "Removal and Installation".
2. Measure the valve clearance as per the following:
   - Use a suitable tool with a curved-tip. This allows the suitable tool to access the clearance between camshaft (drive shaft) nose and valve lifter with ease.

Valve clearance : Refer to EM-155, "Camshaft".

NOTE:
Be sure to note the following points when measuring valve clearance on the intake side.
- Before measuring, check that the position of drive shaft nose is within the angle shown in the figure.

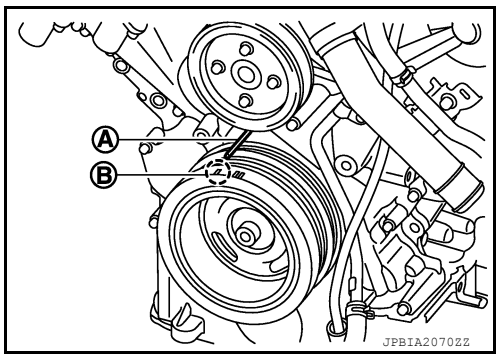
(A) : Bank 2
(B) : Suitable tool
(C) : 45 degrees (drive shaft nose angle)
(D) : View D
⇦ : Insertion direction of feeler gauge on the bank 2
⬅ : Insertion direction of feeler gauge on the bank 1

- Refer to the figure for the insertion direction of the suitable tool since the direction depends on the bank.



a. Set No. 1 cylinder at TDC of its compression stroke.

- Rotate crankshaft pulley clockwise to align timing mark (grooved line without color) (B) with timing indicator (A).

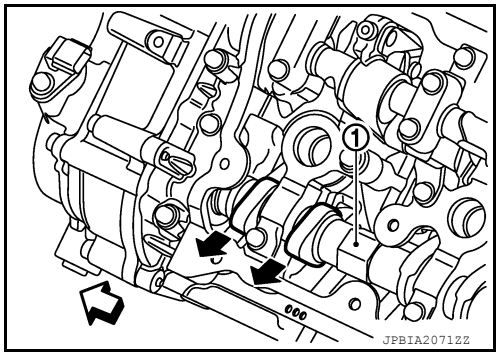


- Check that exhaust cam nose on No. 1 cylinder (engine front side of bank 1) is located as shown in the figure.

(1) : Exhaust camshaft (bank 1)

⇦ : Engine front

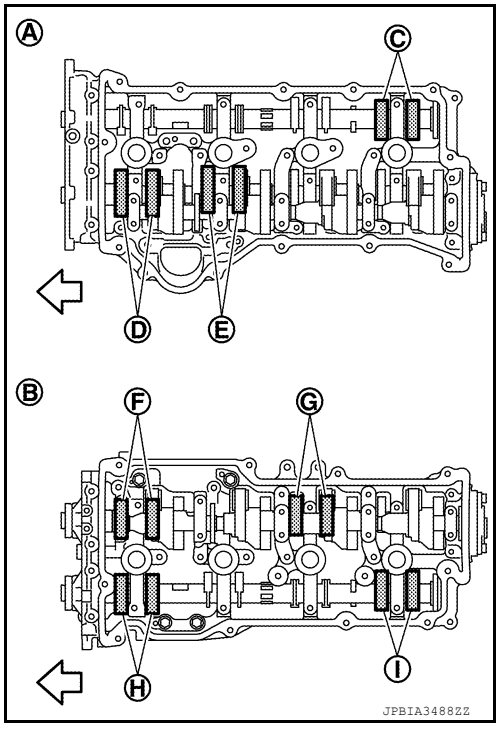
- If not, turn crankshaft one revolution (360 degrees) and align as shown in the figure.



- By referring to the figure, measure the valve clearances at locations marked "×" as shown in the table below (locations indicated in the figure).

⇦ : Engine front

- No. 1 cylinder at compression TDC

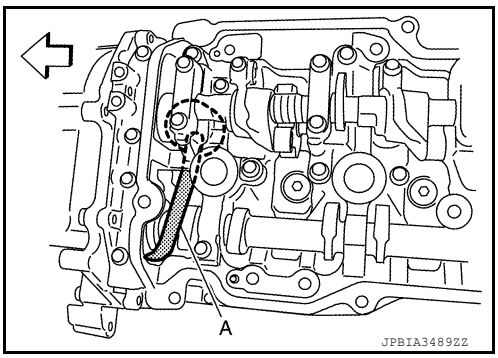


Measuring position [bank 2 (A)]		No. 2 CYL.	No. 4 CYL.	No. 6 CYL.	No. 8 CYL.
No. 1 cylinder at compression TDC	EXH				× (C)
	INT	× (D)	× (E)		
Measuring position [bank 1 (B)]		No. 1 CYL.	No. 3 CYL.	No. 5 CYL.	No. 7 CYL.
No. 1 cylinder at compression TDC	INT	× (F)		× (G)	
	EXH	× (H)			× (I)

NOTE:

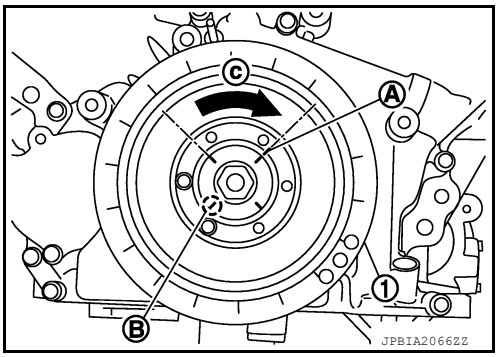
To measure valve clearance of No. 1 cylinder INT valve (front side), insert suitable tool (A) as shown in the figure.

⇦ : Engine front



b. Rotate crankshaft clockwise (when viewed from engine front) to align No. 3 cylinder at TDC its compression stroke.
NOTE:
Crankshaft pulley bolt flange has an angle mark (B) every 90 degrees (c). They can be used as a guide to rotation angle.

(A) : Paint mark

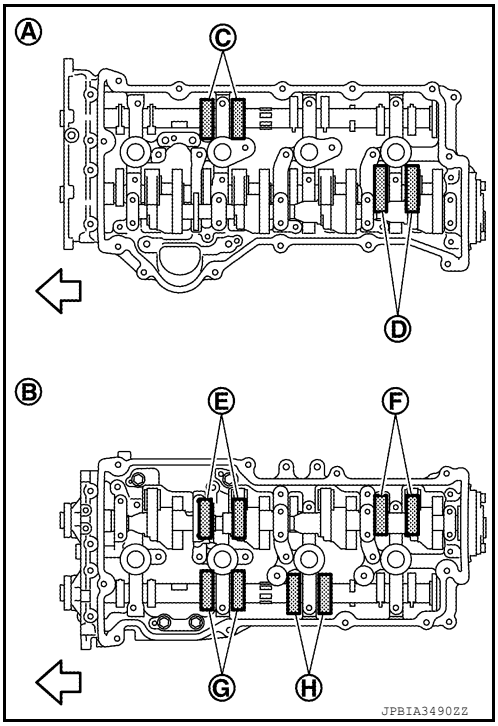


- By referring to the figure, measure the valve clearances at locations marked "×" as shown in the table below (locations indicated in the figure).

⇦ : Engine front

- No. 3 cylinder at compression TDC

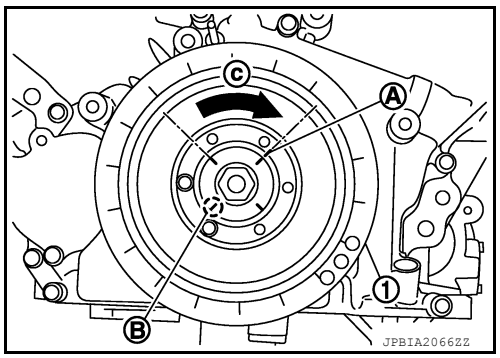
Measuring position [bank 2 (A)]		No. 2 CYL.	No. 4 CYL.	No. 6 CYL.	No. 8 CYL.
No. 3 cylinder at compression TDC	EXH		× (C)		
	INT				× (D)
Measuring position [bank 1 (B)]		No. 1 CYL.	No. 3 CYL.	No. 5 CYL.	No. 7 CYL.
No. 3 cylinder at compression TDC	INT		× (E)		× (F)
	EXH		× (G)	× (H)	



c. Rotate crankshaft clockwise (when viewed from engine front) to align No. 6 cylinder at TDC of compression stroke.
NOTE:

Crankshaft pulley bolt flange has an angle mark (B) every 90 degrees (c). They can be used as a guide to rotation angle.

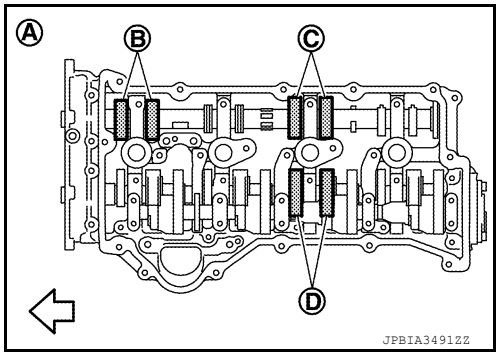
(A) : Paint mark



- By referring to the figure, measure the valve clearances at locations marked "×" as shown in the table below (locations indicated in the figure).

⇦ : Engine front

- No. 6 cylinder at compression TDC



Measuring position [bank 2 (A)]		No. 2 CYL.	No. 4 CYL.	No. 6 CYL.	No. 8 CYL.
No. 6 cylinder at compression TDC	EXH	× (B)		× (C)	
	INT			× (D)	

3. Perform adjustment or replacement if the measured value is out of the standard.
   - If a valve clearance on the exhaust side is out of specification, adjust the valve clearance. Refer to EM-96, "Inspection".
   - If a valve clearance on the intake side is out of specification, adjust the valve clearance. Refer to EM-112, "Inspection".

COMPRESSION PRESSURE

Inspection

INFOID:0000000014418473

1. Warm up engine thoroughly. Then, stop it.
2. Release fuel pressure. Refer to EC-205, "Work Procedure".
   CAUTION:
   If CONSULT is not used to release fuel pressure leave the fuel pump fuse disconnected until step 9.
3. Remove fuel pump fuse in IPDM E/R.
   NOTE:
   - For the fuse number, refer to EC-155, "Wiring Diagram".
   - For the fuse arrangement, refer to PG-174, "IPDM E/R Terminal Arrangement".
4. Remove engine cover. Refer to EM-30, "Exploded View".
5. Remove ignition coil and spark plug from each cylinder. Refer to EM-34, "Exploded View".
6. Connect engine tachometer (not required in use of CONSULT).
7. Install the suitable tool into the spark plug hole.
8. With accelerator pedal fully depressed, turn ignition switch to “START” for cranking. When the gauge pointer stabilizes, read the compression pressure and the engine rpm. Perform these steps to check each cylinder.

   Compression pressure : Refer to EM-154, "General Specification".

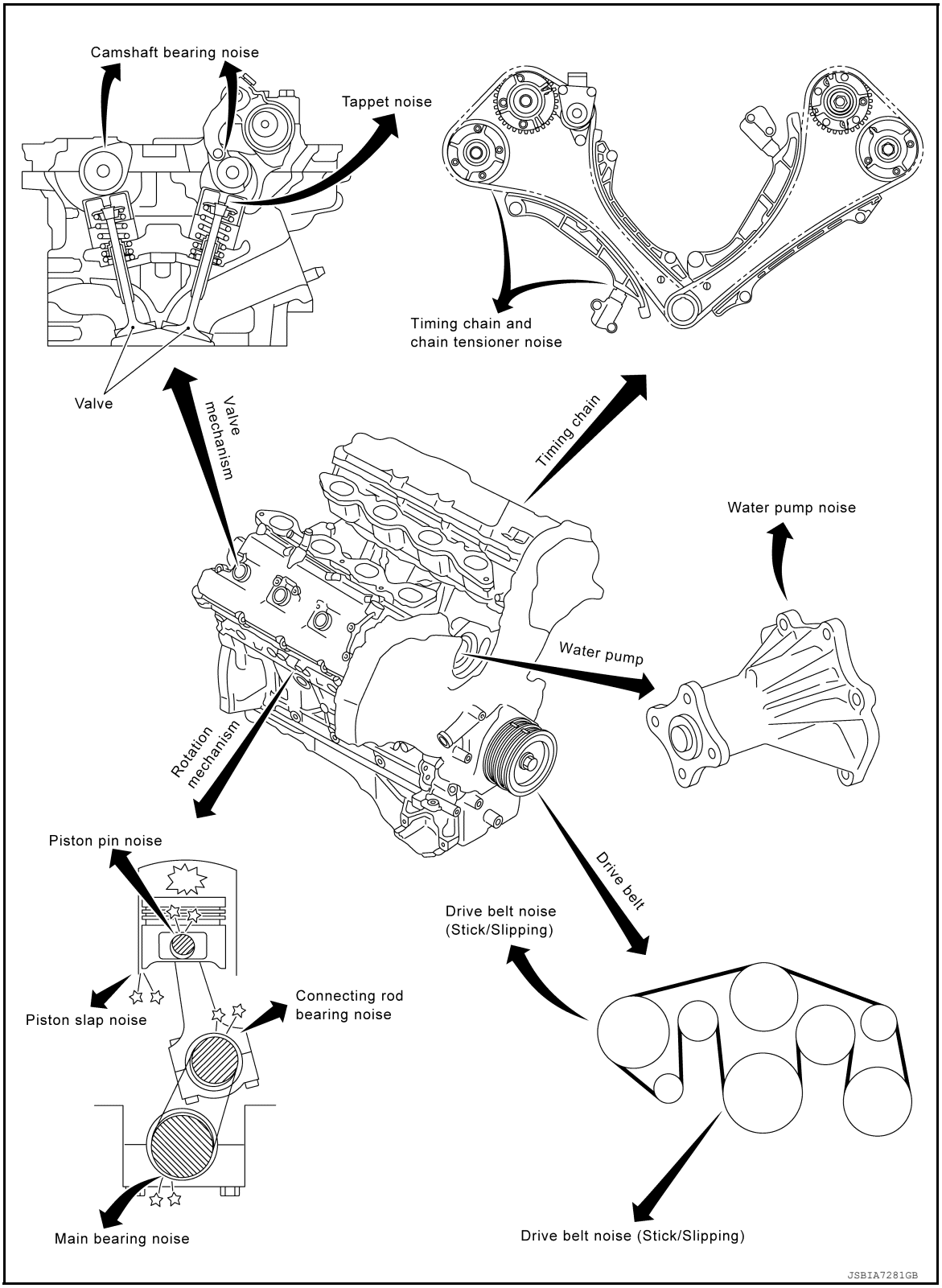
   CAUTION:
   - **Measure a six-cylinder under the same conditions since a measurement depends on measurement conditions (engine water temperature, etc.).**
   - **Always use a fully changed battery to obtain the specified engine speed.**
   - If the engine speed is out of the specified range, check battery liquid for proper gravity. Check the engine speed again with normal battery gravity. Refer to PG-175, "How to Handle Battery".
   - If compression pressure is below the minimum value, check valve clearances and parts associated with combustion chamber (valve, valve seat, piston, piston ring, cylinder bore, cylinder head, cylinder head gasket). After checking, measure compression pressure again.
   - If a cylinder has low compression pressure, pour a small amount of engine oil into the spark plug hole of the cylinder to re-check it for compression.
     - If the added engine oil improves the compression, piston rings may be worn out or damaged. Check piston rings and replace if necessary. Refer to EM-129, "Disassembly and Assembly".
     - If the compression pressure remains at low level despite the addition of engine oil, valves may be malfunctioning. Check valves for damage. Replace valve or valve seat accordingly. Refer to EM-129, "Disassembly and Assembly".
   - If two adjacent cylinders have respectively low compression pressure and their compression remains low even after the addition of engine oil, cylinder head gaskets are leaking. In such a case, replace cylinder head gaskets. Refer to EM-106, "Removal and Installation".
9. After inspection is completed, installation is in the reverse order of removal.
10. Start the engine, and check that the engine runs smoothly.
11. Perform trouble diagnosis. If DTC appears, erase it. Refer to EC-214, "Description".

SYMPTOM DIAGNOSIS

NOISE, VIBRATION AND HARSHNESS (NVH) TROUBLESHOOTING

NVH Troubleshooting - Engine Noise

INFOID:0000000014418474



Use the Chart Below to Help You Find the Cause of the Symptom

INFOID:0000000014418475

1. Locate the area where noise occurs.
2. Confirm the type of noise.
3. Specify the operating condition of the engine.
4. Check specified noise source.

If necessary, repair or replace these parts.

Location of noise	Type of noise	Operating condition of engine						Source of noise	Check item	Reference page
		Before warm-up	After warm-up	When starting	When idling	When racing	While driving			
Top of engine Rocker cover Cylinder head	Ticking or clicking	C	A	—	A	B	—	Tappet noise	Valve clearance	EM-16
	Rattle	C	A	—	A	B	C	Camshaft bearing noise	Camshaft runout Camshaft journal oil clearance	EM-96
Crankshaft pulley Cylinder block (Side of engine) Oil pan	Slap or knock	—	A	—	B	B	—	Piston pin noise	Piston to piston pin oil clearance Connecting rod bushing oil clearance	EM-137
	Slap or rap	A	—	—	B	B	A	Piston slap noise	Piston to cylinder bore clearance Piston ring side clearance Piston ring end gap Connecting rod bend and torsion	EM-137
	Knock	A	B	C	B	B	B	Connecting rod bearing noise	Connecting rod bushing oil clearance Connecting rod bearing oil clearance	EM-137
	Knock	A	B	—	A	B	C	Main bearing noise	Main bearing oil clearance Crankshaft runout	EM-137
Front of engine Timing chain case	Tapping or ticking	A	A	—	B	B	B	Timing chain and timing chain tensioner noise	Timing chain cracks and wears Timing chain tensioner operation	EM-91
Front of engine	Squeaking or fizzing	A	B	—	B	—	C	Drive belts (Sticking or slipping)	Drive belts deflection	EM-23
	Creaking	A	B	A	B	A	B	Drive belts (Slipping)	Idler pulley bearing operation	
	Squall Creak	A	B	—	B	A	B	Water pump noise	Water pump operation	CO-26

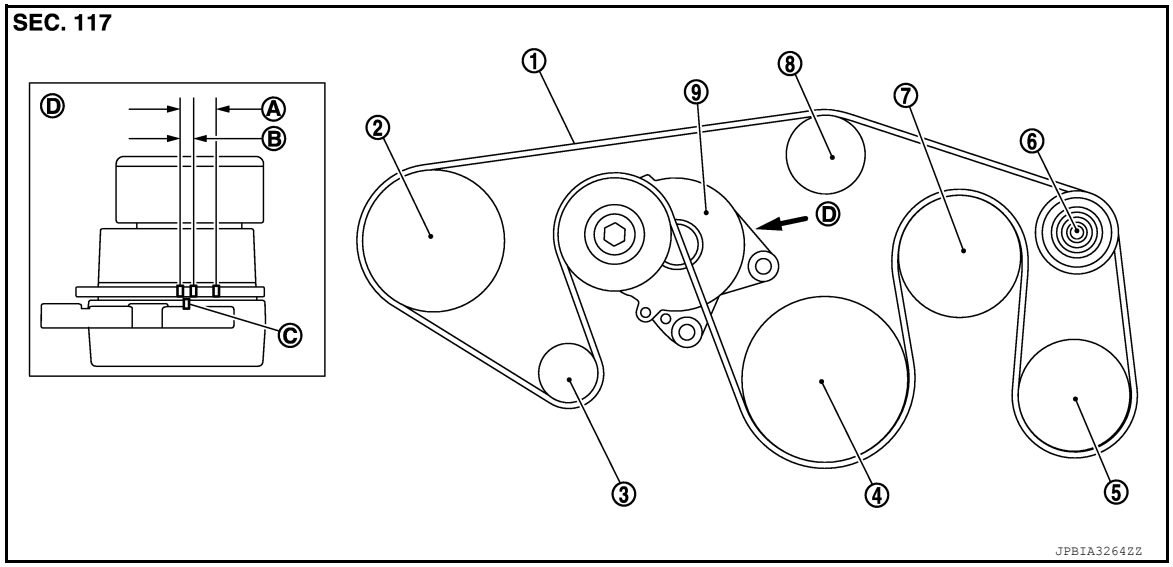
A: Closely related B: Related C: Sometimes related —: Not related

PERIODIC MAINTENANCE

DRIVE BELTS

Exploded View

INFOID:0000000014418476



1. Drive belt
2. Power steering oil pump pulley
3. Alternator pulley
4. Crankshaft pulley
5. A/C compressor
6. Idler pulley
7. Cooling fan pulley
8. Water pump pulley
9. Drive belt auto-tensioner
- A. Possible use range
- B. Range when new drive belt is installed
- C. Indicator
- D. View D

Checking

INFOID:0000000014418477

WARNING:
Be sure to perform the these steps when engine is stopped.
- Check that the indicator (C) (notch on fixed side) of each auto-tensioner is within the possible use range (A).
  NOTE:
  - Check the each auto-tensioners indication when the engine is cold.
  - When new drive belts is installed, the indicator (notch on fixed side) should be within the range (B) in the figure.
- Visually check all drive belts for wear, damage or cracks.
- If the indicator (notch on fixed side) is out of the possible use range or drive belts are damaged, replace drive belts.

Tension Adjustment

INFOID:0000000014418478

Refer to EM-154, "Drive Belts".

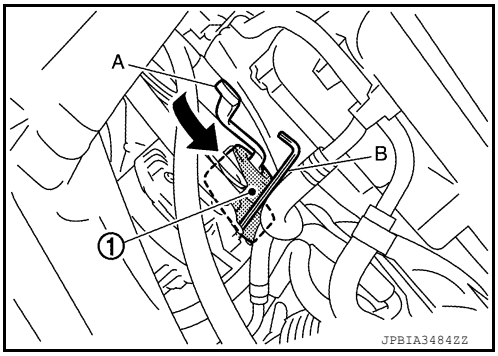
Removal and Installation

INFOID:0000000014418479

REMOVAL

1. Remove engine under cover (Non-XD Models). Refer to EXT-39, "ENGINE UNDER COVER : Removal and Installation".

2. Install suitable tool (A) on drive belt auto tensioner pulley bolt, move in the direction of arrow (loosening direction of tensioner) as shown.
   CAUTION:
   - **Do not place hand in a location where pinching may occur if the holding tool accidentally comes off.**
   - **Do not loosen the hexagonal part in center of auto tensioner pulley (1) (Do not turn it clockwise). If turned clockwise, the complete auto tensioner must be replaced as a unit, including the pulley.**
3. Under the above condition, insert a suitable tool (B) of approximately 6 mm (0.24 in) in diameter through the holding boss to lock auto tensioner pulley arm.
4. Remove drive belt.



INSTALLATION

Installation is in the reverse order of removal.

CAUTION:
- **Check drive belts are securely installed around all pulleys.**
- **Check drive belts are correctly engaged with the pulley groove.**
- **Check for engine oil and engine coolant are not adhered drive belts and pulley groove.**

Inspection

INFOID:0000000014418480

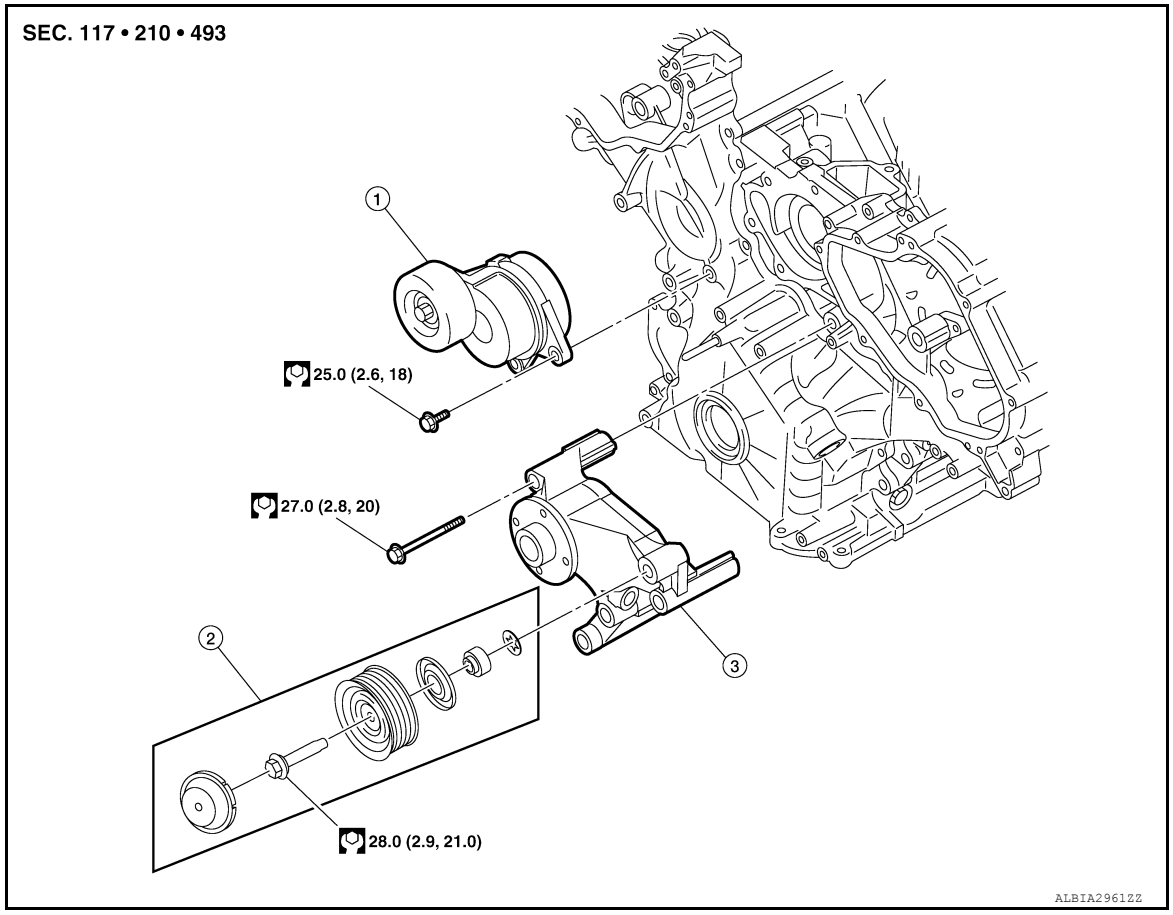
INSPECTION AFTER INSTALLATION

- Turn crankshaft pulley clockwise several times to equalize tension between each pulley, and then confirm tension of drive belts at indicator (notch on fixed side) is within the possible use range. Refer to EM-23, "Exploded View".

DRIVE BELT AUTO TENSIONER AND IDLER PULLEY

Exploded View

INFOID:0000000014418481



1. Drive belt auto-tensioner
2. Idler pulley
3. Fan bracket

Removal and Installation

INFOID:0000000014418482

Removal

CAUTION:

The complete drive belt auto-tensioner must be replaced as a unit, including the pulley.

1. Remove drive belts. Refer to EM-23, "Removal and Installation".
   - Keep auto-tensioner pulley arm locked after drive belt is removed.
2. Remove drive belt auto-tensioner.
   CAUTION:
   Do not loosen the hexagonal part in center of drive belt auto tensioner pulley (Do not turn it clockwise). If turned clockwise, the complete drive belt auto tensioner must be replaced as a unit, including the pulley.
   NOTE:
   Keep auto-tensioner pulley arm locked to install or remove auto-tensioner.
3. Remove idler pulley.

Installation

Installation is the reverse order of removal.

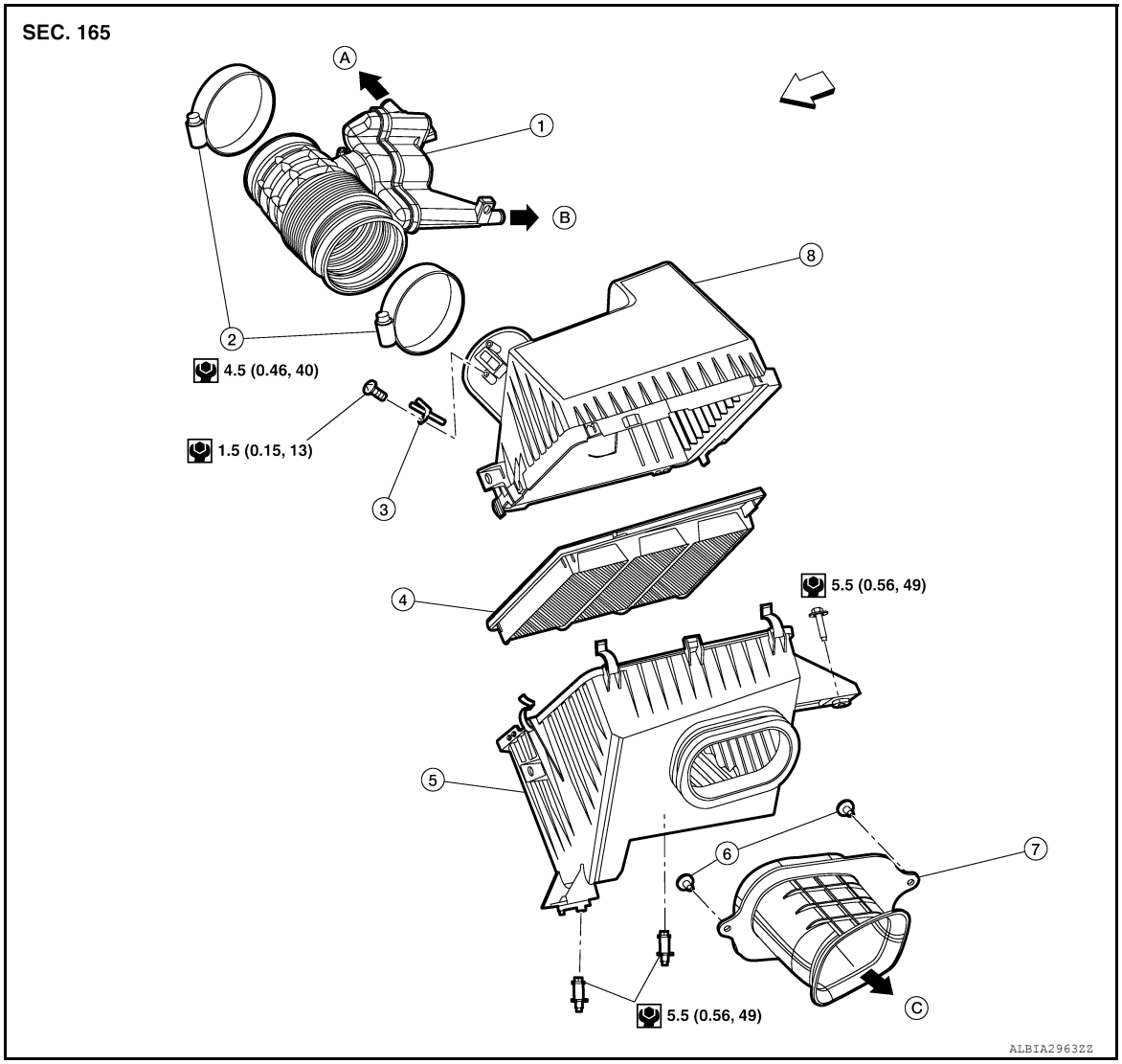
CAUTION:

Do not swap the pulley between new and old drive belt auto tensioner.

AIR CLEANER FILTER

Exploded View

INFOID:0000000014418483



1. Air duct
2. Clamp
3. Mass air flow sensor
4. Air filter
5. Air cleaner case (lower)
6. Clip
7. Adapter
8. Air cleaner case (upper)
A. To PCV hose (bank 2)
B. To PCV hose (bank 1)
C. To hoodledge
⇦ Front

Removal and Installation

INFOID:0000000014418484

REMOVAL

NOTE:

- Replace the air filter as necessary for periodic maintenance. Refer to MA-9, "Introduction of Periodic Maintenance".

1. Unhook clips, and lift air cleaner case (upper).
2. Remove air cleaner filter from air cleaner case.

INSTALLATION

Installation is in the reverse order of removal.

Inspection

INFOID:0000000014418485

INSPECTION AFTER REMOVAL

Examine with eyes that there is no stain, clogging, or damage on air cleaner element.

- Remove dusts (such as dead leafs) on air cleaner element surface and inside cleaner case.
- If clogging or damage is observed, replace the air cleaner element.

CAUTION:

Do not clean the air cleaner element by blowing as there is a risk of deterioration of its performance.

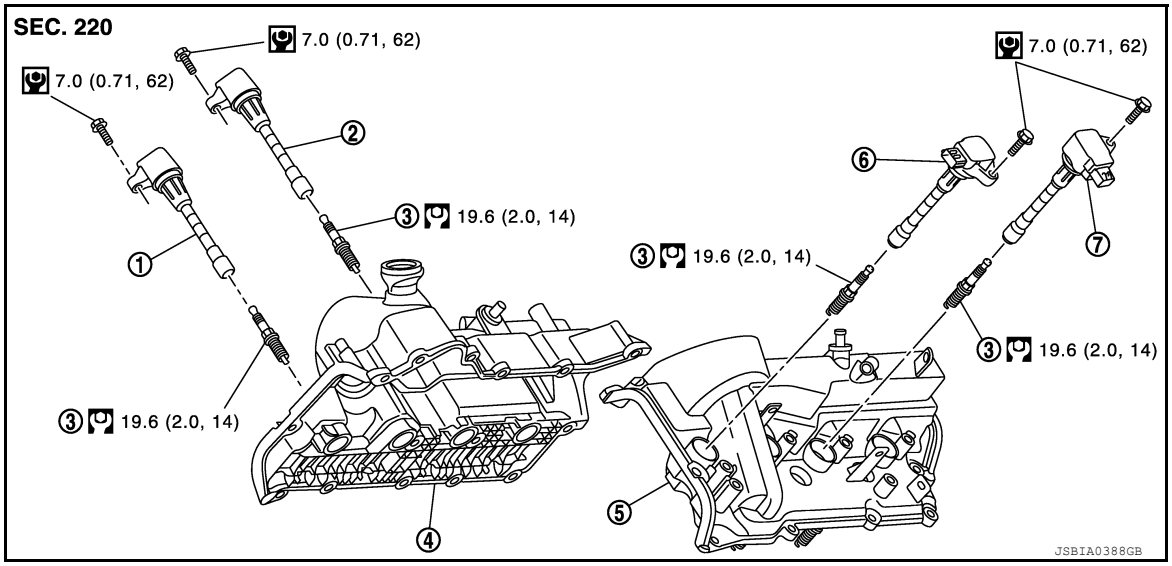
MAINTENANCE INTERVAL

Refer to MA-9, "Introduction of Periodic Maintenance".

SPARK PLUG

Exploded View

INFOID:0000000014418486



1. Ignition coil (No. 2, 4)
2. Ignition coil (No. 6, 8)
3. Spark plug
4. Rocker cover (bank 2)
5. Rocker cover (bank 1)
6. Ignition coil (No. 1, 3)
7. Ignition coil (No. 5, 7)

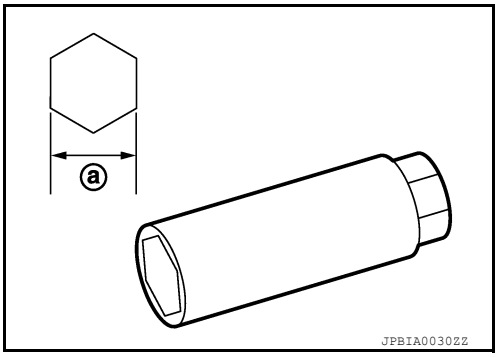
Removal and Installation

INFOID:0000000014418487

REMOVAL

1. Remove ignition coil. Refer to EM-34, "Removal and Installation".
2. Remove spark plug with a suitable tool.

(A) : 14 mm (0.55 in)



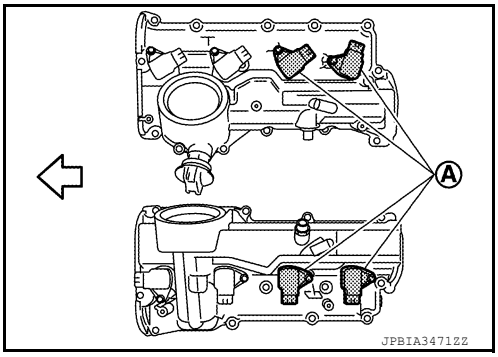
INSTALLATION

Installation is in the reverse order of removal.

CAUTION:

Install ignition coil marked with an identification mark (A) on cylinder No. 5, 6, 7 and 8.

⇦ : Engine front



Inspection

INFOID:0000000014418488

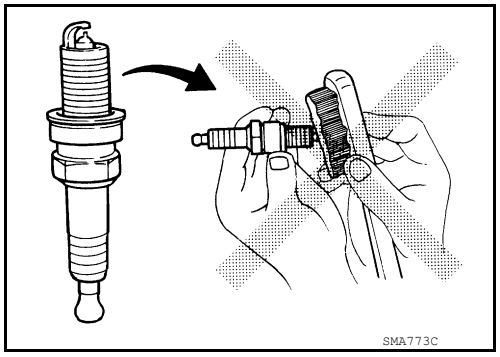
INSPECTION AFTER REMOVAL

Use the standard type spark plug for normal condition.

Spark plug (Standard type) : Refer to EM-154, "Spark Plug".

CAUTION:

- **Do not drop or impact spark plug, if spark plug has been dropped, do not use.**
- **Do not use a wire brush for cleaning.**
- **If plug tip is covered with carbon, use spark plug cleaner to clean.**



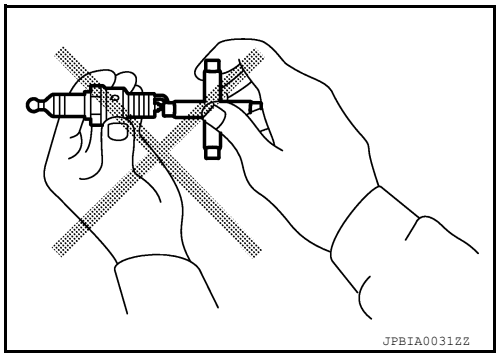
Cleaner air pressure

: Less than 588 kPa (6 kg/cm^2, 85 psi)

Cleaning time

: Less than 20 seconds

- **Measure spark plug gap. When it exceeds the limit, replace spark plug even if it is within the specified replacement mileage. Refer to EM-154, "Spark Plug".**
- **Spark plug gap adjustment is not required between replacement intervals.**

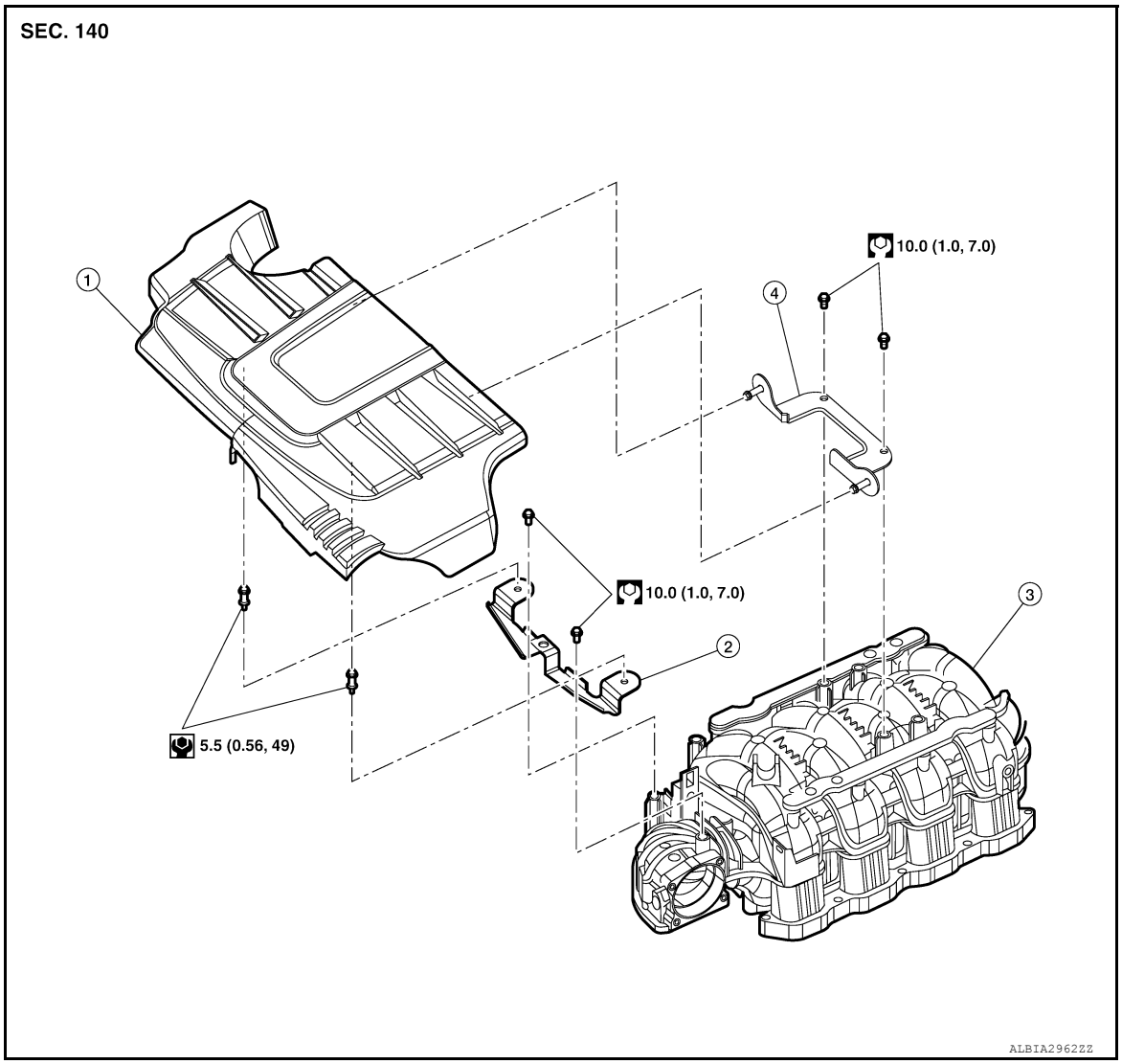


REMOVAL AND INSTALLATION

ENGINE COVER

Exploded View

INFOID:0000000014418489



1. Engine cover
2. Bracket (front)
3. Intake manifold
4. Bracket (rear)

Removal and Installation

INFOID:0000000014418490

REMOVAL

CAUTION:

Do not damage or scratch engine cover when installing or removing.

1. Pull forward and remove engine cover.
2. Remove bracket (front) and bracket (rear) (if necessary).

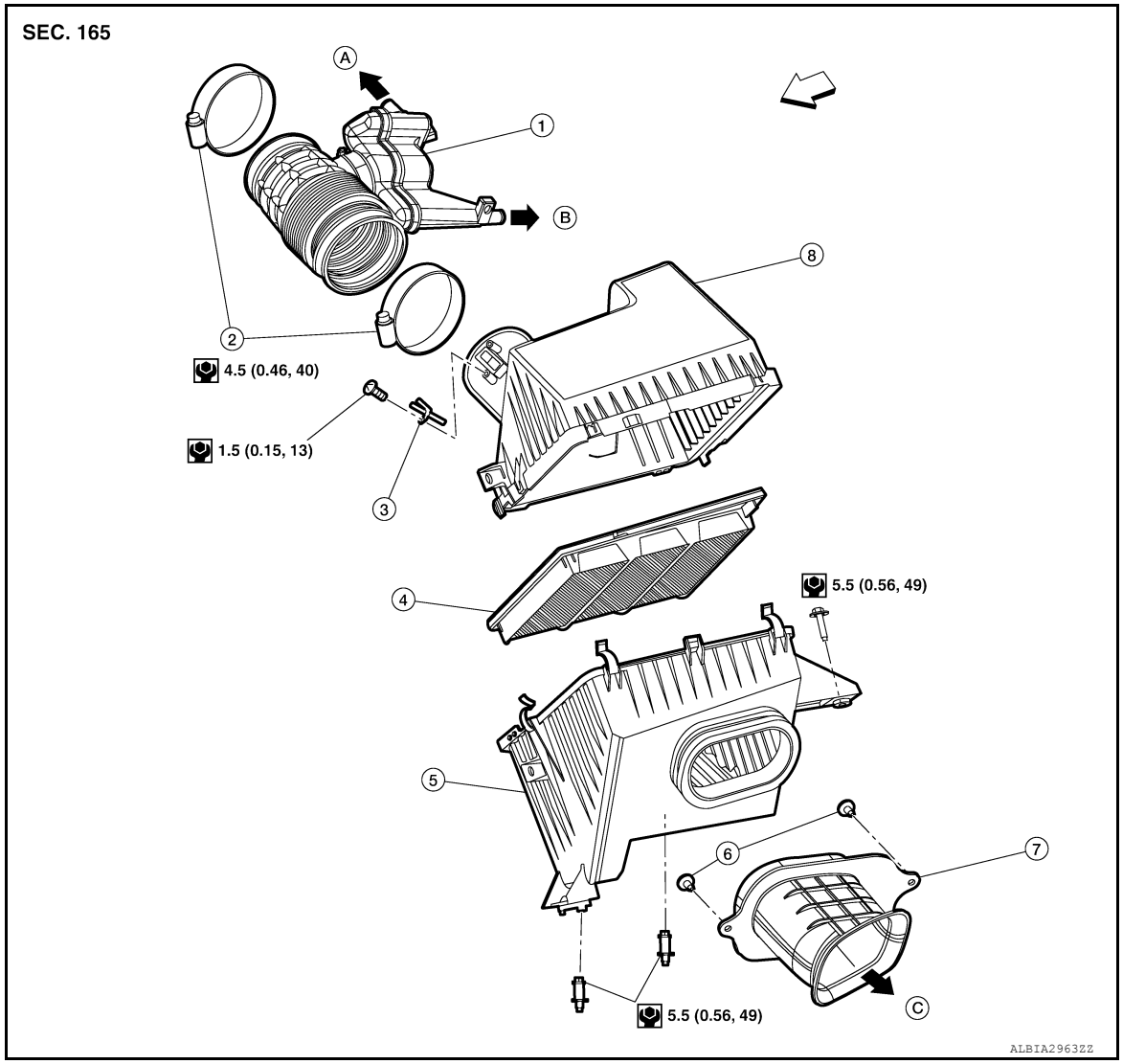
INSTALLATION

Installation is the reverse order of removal.

AIR CLEANER AND AIR DUCT

Exploded View

INFOID:0000000014418491



1.	Air duct	2.	Clamp	3.	Mass air flow sensor
4.	Air filter	5.	Air cleaner case (lower)	6.	Clip
7.	Adapter	8.	Air cleaner case (upper)	A.	To PCV hose (bank 2)
B.	To PCV hose (bank 1)	C.	To hoodledge	⇦	Front

Removal and Installation

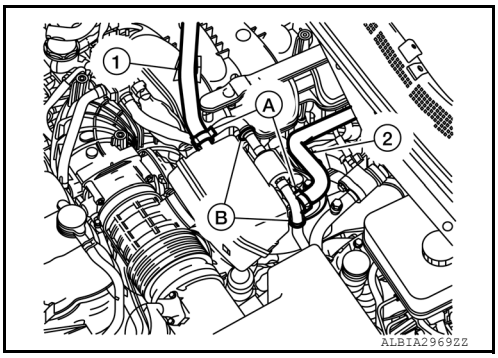
INFOID:0000000014418492

REMOVAL

1. Remove engine cover. Refer to EM-30, "Exploded View".
2. Disconnect mass air flow sensor harness connector.
3. Remove air cleaner case (upper) and mass air flow sensor assembly and air duct by disconnecting their joints.
   • Add matching marks, if necessary for easier installation.
4. Remove mass air flow sensor from air cleaner case (upper) (if necessary).
   CAUTION:
   Handle mass air flow sensor according to the following instructions.
   • Do not impact it.

- **Do not disassemble it.**
- **Do not touch its sensor.**

5. Disconnect clips (B) from air duct.
6. Remove clamps (A) and disconnect PCV hose [bank 1 (2)] and PCV hose [bank 2 (1)] from air duct.



7. Remove air duct.
8. Remove air cleaner filter.
9. Remove air cleaner case (lower).
10. Remove adapter.

INSTALLATION

Installation is in the reverse order of removal.

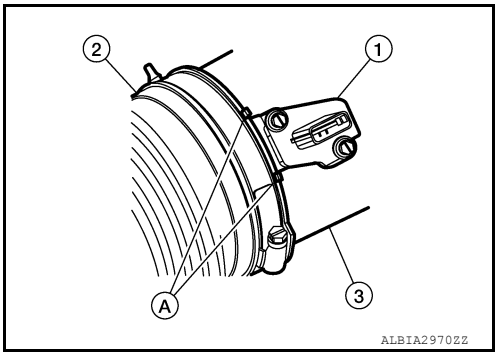
NOTE:

Make sure to align marks when installing air cleaner and air duct components.

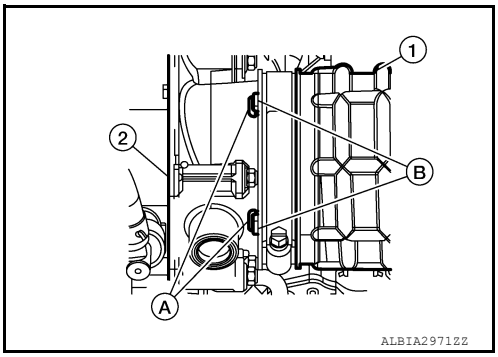
- Align mating marks (A) with mass air flow sensor (1).

(2) : Air duct

(3) : Air cleaner case (upper)



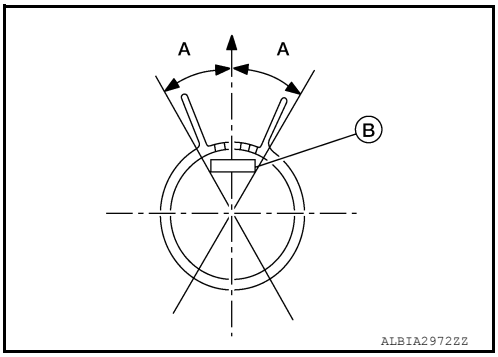
- Align mating marks (A) on the throttle body (2) with the mating marks (B) on the air duct (1).



- When installing PCV hose clamps, orient the clamps as shown.

(A) : 45°

(B) : Marking (top)



Inspection

INFOID:0000000014418493

INSPECTION AFTER REMOVAL

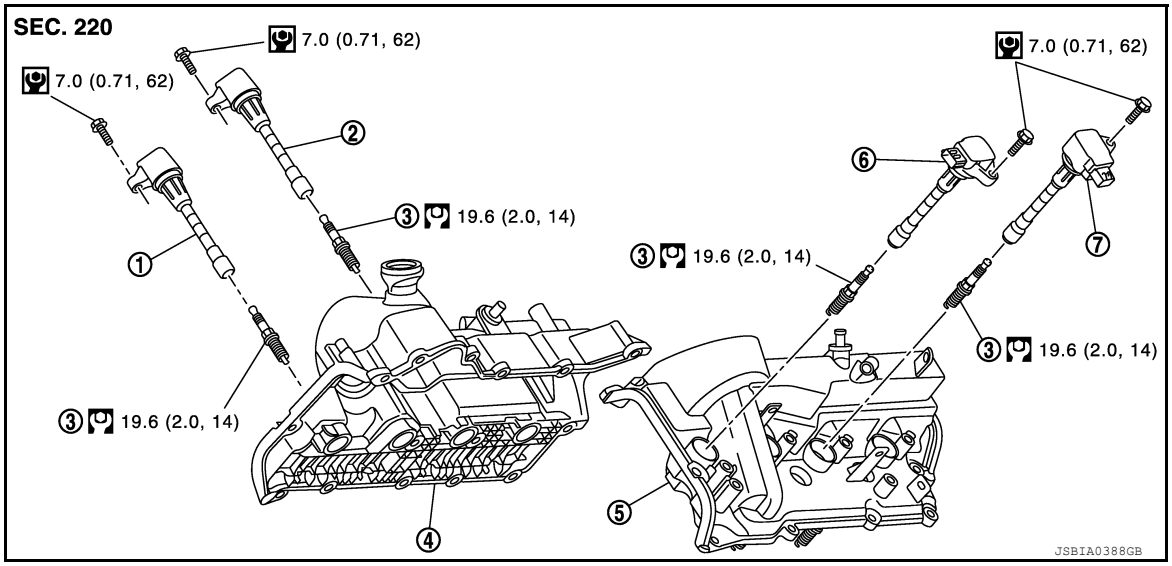
Inspect air duct assembly for crack or tear.

- If damage is found, replace air duct assembly

IGNITION COIL

Exploded View

INFOID:0000000014418494



1. Ignition coil (No. 2, 4)
2. Ignition coil (No. 6, 8)
3. Spark plug
4. Rocker cover (bank 2)
5. Rocker cover (bank 1)
6. Ignition coil (No. 1, 3)
7. Ignition coil (No. 5, 7)

Removal and Installation

INFOID:0000000014418495

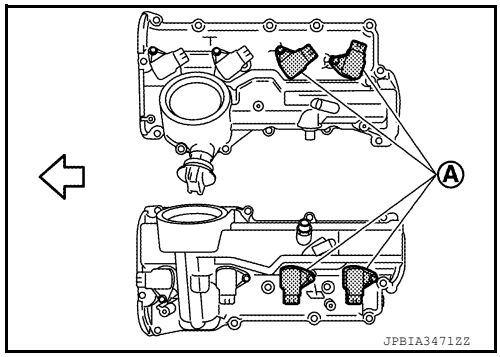
REMOVAL

1. Remove engine cover. Refer to EM-30, "Exploded View".
2. Disconnect harness connector from ignition coil.
3. Remove ignition coil.
   CAUTION:
   Do not shock ignition coil.
   NOTE:
   Installation position of ignition coil depends on cylinder position.
4. Remove spark plug (if necessary).
   CAUTION:
   Do not shock spark plug.

INSTALLATION

1. Install ignition coil.
   CAUTION:
   - **Install Ignition coil marked with an identification mark (A) on cylinder No. 5, 6, 7 and 8.**

   ⇦ : Engine front

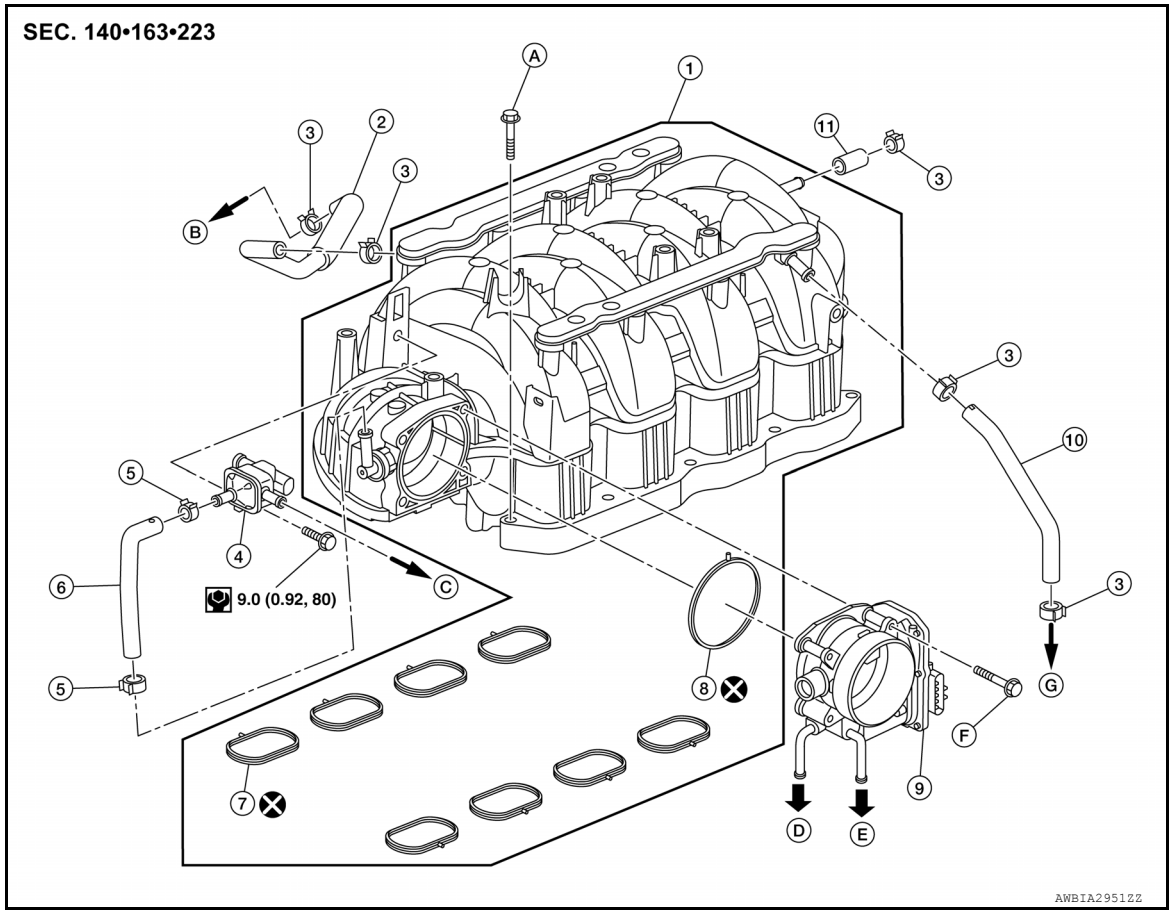


2. Install engine cover.

INTAKE MANIFOLD

Exploded View

INFOID:0000000014418496



1.	Intake manifold	2.	PCV hose	3.	Clamp
4.	EVAP canister purge control solenoid valve	5.	Clamp	6.	EVAP hose
7.	Intake manifold gasket	8.	Electronic throttle control actuator gasket	9.	Electric throttle control actuator
10.	PCV hose	11.	Cap	A.	Refer to INSTALLATION
B.	To rocker cover (bank 2)	C.	To centralized under-floor piping	D.	To multi-way control valve
E.	To water suction pipe	F.	Refer to INSTALLATION	G.	To rocker cover (bank 1)

Removal and Installation

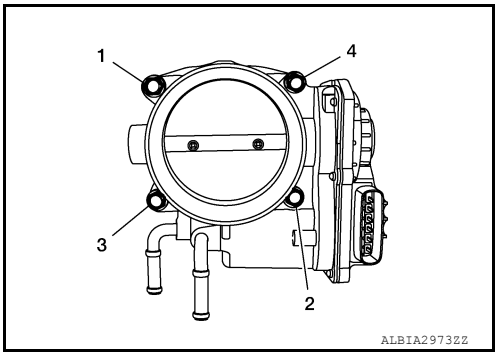
INFOID:0000000014418497

REMOVAL

1. Remove engine cover. Refer to EM-30, "Removal and Installation".
2. Disconnect bank 2 crankcase breather hose from rocker cover.
3. Disconnect EVAP canister purge control solenoid valve hose from EVAP canister purge control solenoid valve.
4. Loosen air duct clamps from resonator, intake manifold, and air cleaner case. Refer to EM-31, "Exploded View".
5. Remove air duct and set aside.
6. Remove cowl top extension. Refer to EXT-36, "Removal and Installation - Cowl Top Extension".
7. Disconnect the harness connector from the EVAP canister purge control solenoid valve.
8. Disconnect bank 1 and bank 2 PCV hoses from intake manifold.

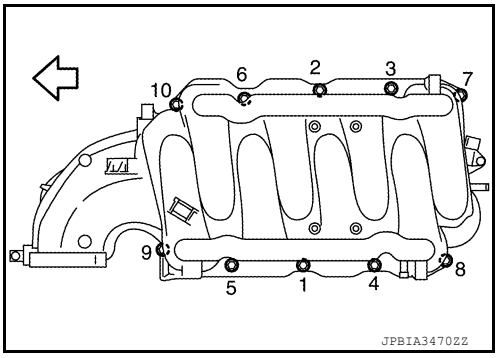
9. Loosen electronic throttle control actuator bolts in reverse of the order shown and reposition the electronic throttle control actuator.
   CAUTION:
   - **Handle carefully to avoid any impact to electric throttle control actuator.**
   - **Do not disassemble.**

   NOTE:
   The figure shows the electric throttle control actuator viewed from the air duct side.



10. Remove heater pipe (inlet) bolts and reposition heater pipe (inlet). Refer to CO-27, "Exploded View".
11. Loosen bolts in the reverse order as shown.

    ⇦ : Engine front



12. Remove intake manifold.
13. Remove intake manifold gaskets.
    CAUTION:
    - **Do not reuse intake manifold gaskets.**
    - **Cover engine openings to avoid entry of foreign materials.**
14. Remove the following parts (if necessary).
    - EVAP canister purge control solenoid valve
    - EVAP canister purge control solenoid valve hose
    - Front engine cover bracket
    - Rear engine cover bracket
    - Cap

INSTALLATION

Installation is in the reverse order of removal.

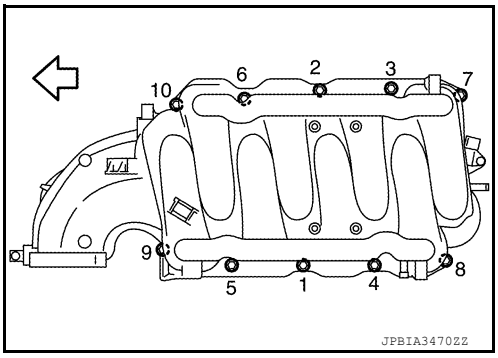
CAUTION:
Do not reuse intake manifold gaskets.

Intake Manifold

Tighten intake manifold bolts in order as shown.

Intake manifold bolts : 11.0 N·m (1.1 kg-m, 8 ft-lb)

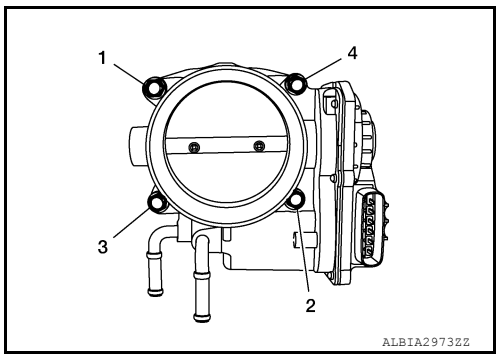
⇦ : Engine front



Electric Throttle Control Actuator

- Tighten electronic throttle control actuator bolts in order as shown.
  NOTE:
  The figure shows the electric throttle control actuator viewed from the air duct side.

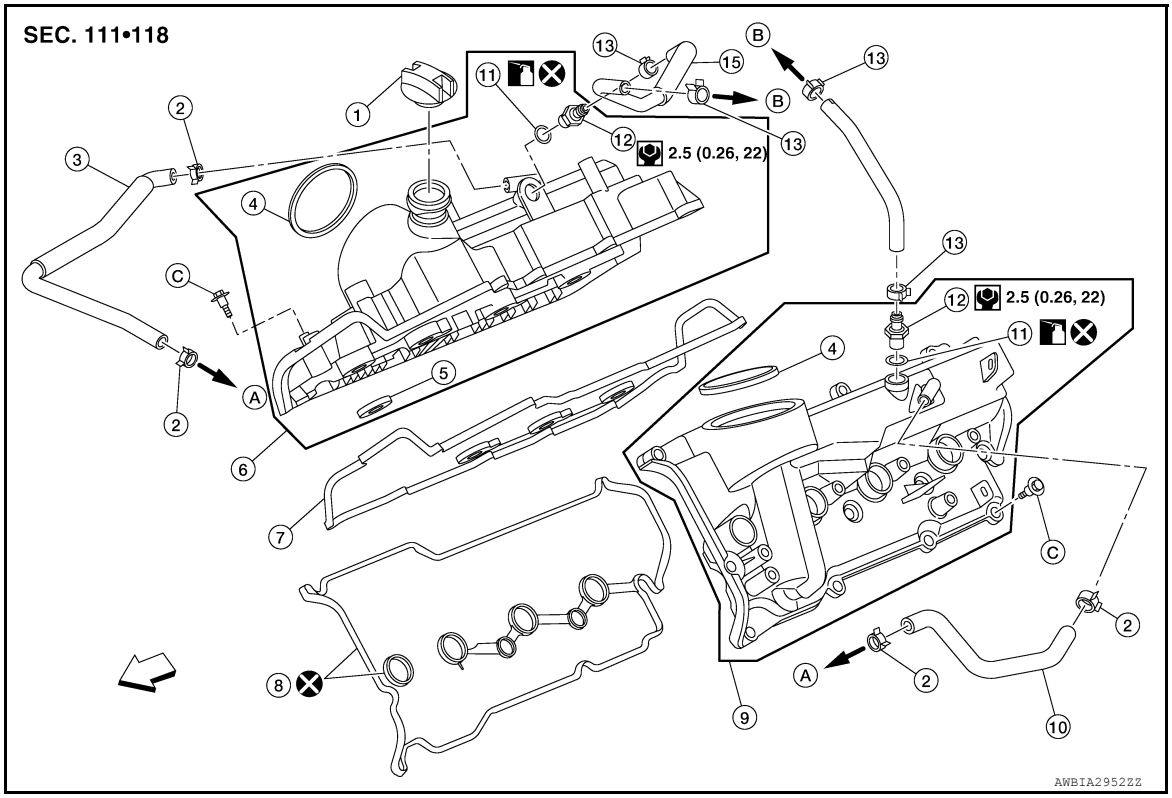
Electronic throttle control actuator bolts : 10 N·m (1.0 kg-m, 7 ft-lb)



ROCKER COVER

Exploded View

INFOID:0000000014418498



1.	Oil filler cap	2.	Clamp	3.	PCV hose
4.	VVEL actuator motor gasket	5.	Rocker cover plug gasket (bank 2)	6.	Rocker cover (bank 2)
7.	Rocker cover gasket (bank 2)	8.	Rocker cover gasket (bank 1)	9.	Rocker cover (bank 1)
10.	PCV hose	11.	O-ring	12.	PCV valve
13.	Clamp	14.	PCV hose	15.	PCV hose
A.	To air duct	B.	To intake manifold	C.	Refer to INSTALLATION
⇦	Front				

Removal and Installation

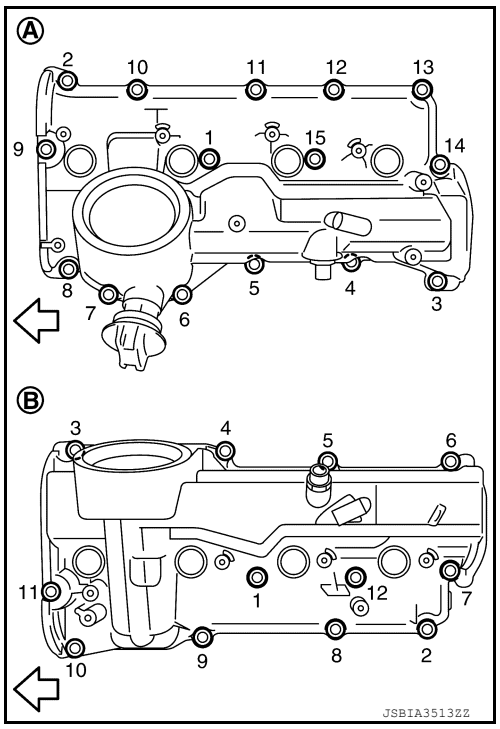
INFOID:0000000014418499

REMOVAL

1. Remove engine cover. Refer to EM-30, "Removal and Installation".
2. Disconnect PCV hoses from rocker cover.
3. Remove air duct. Refer to EM-31, "Exploded View".
4. Reposition the following components if removing rocker cover (bank1):
   - EVAP canister purge control solenoid valve. EM-35, "Exploded View".
   - Fuel feed hose. Refer to EM-52, "Exploded View".
5. Remove VVEL actuator motor assembly and coupler. Refer to EM-41, "Exploded View".
6. Remove ignition coil. Refer to EM-34, "Exploded View".
   CAUTION:
   Do not shock ignition coil.
   NOTE:
   Installation position of ignition coil depends on cylinder position.
7. Disconnect harness retainers from rocker cover and reposition harness.
8. Remove rocker cover.

- Loosen bolts in reverse of the order shown in the figure.

(A) : Bank 2
(B) : Bank 1
⇦ : Engine front



9. Remove rocker cover gasket from rocker cover.
10. Use a suitable tool to remove all traces of liquid gasket from cylinder head & VVEL ladder assembly.
CAUTION:
Do not scratch or damage the mating surface when cleaning off old liquid gasket.
11. Remove PCV valve from rocker cover (if necessary).
12. Remove oil filler cap from rocker cover (if necessary).

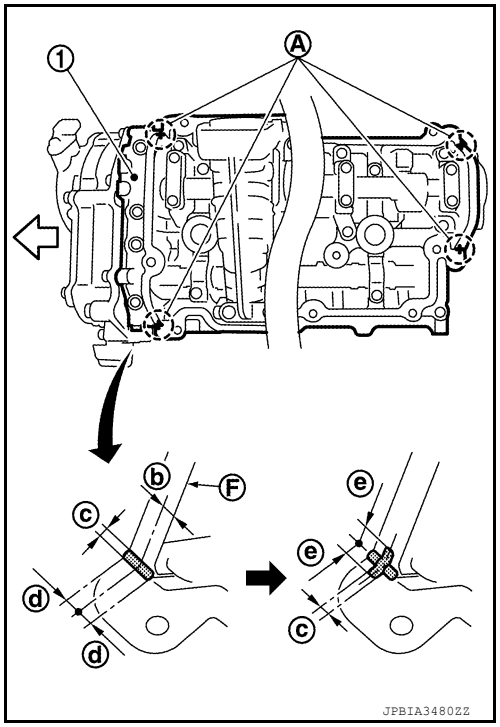
INSTALLATION

CAUTION:
Do not reuse O-rings.

1. Apply liquid gasket with a suitable tool to the VVEL ladder assembly (1).

A : Liquid gasket application point
F : End surface of VVEL ladder assembly
b : 4.0 mm (0.16 in)
c : 2.5 - 3.5 mm (0.098 - 0.138 in)
d : 5.0 mm (0.20 in)
e : 10.0 mm (0.39 in)
⇦ : Engine front

Use Genuine RTV silicone sealant or equivalent. Refer to GI-22, "Recommended Chemical Products and Sealants".
NOTE:
The figure shows an example of bank 1 side.
- Apply liquid gasket on the front and rear side of engine first. [5 mm (0.20 in) + 5 mm (0.20 in) side as shown in the figure]



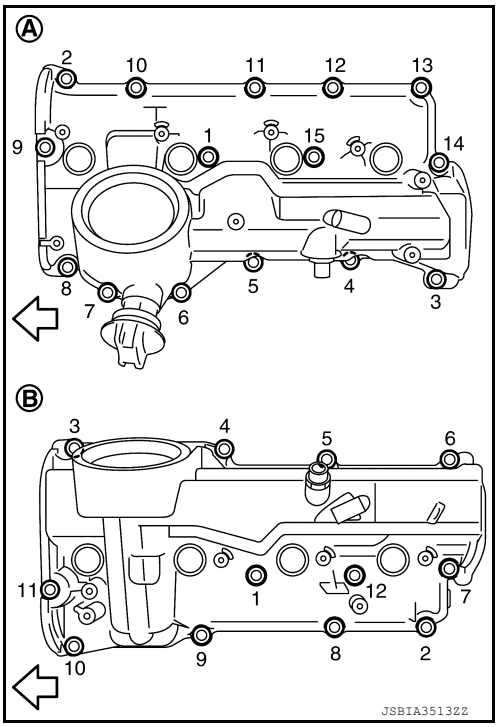
2. Install rocker cover gasket to rocker cover.
3. Install rocker cover.

- Check that rocker cover gasket does not drop from the installation groove of rocker cover.

4. Tighten bolts in the sequence shown to the specified torque.

Step 1 : 2.0 N·m (0.2 kg-m, 18 in-lb)
Step 2 : 8.3 N·m (0.85 kg-m, 73 in-lb)

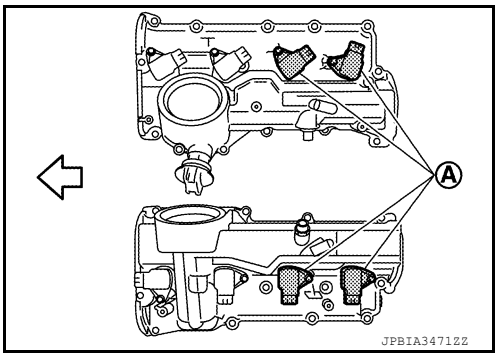
(A) : Bank 2
(B) : Bank 1
⇦ : Engine front



5. Install ignition coil. Refer to EM-34, "Exploded View".

CAUTION:
- **Install Ignition coil marked with an identification mark (A) on cylinder No. 5, 6, 7 and 8.**

⇦ : Engine front

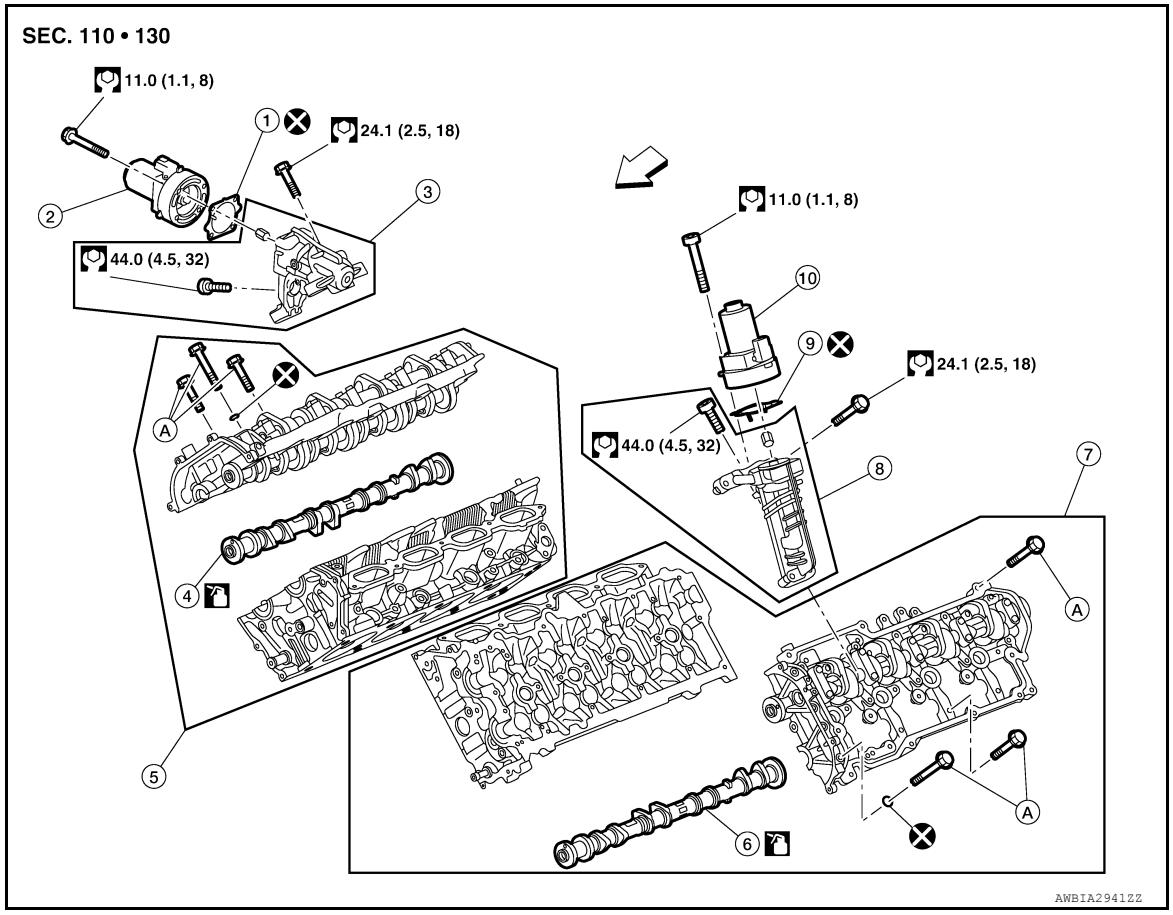


6. Install VVEL actuator motor assembly. Refer to EM-41, "Exploded View".
7. Installation of the remaining components is in the reverse order of removal.

VVEL ACTUATOR ASSEMBLY

Exploded View

INFOID:0000000014418500



1.	Gasket	2.	VVEL actuator motor assembly	3.	VVEL actuator housing assembly (bank 2)
4.	Exhaust camshaft (bank 2)	5.	Cylinder head/VVEL ladder assembly (bank 2)	6.	Exhaust camshaft (bank 1)
7.	Cylinder head/VVEL ladder assembly (bank 1)	8.	VVEL actuator housing assembly (bank 1)	9.	Gasket
10.	VVEL actuator motor assembly	A.	Refer to INSTALLATION	⇦	Front

Removal and Installation

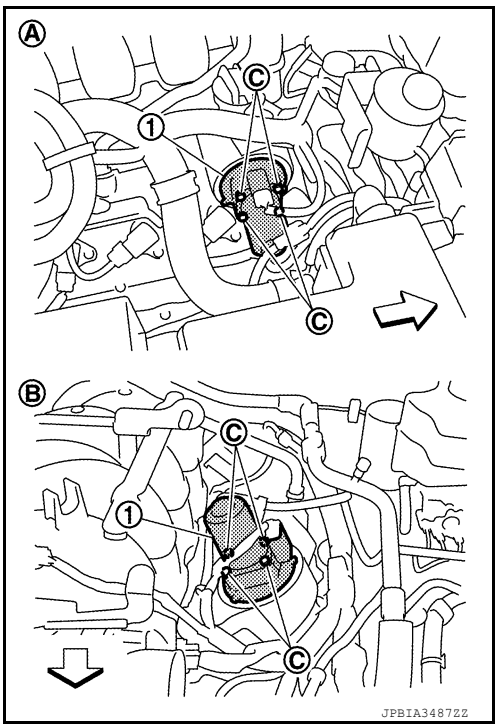
INFOID:0000000014418501

REMOVAL

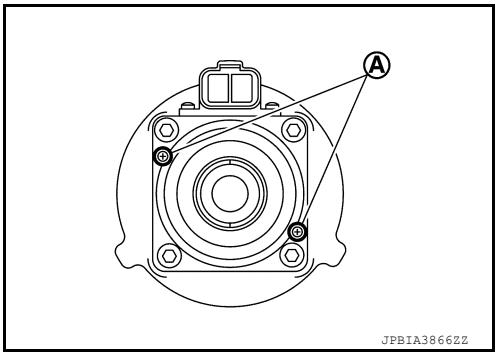
1. Remove engine cover. Refer to EM-30, "Exploded View".
2. Disconnect VVEL actuator motor assembly harness connector.

3. Loosen bolts (C) and then remove VVEL actuator motor assembly (1).

(A) : Bank 2
(B) : Bank 1
⇦ : Engine front



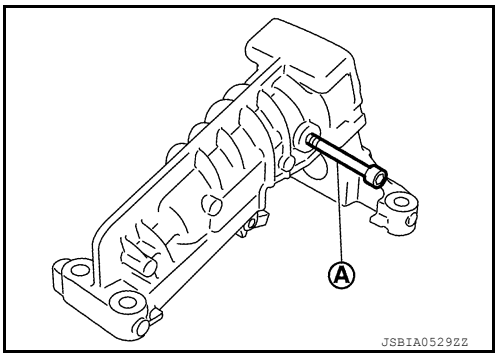
CAUTION:
Do not loosen screws (A) of VVEL actuator motor assembly.



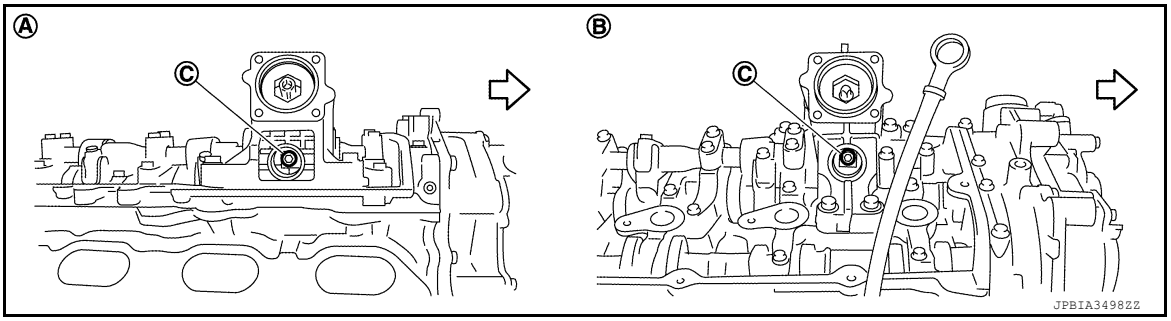
4. If removing the VVEL actuator housing assembly, use the following procedure:

a. Remove rocker cover. Refer to EM-38, "Exploded View".

b. Insert bolt (A) removed in step 2 into VVEL actuator housing assembly.

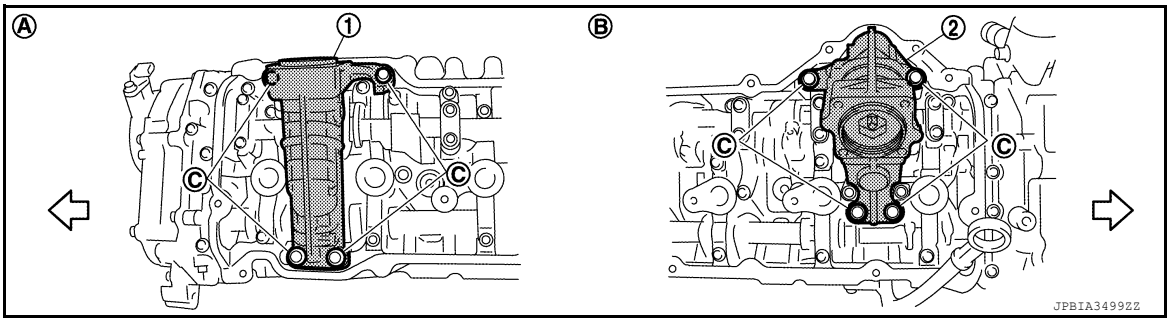


c. Loosen bolt (C) to disengage the control shaft and the actuator arm.



A. Bank 1 B. Bank 2 ⇦ Engine front

d. Loosen bolts (C) and then remove VVEL actuator housing assembly.



1. VVEL actuator housing assembly (bank 1) 2. VVEL actuator housing assembly (bank 2) A. Bank 1
B. Bank 2 ⇦ Engine front

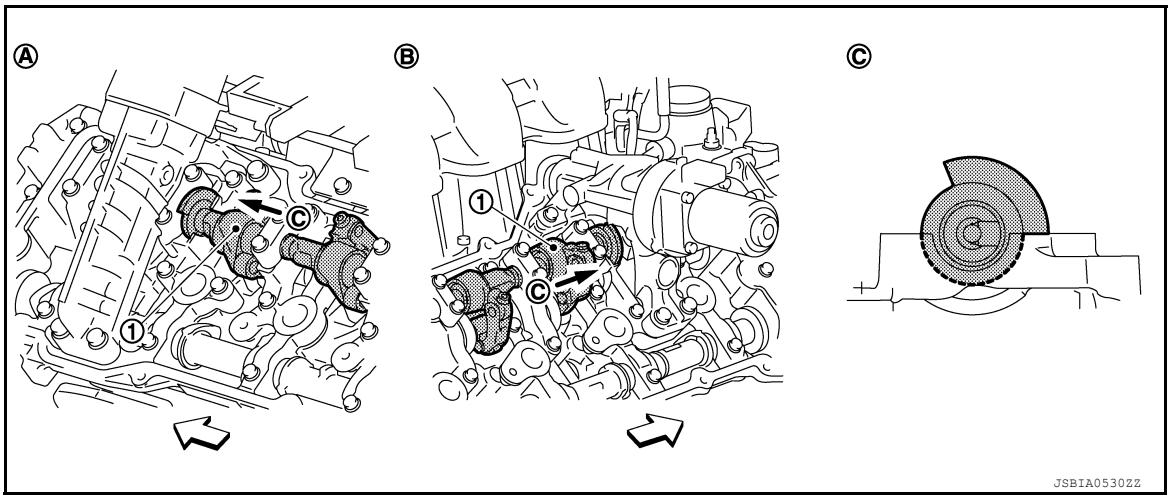
INSTALLATION

Installation is in the reverse order of removal.

CAUTION:

Do not reuse washers.

- When disengaging the control shaft (1) and the actuator arm, hold the stopper of the control shaft in the position shown in the figure.



A. Bank 1 B. Bank 2 C. Control shaft stopper
⇦ : Engine front

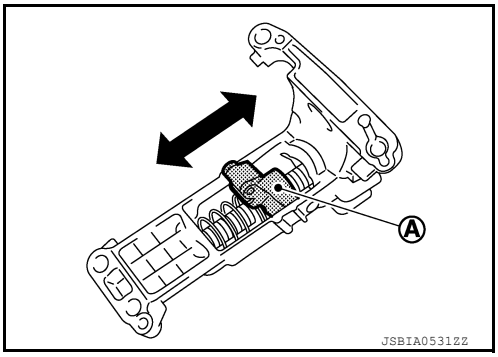
Inspection

INFOID:0000000014418502

INSPECTION AFTER REMOVAL

VVEL actuator housing assembly

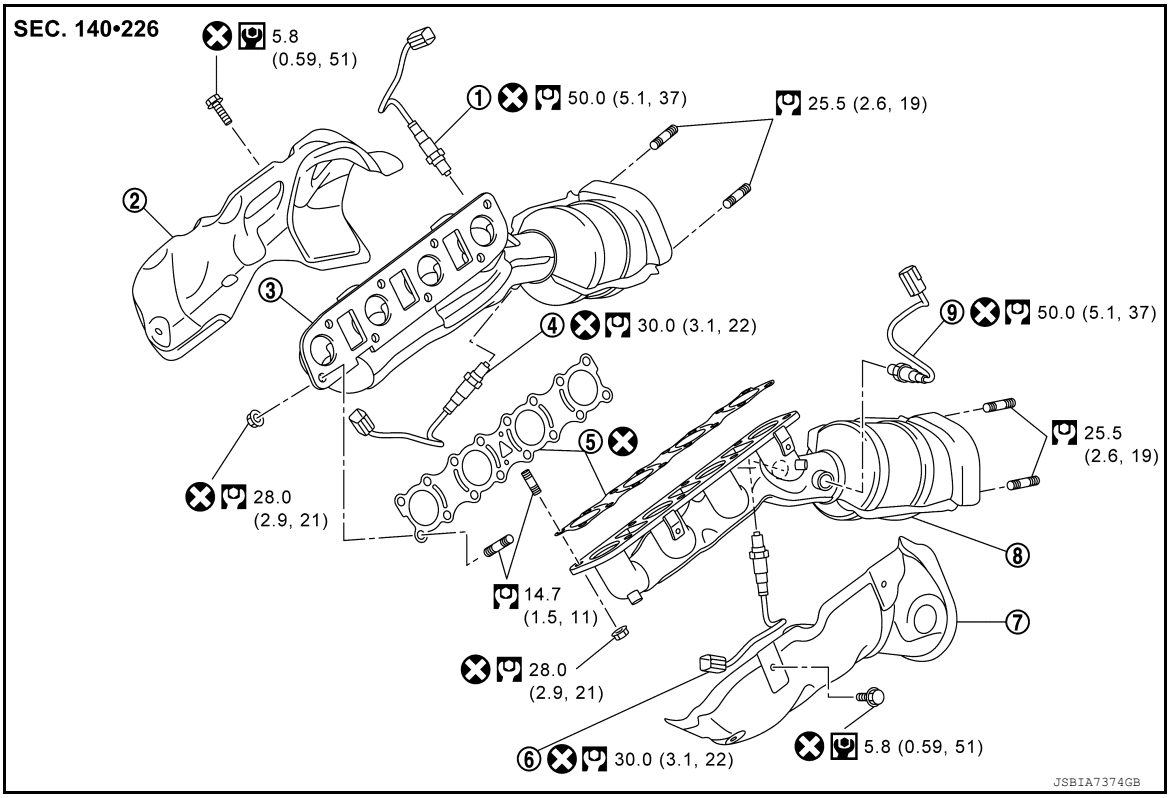
- Move the ball nut (A) in the axial direction to check the smooth rotation.



EXHAUST MANIFOLD AND THREE WAY CATALYST

Exploded View

INFOID:0000000014418503



1. Air fuel ratio sensor 1 (bank 2)
2. Exhaust manifold cover (bank 2)
3. Exhaust manifold and three way catalyst (bank 2)
4. Exhaust temperature sensor (bank 2)
5. Gasket
6. Exhaust temperature sensor (bank 1)
7. Exhaust manifold cover (bank 1)
8. Exhaust manifold and three way catalyst (bank 1)
9. Air fuel ratio sensor 1 (bank 1)

Removal and Installation - XD Models

INFOID:0000000014418504

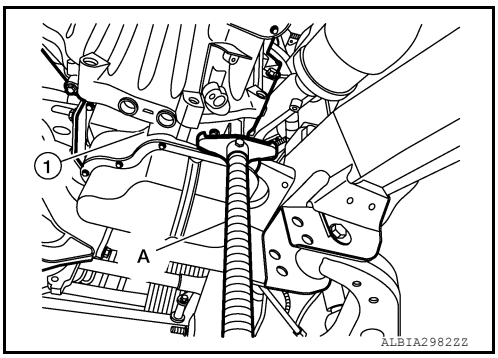
EXHAUST MANIFOLD AND THREE WAY CATALYST (BANK 1)

WARNING:
Perform the work when the exhaust has cooled sufficiently.

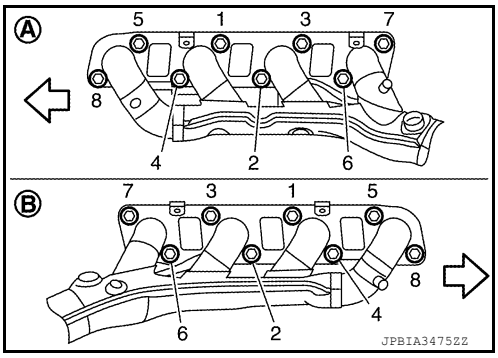
Removal

1. Remove front wheel and tire. Refer to WT-69, "Removal and Installation".
2. Remove fender protector. Refer to EXT-41, "Removal and Installation - Front Fender Protector".
3. Disconnect the harness connectors for the air fuel ratio sensor 1 (bank 1) and exhaust temperature sensor (bank 1).
4. Remove exhaust manifold cover bolts and remove exhaust manifold cover from underneath vehicle.
5. Remove front final drive. Refer to DLN-191, "Removal and Installation".
6. Remove exhaust tube (bank 1 and bank 2). Refer to EX-6, "Exploded View".

7. Support engine assembly (1) with a suitable jack (A).



8. Remove engine mounting bracket and engine mount insulator (LH). Refer to EM-120, "Exploded View".
9. Remove exhaust manifold and three way catalyst (bank 1).
   • Loosen nuts in the reverse of the sequence shown.



(A) : Bank 1
(B) : Bank 2
⇦ : Engine front

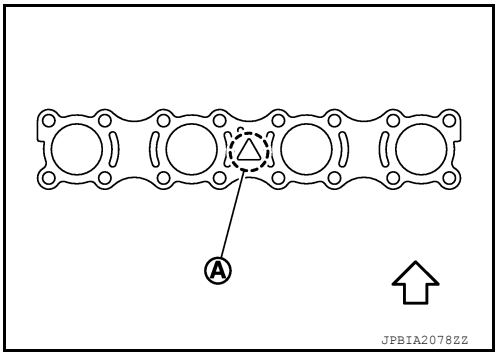
10. Remove exhaust manifold and three way catalyst gasket.
    CAUTION:
    • Do not reuse gasket.
    • Cover engine openings to avoid entry of foreign materials.

Installation

Installation is in the reverse order of removal.

Exhaust Manifold and Three Way Catalyst Gasket

• Install exhaust manifold and three way catalyst gasket in directional shown in the figure.
  CAUTION:
  Do not reuse gasket.
  NOTE:
  When installing exhaust manifold and three way catalyst gasket, coating surface (black) shall be located on the exhaust manifold and three way catalyst side.

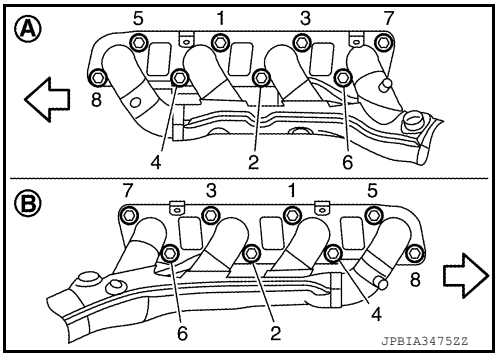


(A) : Triangle press
⇦ : Engine upper

Exhaust Manifold and Three Way Catalyst

• Tighten exhaust manifold and three way catalyst nuts in the sequence shown to the specified torque.
  CAUTION:
  All exhaust manifold and three way catalyst nuts are tightened twice.

Exhaust manifold and three way catalyst nuts : 28.0 N·m (2.9 kg-m, 21 ft-lb)



(A) : Bank 1
(B) : Bank 2
⇦ : Engine front

CAUTION:
Air Fuel Ratio Sensor 1 and Exhaust Temperature Sensor
- **Before installing a new air fuel ratio sensor 1 and exhaust temperature sensor, clean exhaust system threads using Tool and apply a suitable anti-seize lubricant.**
- **Air fuel ratio sensor 1 and exhaust temperature sensor is not reusable. Replace them with a new one after removal. When replacing them, handle with care not to impact on them.**
- **When installing the new air fuel ratio sensors 1 and exhaust temperature sensor, set the Tool in the hexagonal part to tighten them.**
- **Do not over torque sensors. Doing so may cause damage to the sensors, resulting in "MIL" coming on.**
- **Do not allow rust preventatives on sensor body.**

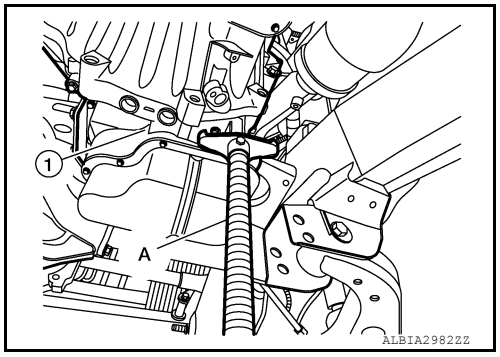
Tool : — (J-43897-18)
: KV10117100 (J-44626)

EXHAUST MANIFOLD AND THREE WAY CATALYST (BANK 2)

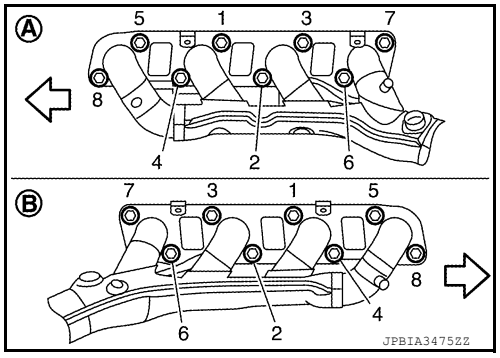
WARNING:
Perform the work when the exhaust has cooled sufficiently.

Removal

1. Remove front wheel and tire. Refer to WT-69, "Removal and Installation".
2. Remove fender protector. Refer to EXT-41, "Removal and Installation - Front Fender Protector".
3. Disconnect the harness connectors for the air fuel ratio sensor 1 (bank 1) and exhaust temperature sensor (bank 1).
4. Remove the oil level gauge and oil level gauge guide. Refer to EM-70, "Exploded View".
5. Remove exhaust manifold cover bolts and remove exhaust manifold cover through fender opening.
6. Remove engine undercover and front cross member assembly. Refer to DLN-191, "Exploded View".
7. Support engine assembly (1) with a suitable jack (A).



8. Remove engine mounting bracket and engine mount insulator (RH). Refer to EM-120, "Exploded View".
9. Remove exhaust manifold and three way catalyst (bank 2).
   - Loosen nuts in the reverse of the sequence shown.



(A) : Bank 1
(B) : Bank 2
⇦ : Engine front

10. Remove exhaust manifold and three way catalyst gasket.
    CAUTION:
    - **Do not reuse gasket.**
    - **Cover engine openings to avoid entry of foreign materials.**

Installation

Installation is in the reverse order of removal.

Exhaust Manifold and Three Way Catalyst Gasket

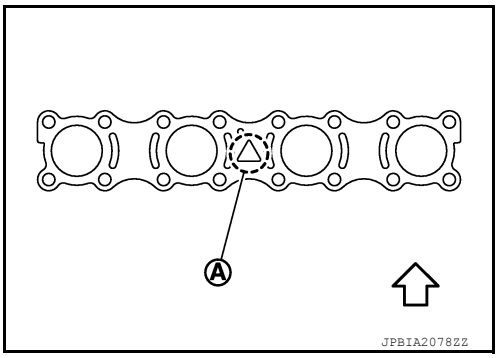
- Install exhaust manifold and three way catalyst gasket in directional shown in the figure.

CAUTION:

Do not reuse gasket.

NOTE:

When installing exhaust manifold and three way catalyst gasket, coating surface (black) shall be located on the exhaust manifold and three way catalyst side.



(A) : Triangle press

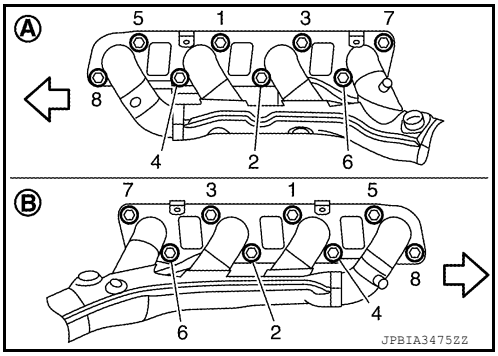
⇦ : Engine upper

Exhaust Manifold and Three Way Catalyst

- Tighten exhaust manifold and three way catalyst nuts in the sequence shown to the specified torque.

CAUTION:

All exhaust manifold and three way catalyst nuts are tightened twice.



Exhaust manifold and three way catalyst nuts : 28.0 N·m (2.9 kg-m, 21 ft-lb)

(A) : Bank 1

(B) : Bank 2

⇦ : Engine front

CAUTION:

Air Fuel Ratio Sensor 1 and Exhaust Temperature Sensor

- **Before installing a new air fuel ratio sensor 1 and exhaust temperature sensor, clean exhaust system threads using Tool and apply a suitable anti-seize lubricant.**
- **Air fuel ratio sensor 1 and exhaust temperature sensor is not reusable. Replace them with a new one after removal. When replacing them, handle with care not to impact on them.**
- **When installing the new air fuel ratio sensors 1 and exhaust temperature sensor, set the Tool in the hexagonal part to tighten them.**
- **Do not over torque sensors. Doing so may cause damage to the sensors, resulting in "MIL" coming on.**
- **Do not allow rust preventatives on sensor body.**

Tool : — (J-43897-18)

: KV10117100 (J-44626)

Removal and Installation - Non-XD Models

INFOID:0000000014681915

EXHAUST MANIFOLD AND THREE WAY CATALYST (BANK 1)

WARNING:

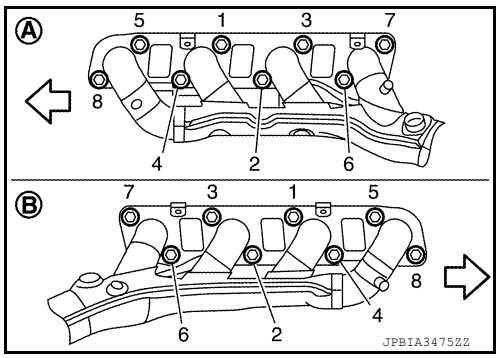
Perform the work when the exhaust has cooled sufficiently.

Removal

1. Remove engine. Refer to EM-120, "Removal and Installation".
2. Disconnect the harness connectors for the air fuel ratio sensor 1 (bank 1) and exhaust temperature sensor (bank 1).
3. Remove exhaust manifold cover bolts and remove exhaust manifold cover.
4. Remove exhaust manifold and three way catalyst (bank 1).

- Loosen nuts in the reverse of the sequence shown.

(A) : Bank 1
(B) : Bank 2
⇦ : Engine front



5. Remove exhaust manifold and three way catalyst gasket.

CAUTION:
- **Do not reuse gasket.**
- **Cover engine openings to avoid entry of foreign materials.**

Installation

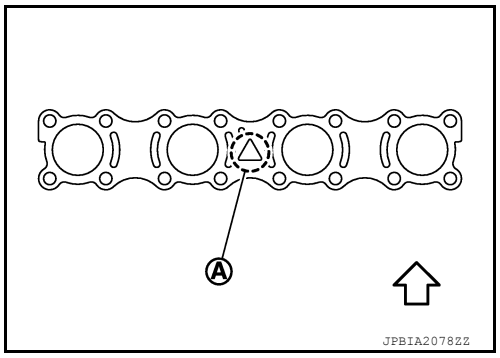
Installation is in the reverse order of removal.

Exhaust Manifold and Three Way Catalyst Gasket

- Install exhaust manifold and three way catalyst gasket in directional shown in the figure.

CAUTION:
Do not reuse gasket.
NOTE:
When installing exhaust manifold gasket, coating surface (black) shall be located on the exhaust manifold and three way catalyst side.

(A) : Triangle press
⇦ : Engine upper



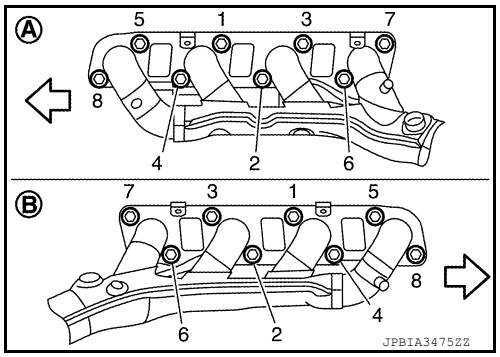
Exhaust Manifold and Three Way Catalyst

- Tighten exhaust manifold and three way catalyst nuts in the sequence shown to the specified torque.

CAUTION:
All exhaust manifold nuts are tightened twice.

Exhaust manifold and three way catalyst nuts : 28.0 N·m (2.9 kg-m, 21 ft-lb)

(A) : Bank 1
(B) : Bank 2
⇦ : Engine front



CAUTION:
Air Fuel Ratio Sensor 1 and Exhaust Temperature Sensor
- **Before installing a new air fuel ratio sensor 1 and exhaust temperature sensor, clean exhaust system threads using Tool and apply a suitable anti-seize lubricant.**
- **Air fuel ratio sensor 1 and exhaust temperature sensor is not reusable. Replace them with a new one after removal. When replacing them, handle with care not to impact on them.**
- **When installing the new air fuel ratio sensors 1 and exhaust temperature sensor, set the Tool in the hexagonal part to tighten them.**
- **Do not over torque sensors. Doing so may cause damage to the sensors, resulting in "MIL" coming on.**
- **Do not allow rust preventatives on sensor body.**

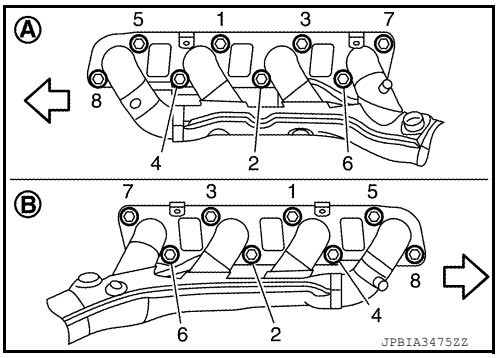
Tool : — (J-43897-18)
: KV10117100 (J-44626)

EXHAUST MANIFOLD AND THREE WAY CATALYST (BANK 2)

WARNING:
Perform the work when the exhaust has cooled sufficiently.

Removal

1. Remove engine. Refer to EM-120, "Removal and Installation".
2. Disconnect the harness connectors for the air fuel ratio sensor 1 (bank 1) and exhaust temperature sensor (bank 1).
3. Remove the oil level gauge and oil level gauge guide. Refer to EM-70, "Exploded View".
4. Remove exhaust manifold cover bolts and remove exhaust manifold cover.
5. Remove exhaust manifold and three way catalyst (bank 2).
   - Loosen nuts in the reverse of the sequence shown.



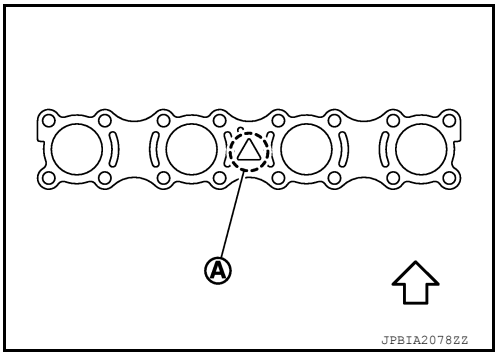
(A) : Bank 1
(B) : Bank 2
⇦ : Engine front

6. Remove exhaust manifold and three way catalyst gasket.
   CAUTION:
   - **Do not reuse gasket.**
   - **Cover engine openings to avoid entry of foreign materials.**

Installation
Installation is in the reverse order of removal.

Exhaust Manifold and Three Way Catalyst Gasket

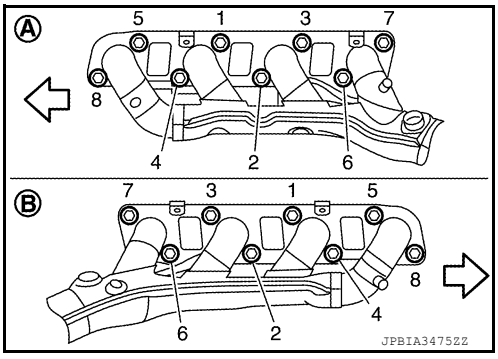
- Install exhaust manifold and three way catalyst gasket in directional shown in the figure.
  CAUTION:
  Do not reuse gasket.
  NOTE:
  When installing exhaust manifold and three way catalyst gasket, coating surface (black) shall be located on the exhaust manifold and three way catalyst side.



(A) : Triangle press
⇦ : Engine upper

Exhaust Manifold and Three Way Catalyst

- Tighten exhaust manifold and three way catalyst nuts in the sequence shown to the specified torque.
  CAUTION:
  All exhaust manifold and three way catalyst nuts are tightened twice.



Exhaust manifold and three way catalyst nuts : 28.0 N·m (2.9 kg-m, 21 ft-lb)

(A) : Bank 1
(B) : Bank 2
⇦ : Engine front

CAUTION:

Air Fuel Ratio Sensor 1 and Exhaust Temperature Sensor

- **Before installing a new air fuel ratio sensor 1 and exhaust temperature sensor, clean exhaust system threads using Tool and apply a suitable anti-seize lubricant.**
- **Air fuel ratio sensor 1 and exhaust temperature sensor is not reusable. Replace them with a new one after removal. When replacing them, handle with care not to impact on them.**
- **When installing the new air fuel ratio sensors 1 and exhaust temperature sensor, set the Tool in the hexagonal part to tighten them.**
- **Do not over torque sensors. Doing so may cause damage to the sensors, resulting in "MIL" coming on.**
- **Do not allow rust preventatives on sensor body.**

Tool : — (J-43897-18)
: KV10117100 (J-44626)

Inspection

INFOID:0000000014418505

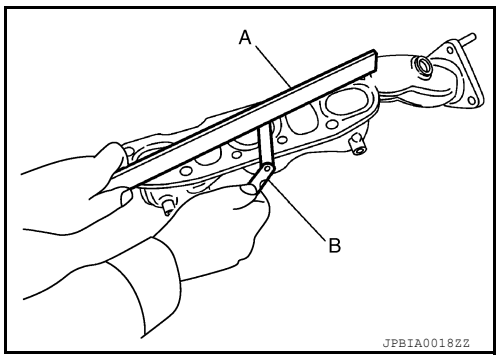
INSPECTION AFTER DISASSEMBLY

Surface Distortion

- Check the surface distortion of the exhaust manifold mating surface with a straightedge (A) and a feeler gauge (B).

Limit : Refer to EM-155, "Exhaust Manifold".

- If it exceeds the limit, replace exhaust manifold.

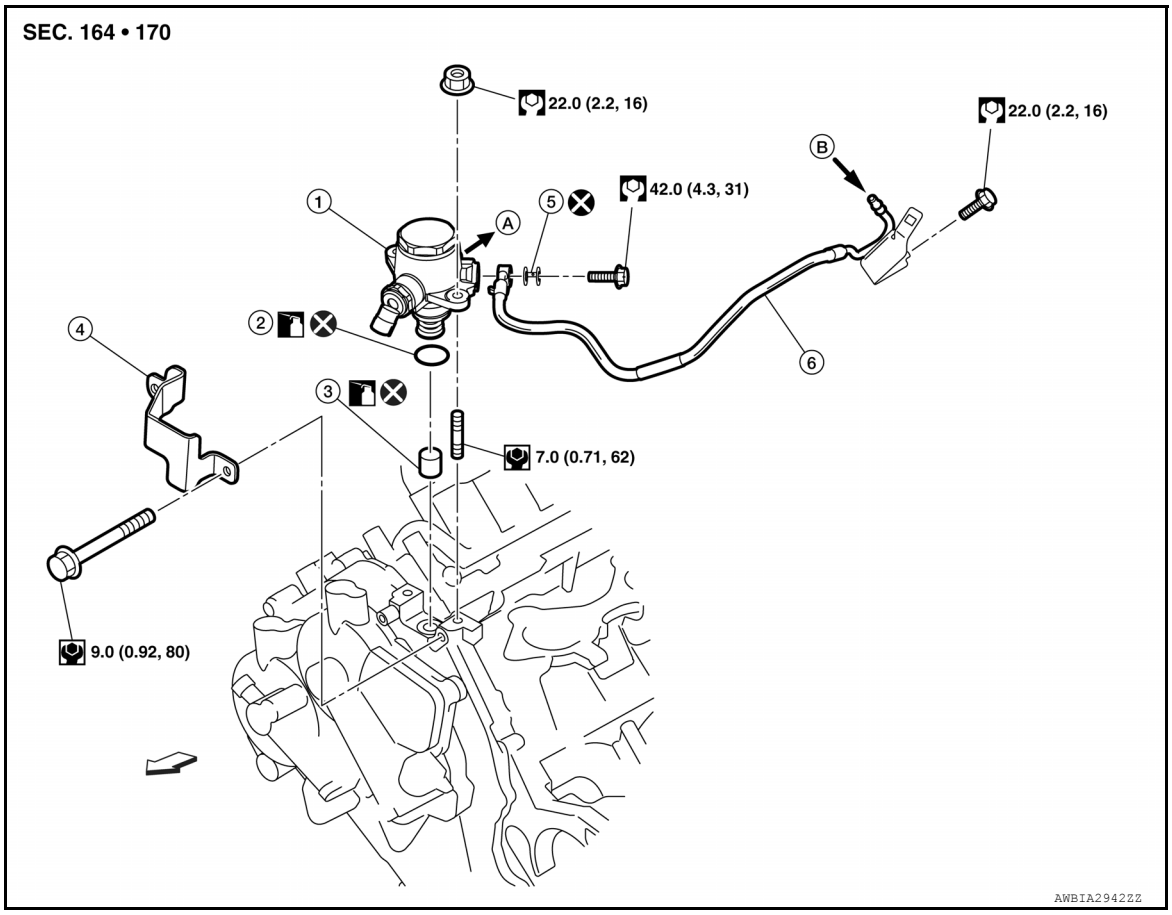


HIGH PRESSURE FUEL PUMP AND FUEL HOSE

Exploded View

INFOID:0000000014418506

CAUTION:
Do not remove or disassemble parts unless instructed.



1. High pressure fuel pump
2. O-ring
3. Lifter
4. Fuel pump connector protector
5. Copper washer
6. Fuel feed hose
A. To fuel feed tube (pump side)
B. From fuel tank
⇦ Engine front

Removal and Installation

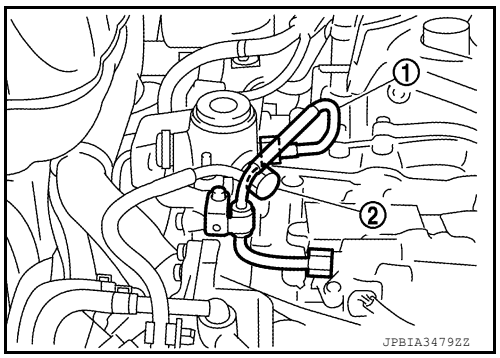
INFOID:0000000014418507

REMOVAL

WARNING:
- **Be sure to read EM-7, "Precaution for Handling High Pressure Fuel System" when working on the high pressure fuel system.**
- **Put a “CAUTION: FLAMMABLE” sign in the workshop.**
- **Be sure to work in a well ventilated area and furnish workshop with a CO_2 fire extinguisher.**
- **Do not smoke while servicing fuel system. Keep open flames and sparks away from the work area.**

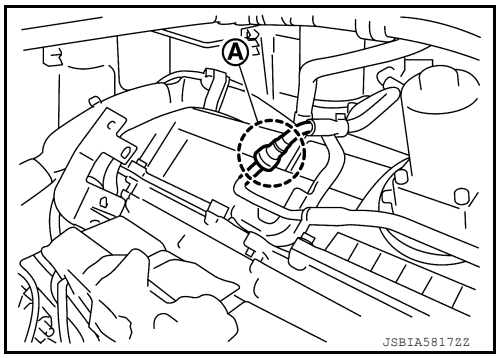
1. Release fuel pressure. Refer to EC-205, "Work Procedure".
2. Remove intake manifold. Refer to EM-35, "Removal and Installation".
3. Disconnect harness connector from high pressure fuel pump.

4. Remove fuel feed tube (pump side) (1).
5. Disconnect fuel feed hose (2) from high pressure fuel pump.



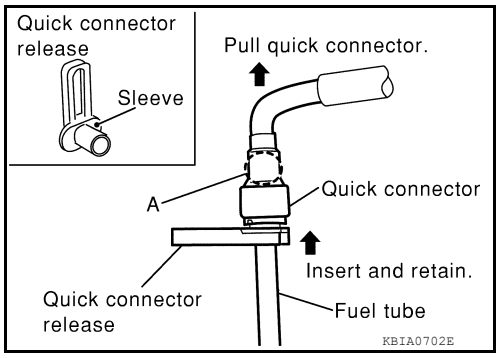
6. Remove high pressure fuel pump and lifter.
CAUTION:
- **Do not reuse lifter or O-ring.**
- **Do not disassemble plunger on bottom of high pressure fuel pump.**

7. Disconnect quick connector (A) with the following procedure.



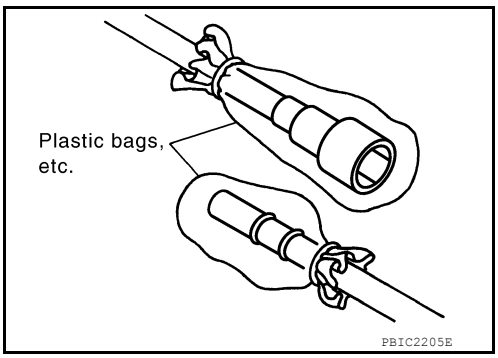
a. Remove quick connector cap from quick connector connection.
b. With the sleeve side of quick connector release facing quick connector, install Tool onto fuel tube.
c. Insert Tool into quick connector until sleeve contacts and goes no further. Hold Tool in that position.
CAUTION:
Inserting Tool hard will not disconnect quick connector. Hold quick connector release where it contacts and goes no further.

Tool : — (J-45488)



d. Draw and pull out quick connector straight from fuel tube.
CAUTION:
- **Pull quick connector holding (A) position as shown in the figure.**
- **Do not pull with lateral force applied. O-ring inside quick connector may be damaged.**
- **Prepare container and cloth beforehand because fuel will leak out.**
- **Avoid fire and sparks.**
- **Keep parts away from heat source. Especially, be careful when welding is performed around them.**
- **Do not expose parts to battery electrolyte or other acids.**
- **Do not bend or twist connection between quick connector and fuel feed hose (with damper) during installation/removal.**

- **To keep clean the connecting portion and to avoid damage and foreign materials, cover them completely with plastic bags, etc. or a similar item.**



8. Remove fuel feed hose.

INSTALLATION

CAUTION:

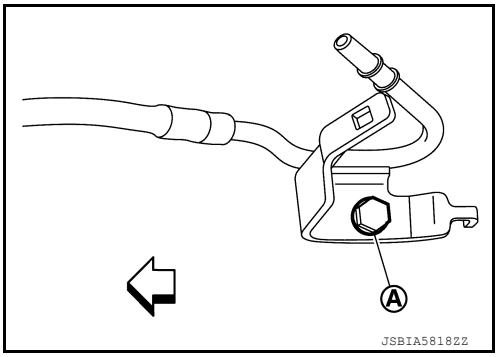
Do not reuse O-rings, washers or lifter.

1. Install O-ring to high pressure fuel pump. When handing new O-ring, paying attention to the following caution items:

   CAUTION:
   - **Do not reuse O-ring.**
   - **Handle O-ring with bare hands. Do not wear gloves.**
   - **Lubricate O-ring with new engine oil.**
   - **clean O-ring with solvent.**
   - **Check that O-ring and its mating part are free of foreign material.**
   - **When installing O-ring, be careful not to scratch it with tool or fingernails. Also be careful not to twist or stretch O-ring. If O-ring was stretched while it was being attached, do not insert it quickly into front cover.**
   - **Insert new O-ring straight into high pressure fuel pump. Do not decenter or twist it.**

2. Install fuel feed hose.
   - Temporarily tighten bolt (A) as shown in the figure.

   ⇦ : Engine front



3. Install high pressure fuel pump and lifter to front cover.

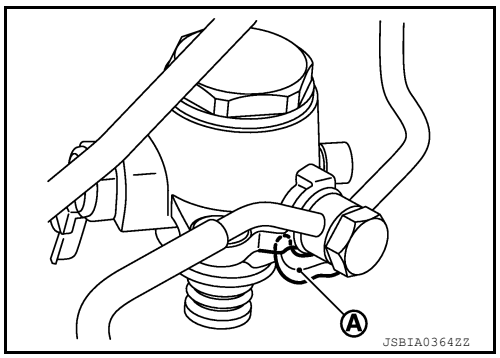
   CAUTION:
   - **Do not reuse lifter or O-ring.**
   - **Do not disassemble plunger on bottom of high pressure fuel pump.**

4. Connect fuel feed hose and fuel feed tube (pump side) to high pressure fuel pump. Refer to EM-57, "Exploded View".

   CAUTION:
   - **Do not reuse copper washer.**
   - **When removing fuel feed tube (pump side), always replace fuel feed tube (bank side) together with fuel feed tube (pump side).**

   NOTE:
   - Do not allow the machined edge of the high pressure fuel pump to contact with gasket.
   - The gasket contact area must be free of dust and scratches.

- Check that rotation stopper (A) of fuel feed hose contact high pressure fuel pump.

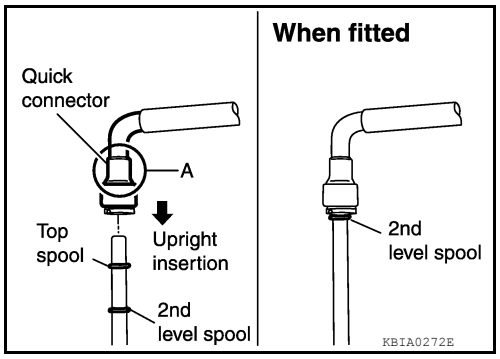


5. Tighten mounting bolts that are temporarily tightened in step 2.
6. Connect harness connector to high pressure fuel pump.
7. Note the following, and connect quick connector to install fuel feed hose.

a. Check the connection for foreign material and damage.

b. Align center to insert quick connector straightly into fuel tube.
NOTE:
The figure shows engine side as an example.
- Insert fuel tube into quick connector until the top spool on fuel tube is inserted completely and the second level spool is positioned slightly below quick connector bottom end.

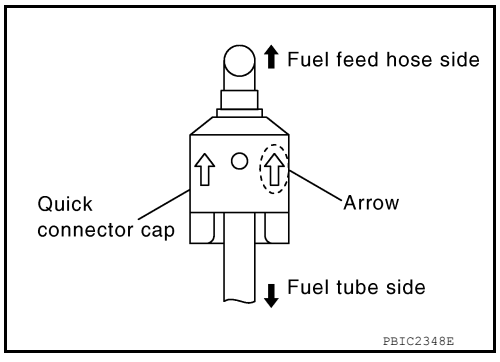
CAUTION:
- **Hold "A" position in the figure when inserting fuel tube into quick connector.**
- **Carefully align center to avoid inclined insertion to prevent damage to O-ring inside quick connector.**
- **Insert until you hear a "click" sound and actually feel the engagement.**
- **To avoid misidentification of engagement with a similar sound, be sure to perform the next step.**



c. Before clamping fuel feed hose with hose clamps, pull quick connector hard by hand holding "A" position. Check it is completely engaged (connected) so that it does not come out from fuel feed tube.

d. Install quick connector cap to quick connector connection.
- Install so that the arrow mark on the side faces up.

CAUTION:
- **Check that quick connector and fuel tube are securely fit into quick connector cap installation groove.**
- **If quick connector cap cannot be installed smoothly, quick connector may have not been installed correctly. Check connection again.**



8. Installation of the remaining components is in the reverse order of removal.
CAUTION:
After checking fuel leakage, maintain ten minutes of idling to bleed the fuel line.

Inspection

INFOID:0000000014418508

INSPECTION AFTER INSTALLATION

Check for Fuel Leakage

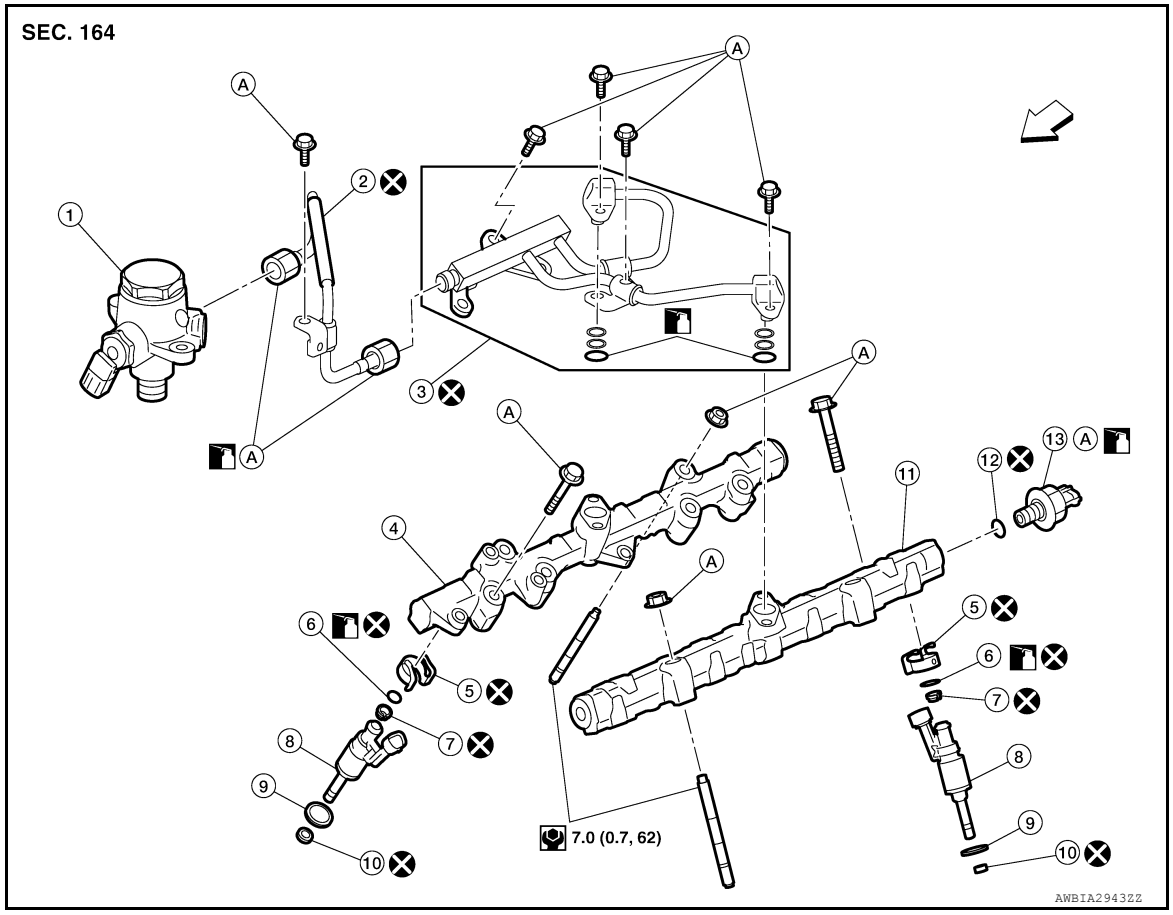
1. Turn ignition switch "ON" (with the engine stopped). With fuel pressure applied to fuel piping, check that there is no fuel leaks at connection points.
NOTE:
Use mirrors for checking at points out of clear sight.

2. Start the engine. With engine speed increased, check again that there is no fuel leaks at connection points.
   CAUTION:
   Do not touch the engine immediately after it is stopped because the engine is extremely hot.

FUEL INJECTOR AND FUEL TUBE

Exploded View

INFOID:0000000014418509



1. Fuel feed tube (bank side)	2. Fuel feed tube (pump side)	3. High pressure fuel pump
4. Fuel rail (bank 2)	5. Injector holder	6. O-ring (blue)
7. Backup ring	8. Fuel injector	9. Seal ring
10. Insulator	11. Fuel rail (bank 1)	12. Gasket
13. Fuel rail pressure sensor	A. Refer to INSTALLATION	⇦ Front

CAUTION:
- **Do not remove or disassemble parts unless instructed as shown in the figure.**
- **Be sure to follow the tightening instruction to avoid fuel leakage.**

NOTE:
Replace both fuel feed tube (pump side) and fuel feed tube (bank side) simultaneously.

Removal and Installation

INFOID:0000000014418510

REMOVAL

WARNING:
- **Be sure to read EM-7, "Precaution for Handling High Pressure Fuel System" when working on the high pressure fuel system.**
- **Put a "CAUTION: FLAMMABLE" sign in the workshop.**
- **Be sure to work in a well ventilated area and furnish workshop with a CO_2 fire extinguisher.**
- **Do not smoke while servicing fuel system. Keep open flames and sparks away from the work area.**

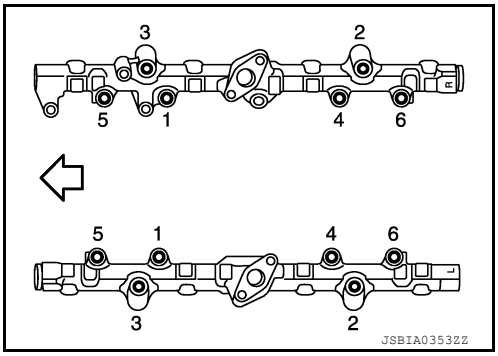
1. Release fuel pressure. Refer to EC-205, "Work Procedure".
2. Remove intake manifold. Refer to EM-35, "Removal and Installation".
3. Remove fuel feed tube (pump side) and fuel feed tube (bank side).

CAUTION:
Do not reuse fuel feed tube.

4. Disconnect harness connector from fuel injectors.
5. Loosen fuel rail (bank 1) and fuel rail (bank 2) nuts and bolts in the reverse sequence shown.

CAUTION:
- **Be careful with remaining fuel that may come out from fuel rail (bank 1) or fuel rail (bank 2).**
- **Be careful not to damage injector nozzles during removal.**
- **Do not bump or drop fuel injector.**
- **Do not disassemble fuel injector.**

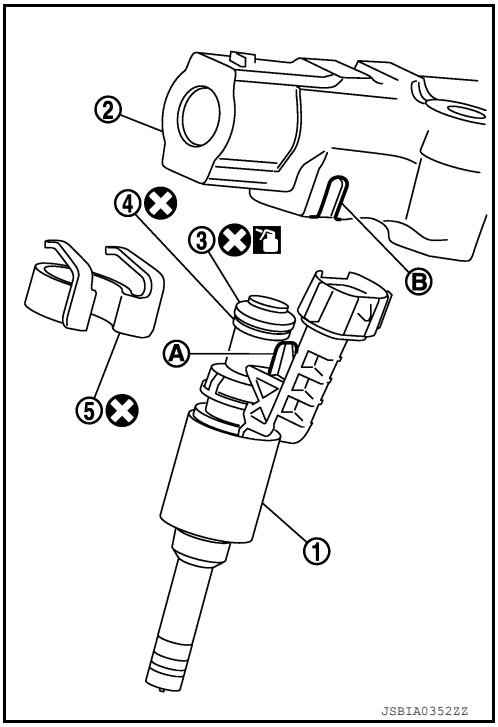
⇦ : Engine front



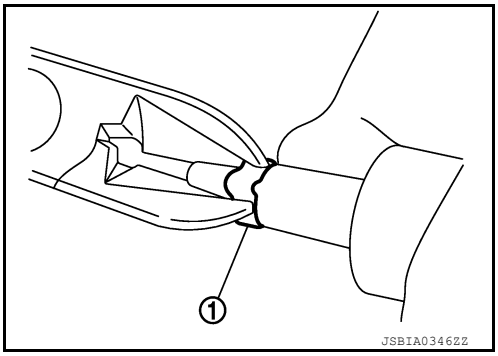
6. Remove fuel injector (1) from fuel rail (2).
7. Remove fuel injector holder (5) from fuel injector.

CAUTION:
Do not reuse fuel injector holder, O-ring [blue (3)] and back-up ring (4).

(A) : Injector protrusion
(B) : Fuel rail cutout



8. Cut seal ring (1) while pinching it. Be careful not to damage injector.



9. Remove insulator from fuel injector bore in cylinder head.

NOTE:
Insulator may stuck to fuel injector when it is removed.

10. Remove fuel rail pressure sensor from fuel rail [bank 1 (if necessary)].

INSTALLATION

CAUTION:
Do not reuse O-rings.

1. If fuel rail pressure sensor was removed, refer to the following procedure:

a. Fix fuel rail (bank 1) in a vice.
CAUTION:
Do not scratch or crack fuel rail during work procedure.

b. Apply engine oil to the entire perimeter of the fuel pressure sensor screw.
CAUTION:
Check that fuel rail and fuel pressure sensor screw have no damage, foreign matter, or stains.

c. Install gasket to fuel pressure sensor.
CAUTION:
Do not reuse gasket.

d. Tighten fuel pressure sensor.

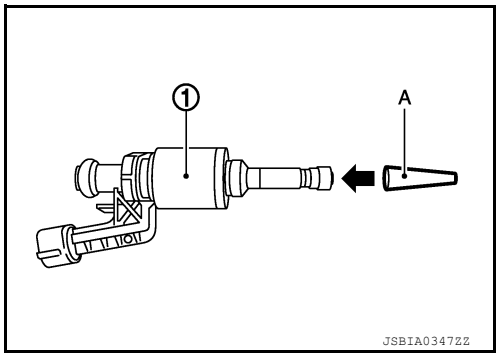
Fuel rail pressure sensor : 30.0 N·m (3.1 kg-m, 22 ft-lb)

CAUTION:
- **Do not use any fuel pressure sensor or gasket which has been dropped.**

2. Install seal ring to fuel injector using the following procedure:
CAUTION:
- **Handle seal ring with bare hands. Do not wear gloves.**
- **Do not apply engine oil to seal ring.**
- **Do not clean seal ring with solvent.**

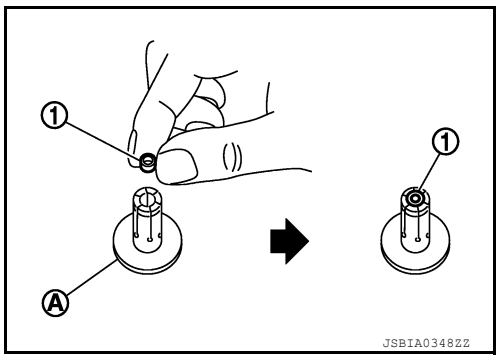
a. Install Tool (A) onto fuel injector (1).

Tool : KV10119720 (J-50364)

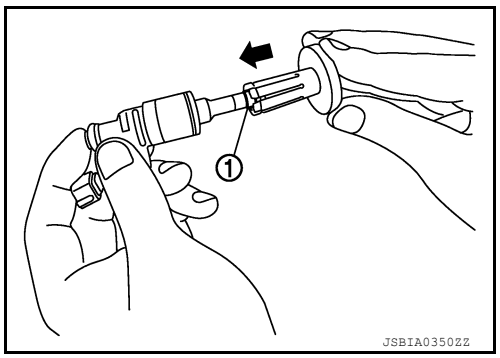


b. Set seal ring (1) into Tool (A).

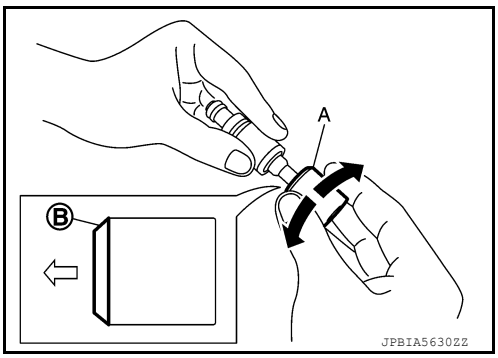
Tool : KV10119720 (J-50364)



c. Straightly insert seal ring (1), which is set in precedent step, onto fuel injector as shown in the figure and install.
CAUTION:
Be careful that seal ring does not exceed the groove portion of fuel injector.



d. Insert Tool (A) onto injector and rotate clockwise and counter-clockwise by 90° while pressing seal ring to fit it.



Tool : KV10119720 (J-50364)

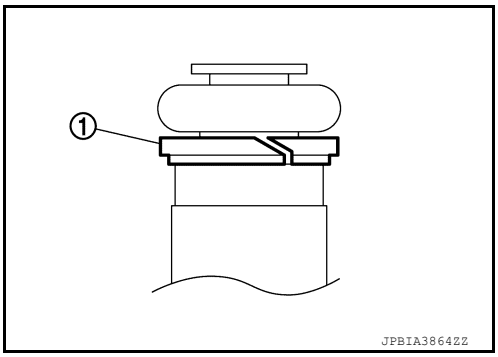
(B) : Chamfering

⇦ : Injector side

CAUTION:
Be careful to a direction of the tool.
NOTE:
Compress seal ring, because this operation is for rectifying stretch of seal ring caused by installation and for preventing sticking when inserting injector into cylinder head.

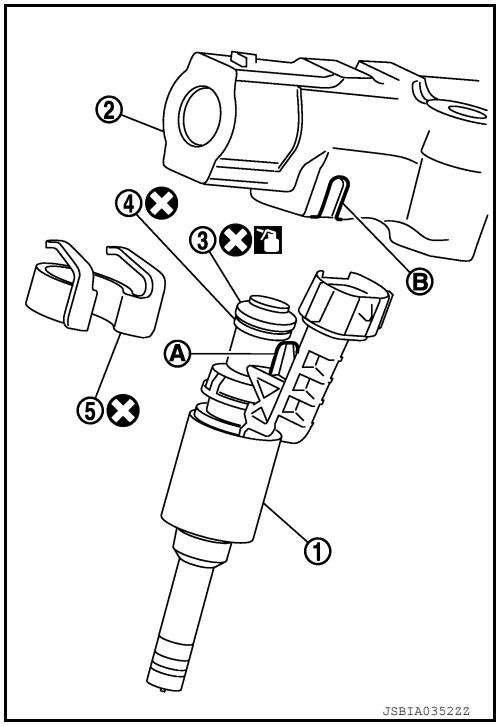
3. Install O-ring and backup ring to fuel injector. When handing new O-ring and backup ring, paying attention to the following caution items:

CAUTION:
- **Do not reuse O-ring and backup ring.**
- **Handle O-ring with bare hands. Do not wear gloves.**
- **Lubricate O-ring with new non-silicone engine oil.**
- **Do not allow engine oil to enter fuel passage ways.**
- **Do not clean O-ring with solvent.**
- **Check that O-ring and its mating part are free of foreign material.**
- **When installing O-ring, be careful not to scratch it with tool or fingernails. Also be careful not to twist or stretch O-ring. If O-ring was stretched while it was being attached, do not insert it quickly into fuel tube.**
- **Insert new O-ring straight into fuel rail. Do not decenter or twist it.**
- **Always install the back up ring (1) in the right direction as instructed.**



4. Install fuel injector (1) to fuel rail (2) as per the following:

(3) : O-ring (blue)
(4) : Backup ring



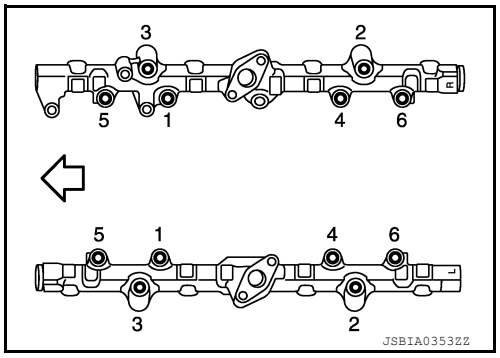
a. Install fuel injector holder (5) to fuel injector.
CAUTION:
- **Do not reuse injector holder. Replace it with a new one.**
- **Be careful to keep fuel injector holder from interfering with O-ring. If interference occurs, replace O-ring.**

b. Insert fuel injector into fuel rail with fuel injector holder attached.
- Insert it while matching it to the axial center.
- Insert so that protrusion (A) of fuel injector is aligned to cutout (B).

c. Check that installation is complete by checking that fuel injector does not rotate or come off.
- Check that protrusions of fuel injectors and fuel rail are aligned with cutouts of clips after installation.

5. Insert insulator into fuel injector bore in cylinder head.

6. Install fuel rail and fuel injector assembly to cylinder head.
- Tighten bolts and nuts in two steps in numerical order as shown in the figure.

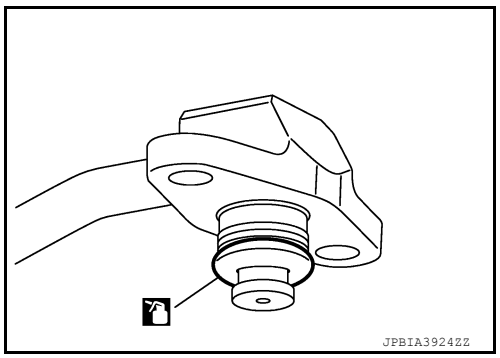


⇦ : Engine front

1st step : 10.0 N·m (1.0 kg-m, 89 in-lb)
2nd step : 20.5 N·m (2.1 kg-m, 15 ft-lb)

7. Connect injector harness connector.

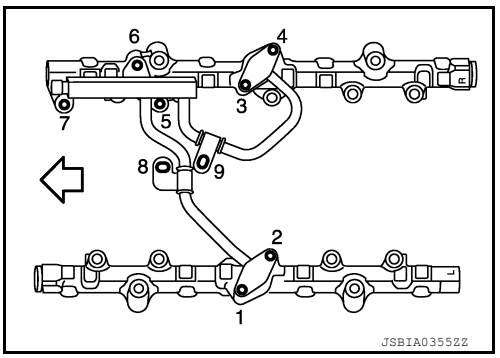
8. Install fuel feed tube (bank side) to fuel rail.
CAUTION:
- **Do not reuse fuel feed tube (bank side).**
- **When installing fuel feed tube (bank side) to fuel rail, press the flange part to install the tube.**
- **Handle O-ring with bare hands. Do not wear gloves.**
- **Lubricate O-ring with new engine oil.**
- **Do not clean O-ring with solvent.**
- **Check that O-ring and its mating part are free of foreign material.**
- **Do not scratch O-ring with tools or fingernails when installing fuel feed tube (bank side).**
- **Insert new fuel feed tube (bank side) straight into fuel rail. Do not decenter or twist the fuel feed tube (bank side) during insertion.**



- Tighten bolts in numerical order as shown in the figure.

Fuel feed tube (bank side) bolts : 11.0 N·m (1.1 kg-m, 8 ft-lb)

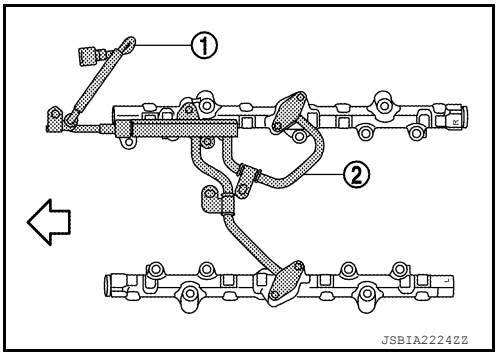
⇦ : Engine front



9. Install fuel feed tube (pump side) (1) to fuel feed tube [bank side (2)] as per the following:

CAUTION:
- **When removing fuel feed tube (pump side), always replace fuel feed tube (bank side) together with fuel feed tube (pump side).**
- **Do not reuse fuel feed tube (pump side).**
- **Do not use fuel feed tube (pump side) if its terminal tip is damaged.**
- **Observe the tightening order and the tightening torque.**

⇦ : Engine front



a. Apply engine oil to flare screw parts of high pressure pump and tube between banks.

b. Manually tighten 2 flare nuts without using a tool until they are seated to screw thread.

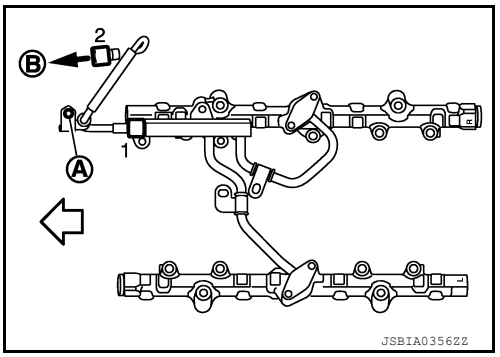
CAUTION:
When temporarily tightening flare nut, place pipe in the center of the nut inner diameter.

c. Tighten bolt (A).

Fuel feed tube (pump side) bolt : 11.0 N·m (1.1 kg-m, 8 ft-lb)

(B) :To high pressure fuel pump

⇦ : Engine front



d. Tighten flare nuts in the sequence shown to the specified torque.

CAUTION:
Always fit the tool completely with the nut.

Fuel feed tube (pump side) flare nuts : 33.4 N·m (3.4 kg-m, 25 ft-lb)

10. Installation of the remaining components is in the reverse order of removal.

CAUTION:
After checking for fuel leaks, maintain ten minutes of idling to bleed the fuel line.

Inspection

INFOID:0000000014418511

INSPECTION AFTER INSTALLATION

Check for Fuel Leakage

1. Turn ignition switch “ON” (with the engine stopped). With fuel pressure applied to fuel piping, check that there is no fuel leaks at connection points.

NOTE:
Use mirrors for checking at points out of clear sight.

2. Start the engine. With engine speed increased, check again that there is no fuel leaks at connection points.

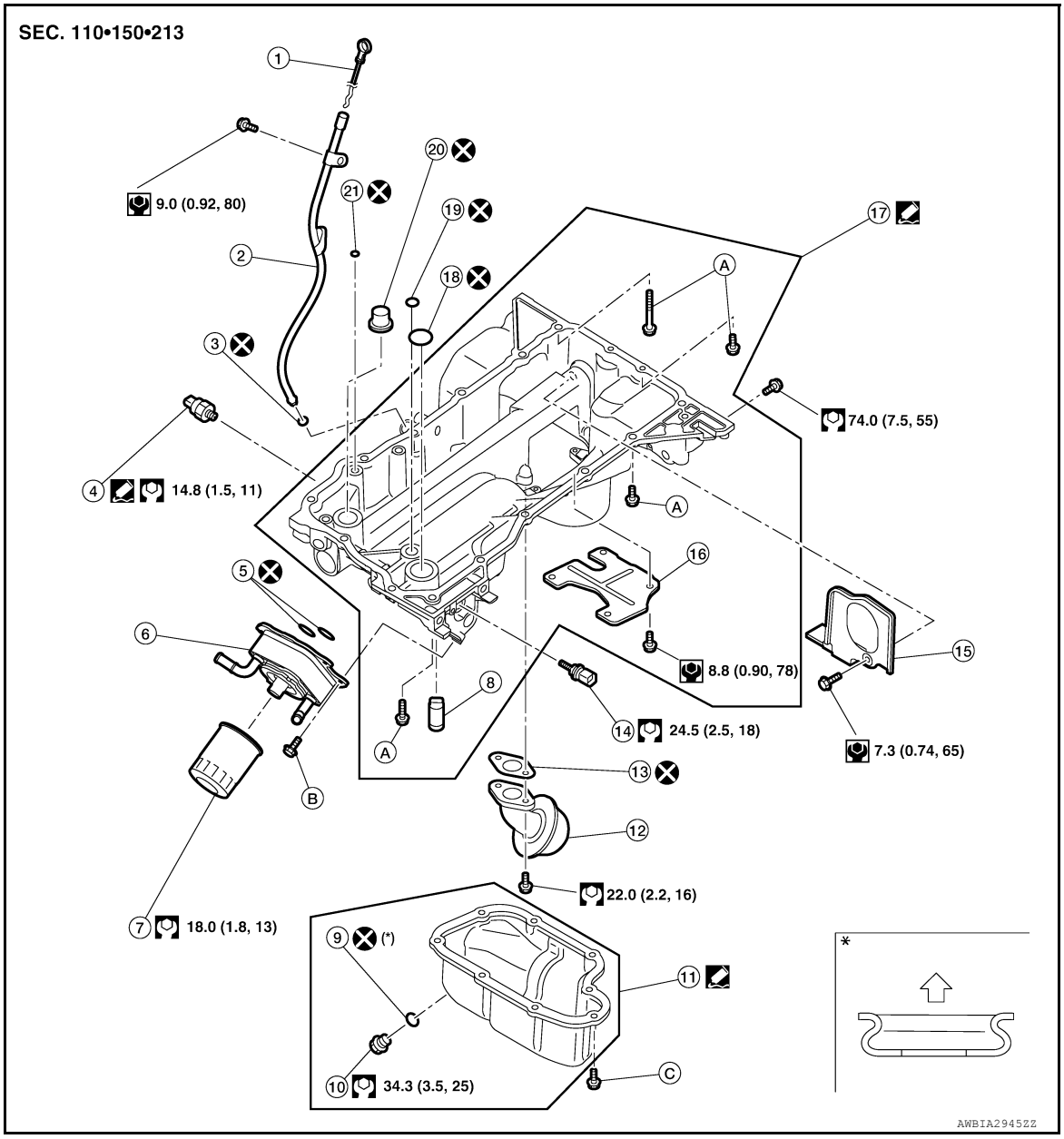
CAUTION:

Do not touch the engine immediately after it is stopped because the engine is extremely hot.

OIL PAN (LOWER) AND OIL STRAINER

Exploded View

INFOID:0000000014418512



1. Oil level gauge
2. Oil level gauge guide
3. O-ring
4. Oil pressure sensor
5. O-ring
6. Oil cooler
7. Oil filter
8. Relief valve
9. Drain plug washer
10. Drain plug
11. Oil pan (lower)
12. Oil strainer
13. Gasket
14. Oil temperature sensor
15. Rear plate cover
16. Baffle plate
17. Oil pan (upper)
18. O-ring
19. O-ring
20. O-ring
21. O-ring

A. Refer to EM-71, "Removal and Installation".
B. Refer to LU-13, "Removal and Installation".
C. Refer to INSTALLATION

⇦ : Oil pan side

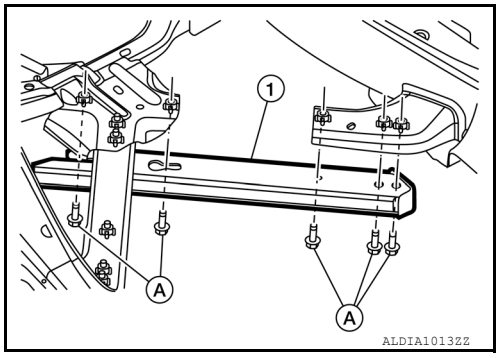
Removal and Installation

INFOID:0000000014418513

REMOVAL

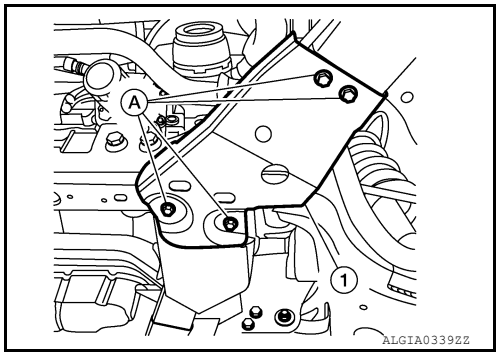
WARNING:
To avoid the danger of being scalded, never drain engine oil when engine is hot.

1. Drain engine oil. Refer to LU-10, "Draining".
2. Remove engine undercover. Refer to EXT-39, "ENGINE UNDER COVER : Removal and Installation".
3. For Non-XD Models, remove bolts (A) then remove rear diagonal cross member assemblies [1 (LH/RH)].
   NOTE:
   RH shown, LH similar.

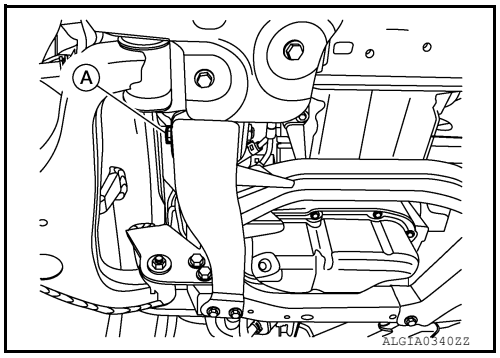


4. For 2WD Non-XD models, remove the following components.

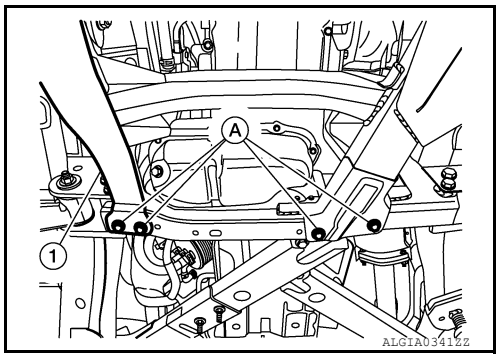
a. Remove bolts (A) and remove front suspension member reinforcement [LH (1)].



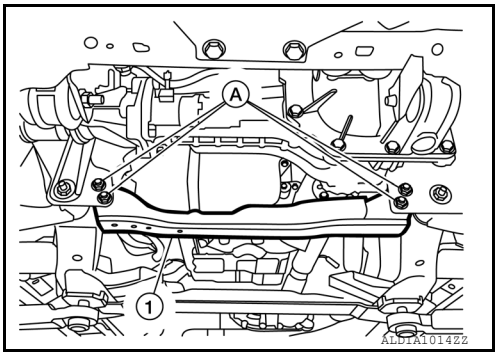
b. Remove differential mounting bolt (A).



c. Remove bolts (A) and remove diagonal member (1).

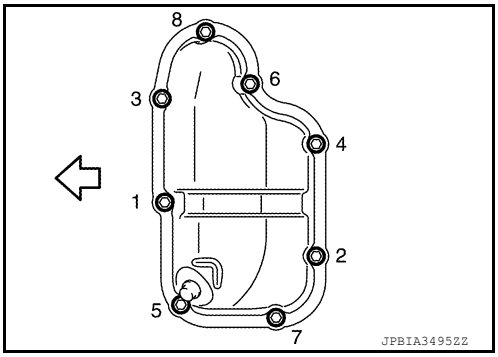


d. Remove bolts and nuts (A) from front cross member (1), then remove front cross member.
CAUTION:
Do not reuse nuts.



5. Remove oil pan (lower) in the following sequence.
a. Remove bolts in order as shown.

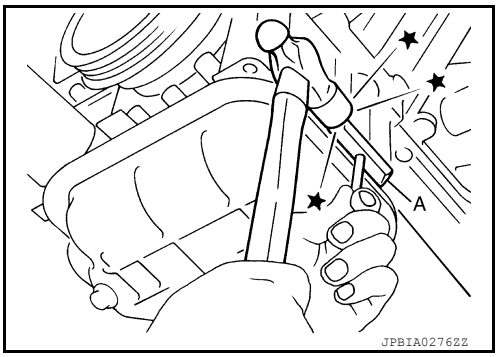
⇦ : Engine front



b. Insert Tool (A) between oil pan (upper) and oil pan (lower).
CAUTION:
- **Be careful not to damage the mating surfaces.**
- **Do not insert a screwdriver. This damages the mating surfaces.**

Tool : KV10111100 (J-37228)

c. Slide the Tool by tapping on the side of tool with a suitable tool and remove oil pan (lower).



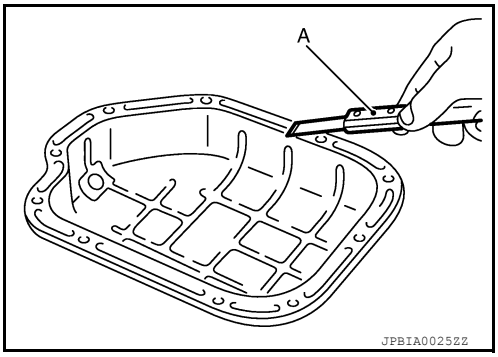
6. Remove oil strainer (if necessary).

INSTALLATION

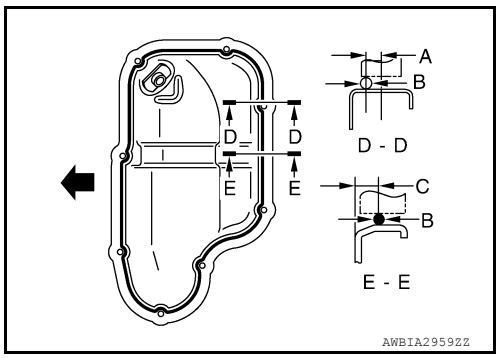
CAUTION:
Do not reuse drain plug washer.

1. Install oil strainer (if removed).
2. Install oil pan (lower) in the following sequence.
a. Use suitable tool (A) to remove old liquid gasket from mating surfaces.
- Remove old liquid gasket from the bolt holes and thread.

CAUTION:
Do not scratch or damage the mating surfaces when cleaning off old liquid gasket.



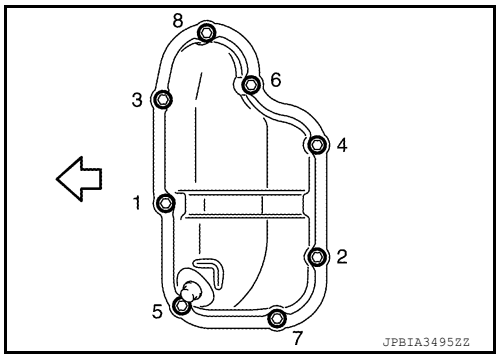
b. Apply a continuous bead of liquid gasket with a suitable tool to the oil pan (lower) as shown.



(A) : 5.0 - 7.0 mm (0.20 - 0.28 in)
(B) : ϕ4.0 - 5.0 mm (0.16 - 0.20 in)
(C) : 7.5 - 9.5 mm (0.30 - 0.37 in)
⇦ : Engine front

Use Genuine RTV silicone sealant or equivalent. Refer to GI-22, "Recommended Chemical Products and Sealants".
CAUTION:
Tighten oil pan (lower) bolts to specification within 5 minutes of application of liquid gasket.

c. Install oil pan (lower).
• Tighten bolts to specification in the sequence shown.

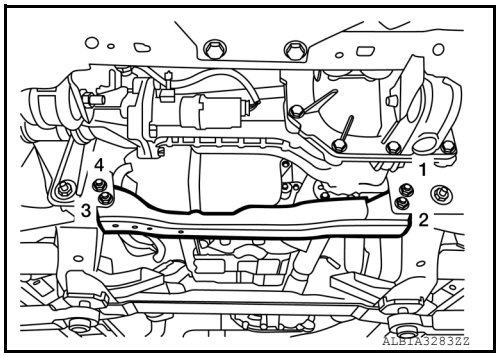


Oil pan (lower) bolts : 9.0 N·m (0.9 kg-m, 80 in-lb)

⇦ : Engine front

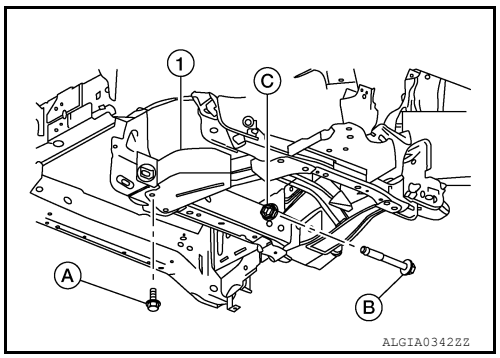
3. Install oil pan drain plug.
CAUTION:
Do not reuse drain plug washer.

4. Install front cross member assembly bolts and nuts, then tighten nuts to specification in sequence as shown.
CAUTION:
Do not reuse nuts.



Front cross member nuts : 180 Nm (18 kg-m, 133 ft-lb)

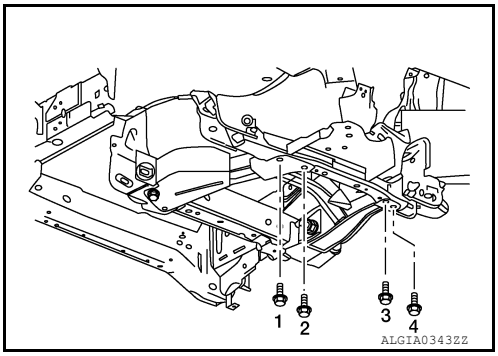
5. Install the diagonal member using the following steps.
a. Install diagonal member (1)
b. Temporarily install bolt (A) finger tight.
c. Install bolt (B) and nut (C) finger tight, then tighten to specification.



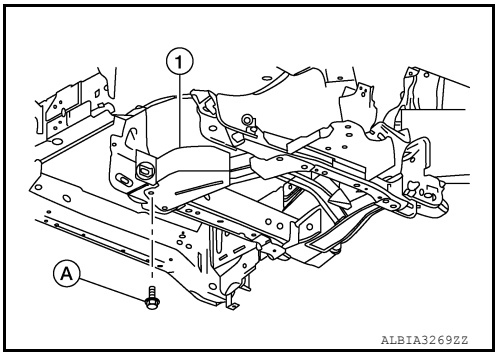
Nut (C) : 210 Nm (21 kg-m, 155 ft-lb)

d. Install diagonal member bolts finger tight, then tighten to specification in sequence as shown.

Diagonal member bolts : 80.0 Nm (8.2 kg-m, 59 ft-lb)

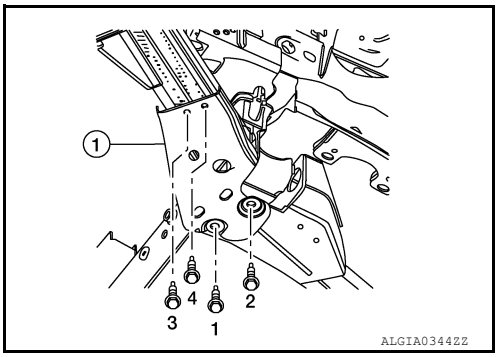


6. Remove bolt (A) from diagonal member (1).



7. Install front frame member reinforcement [LH (1)] bolts finger tight, then tighten to specification in sequence as shown.

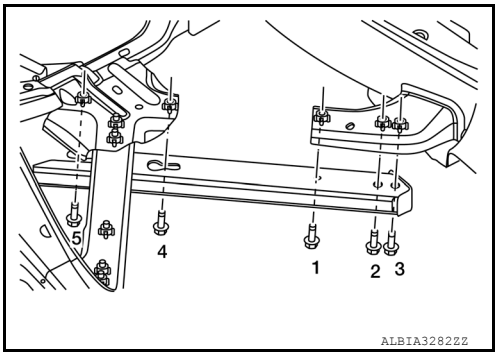
Bolts 1-4 : 80.0 Nm (8.2 kg-m, 59 ft-lb)



8. Install rear diagonal cross member assembly (LH/RH) bolts, then tighten to specification in sequence as show (Non-XD Models).

Rear diagonal cross member bolts : 130 Nm (13 kg-m, 96 ft-lb)

NOTE:
RH show, LH similar.



9. Installation of the remaining components is in the reverse order of removal.
NOTE:
Wait at least 30 minutes after oil pan is installed before refilling engine oil.

Inspection

INFOID:0000000014418514

INSPECTION AFTER REMOVAL

Clean oil strainer if any object is attached.

INSPECTION AFTER INSTALLATION

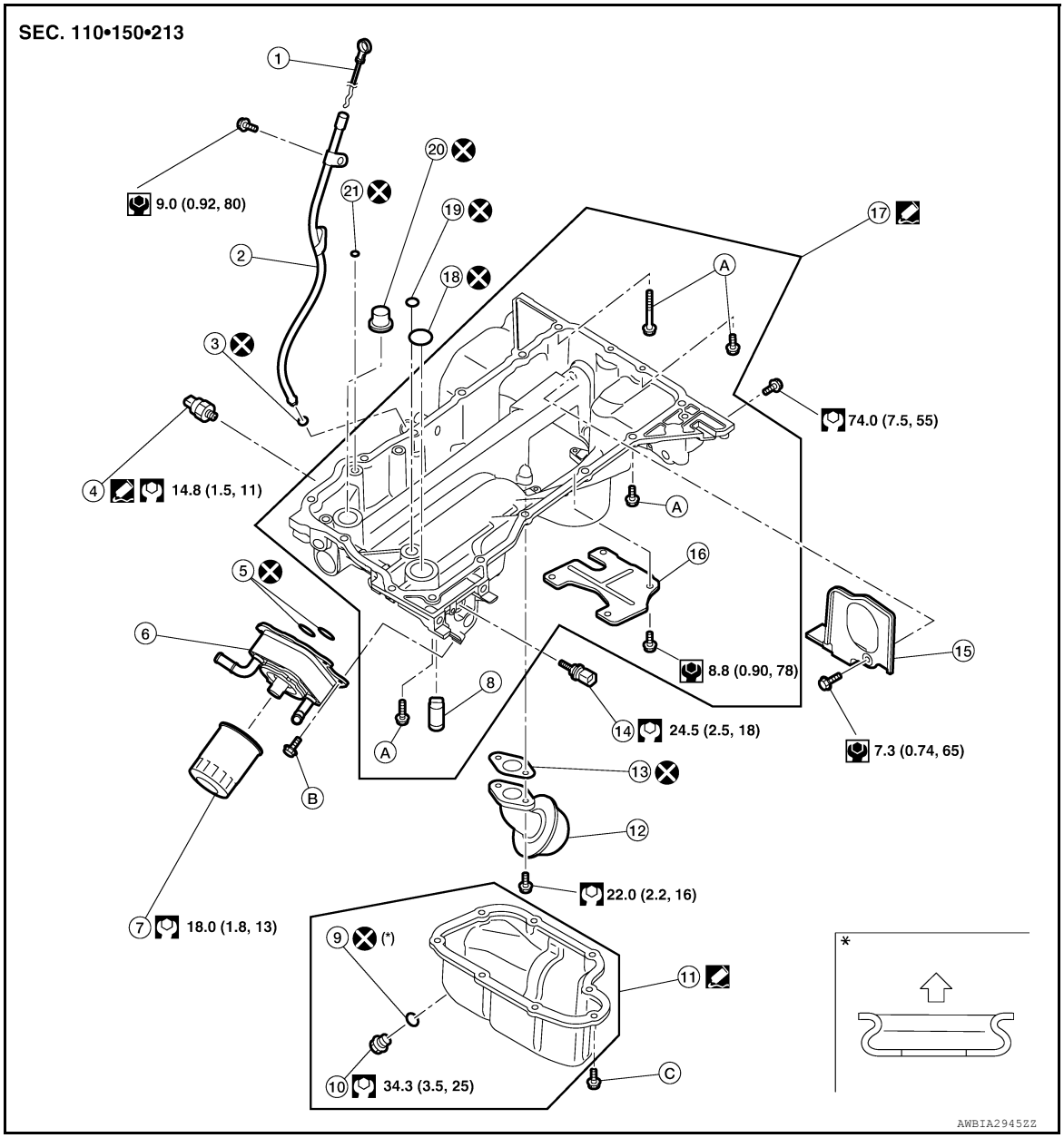
1. Check the engine oil level and adjust engine oil. Refer to LU-9, "Inspection".
2. Start engine, and check there is no leakage of engine oil.

3. Stop engine and wait for 15 minutes.
4. Check the engine oil level again. Refer to LU-9, "Inspection".

OIL PAN (UPPER)

Exploded View

INFOID:0000000014418515



1. Oil level gauge	2. Oil level gauge guide	3. O-ring
4. Oil pressure sensor	5. O-ring	6. Oil cooler
7. Oil filter	8. Relief valve	9. Drain plug washer
10. Drain plug	11. Oil pan (lower)	12. Oil strainer
13. Gasket	14. Oil temperature sensor	15. Rear plate cover
16. Baffle plate	17. Oil pan (upper)	18. O-ring
19. O-ring	20. O-ring	21. O-ring
A. Refer to INSTALLATION	B. Refer to LU-13, "Removal and Installation".	C. Refer to EM-65, "Removal and Installation".

⇦ : Oil pan side

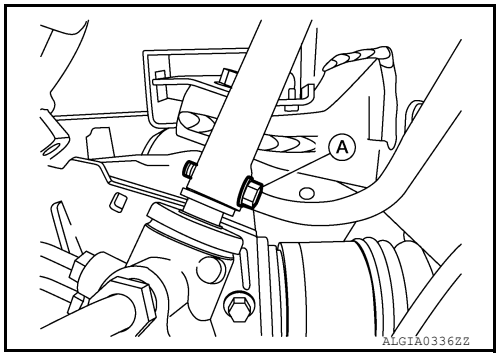
Removal and Installation

INFOID:0000000014418516

REMOVAL

WARNING:
To avoid the danger of being scalded, never drain engine oil when engine is hot.

1. Remove oil pan (lower). Refer to EM-65, "Removal and Installation".
2. Remove oil strainer.
3. Remove oil cooler. Refer to LU-13, "Removal and Installation".
4. Remove A/T fluid warmer (XD Models only). Refer to TM-499, "Exploded View - Non-XD Models".
5. Remove drive belt. Refer to EM-23, "Removal and Installation".
6. Unbolt A/C compressor and reposition. Refer to HA-31, "Exploded View".
   NOTE:
   It is not required to remove the high-pressure and low-pressure flexible hoses from the A/C compressor.
7. Remove oil level gauge and oil level gauge guide.
8. Disconnect oil pressure sensor and oil temperature sensor harness connectors.
9. Remove rear plate cover.
10. Remove floor under cover. Refer to EXT-40, "FLOOR UNDER COVER : Removal and Installation".
11. Remove front final drive assembly. Refer to DLN-191, "Removal and Installation" [XD 4WD models only (MA235)] or DLN-220, "Removal and Installation" [Non-XD 4WD models only (MA210)].
12. Remove pinch bolt (A) from lower joint and separate lower joint from steering gear (Non-XD Models).

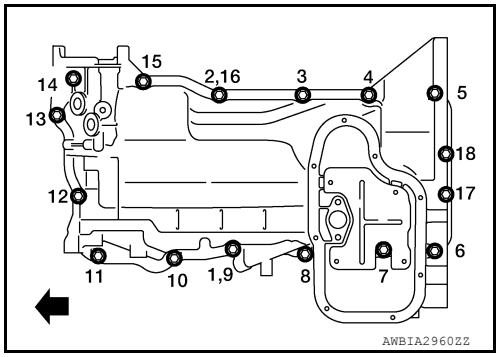


13. Remove steering gear bolts and position steering gear aside (Non-XD Models). Refer to ST-77, "Exploded View".
14. Remove bolts fixing oil pan (upper) to transmission assembly. Refer to TM-506, "2WD : Exploded View" (2WD) or TM-511, "4WD : Exploded View" (4WD).
15. Remove oil pan (upper) as per the following:

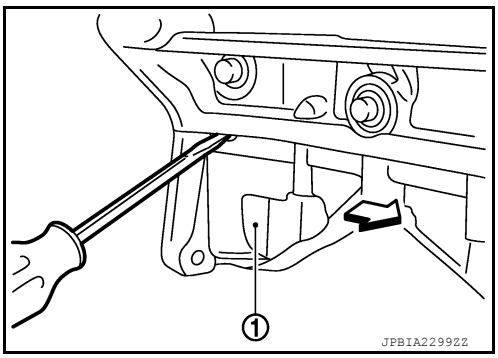
a. Loosen bolts in the reverse of the sequence as shown.

⇦ : Engine front

NOTE:
Disregard No. 9, 16 when loosening.



b. Insert a suitable tool into the notch at oil pan (upper) (1) as shown.
• Pry off case by moving a suitable tool.



⇦ : Engine front

CAUTION:
Be careful not to damage the mating surfaces.

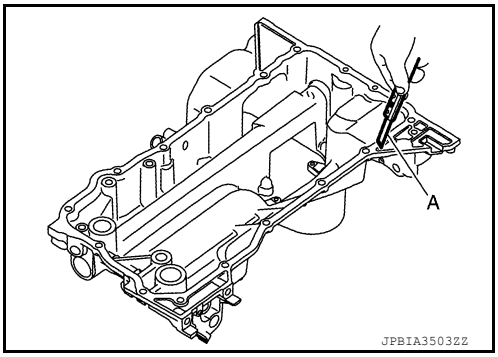
16. Remove O-rings from bottom of cylinder block and oil pump.
CAUTION:
Do not reuse O-rings.
17. Remove oil pressure sensor and oil temperature sensor (if necessary).

INSTALLATION

CAUTION:
Do not reuse O-rings.

1. Install oil pan (upper) as per the following:

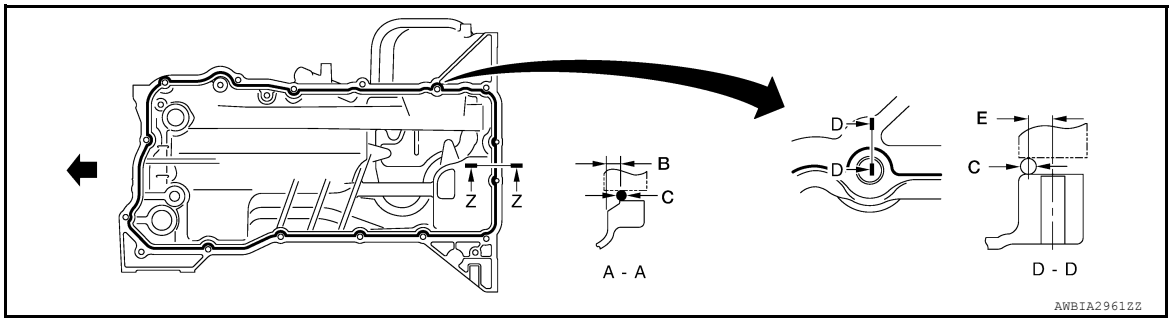
a. Use a suitable tool (A) to remove old liquid gasket from mating surfaces.
• Also remove the old liquid gasket from mating surface of cylinder block.
• Remove old liquid gasket from the bolt holes and threads.



CAUTION:
Do not scratch or damage the mating surfaces when cleaning off old liquid gasket.

b. Install new O-rings on the bottom of cylinder block and oil pump.
CAUTION:
Do not reuse O-rings.

c. Apply a continuous bead of liquid gasket with tube presser (commercial service tool) to the cylinder block mating surfaces of oil pan (upper) to a limited portion as shown in the figure.



B : 5.5 - 7.5 mm (0.217 - 0.295 in) C. : ϕ4.0 - 5.0 mm (0.157 - 0.197 in) E. : 6.2 - 8.2 mm (0.244 - 0.323 in)

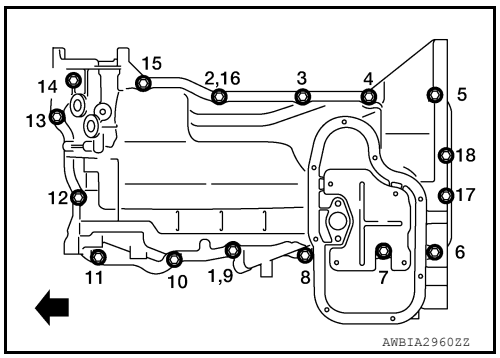
⇦ : Engine front

Use Genuine RTV silicone sealant or equivalent. Refer to GI-22, "Recommended Chemical Products and Sealants".
CAUTION:
Tighten oil pan (upper) bolts within 5 minutes of application of sealant.

d. Tighten bolts in the sequence shown to the specified torque.
CAUTION:
Install avoiding misalignment of O-rings.
NOTE:
Tighten bolts No. 1 and 2 in two steps. The numerical order No. 9 and 16 shown second steps.

⇦ : Engine front

- There are four types of bolts. Refer to the following for locating bolts.



Order number for tightening	17, 18	2 (16), 3, 4, 7, 8, 10, 11, 12, 13, 15	1(9), 14	5, 6
Bolt size	M6	M8		
Bolt length ℓ	45 mm (1.77 in)	25 mm (0.98 in)	30.0 mm (1.18 in)	120 mm (4.72 in)
Tightening torque	9.0 N· (0.92 kg-m, 80 in-lb)	22.0 N·m (2.2 kg-m, 16 ft-lb)		

e. Tighten transmission joint bolts.
f. Install rear plate cover.
2. Install oil strainer.
3. Install oil pan (lower). Refer to EM-65, "Removal and Installation".
4. Installation of remaining components is in the reverse order of removal.
NOTE:
At least 30 minutes after oil pan is installed to refill engine oil.

Inspection

INFOID:0000000014418517

INSPECTION AFTER DISASSEMBLY

Clean oil strainer if any object is attached.

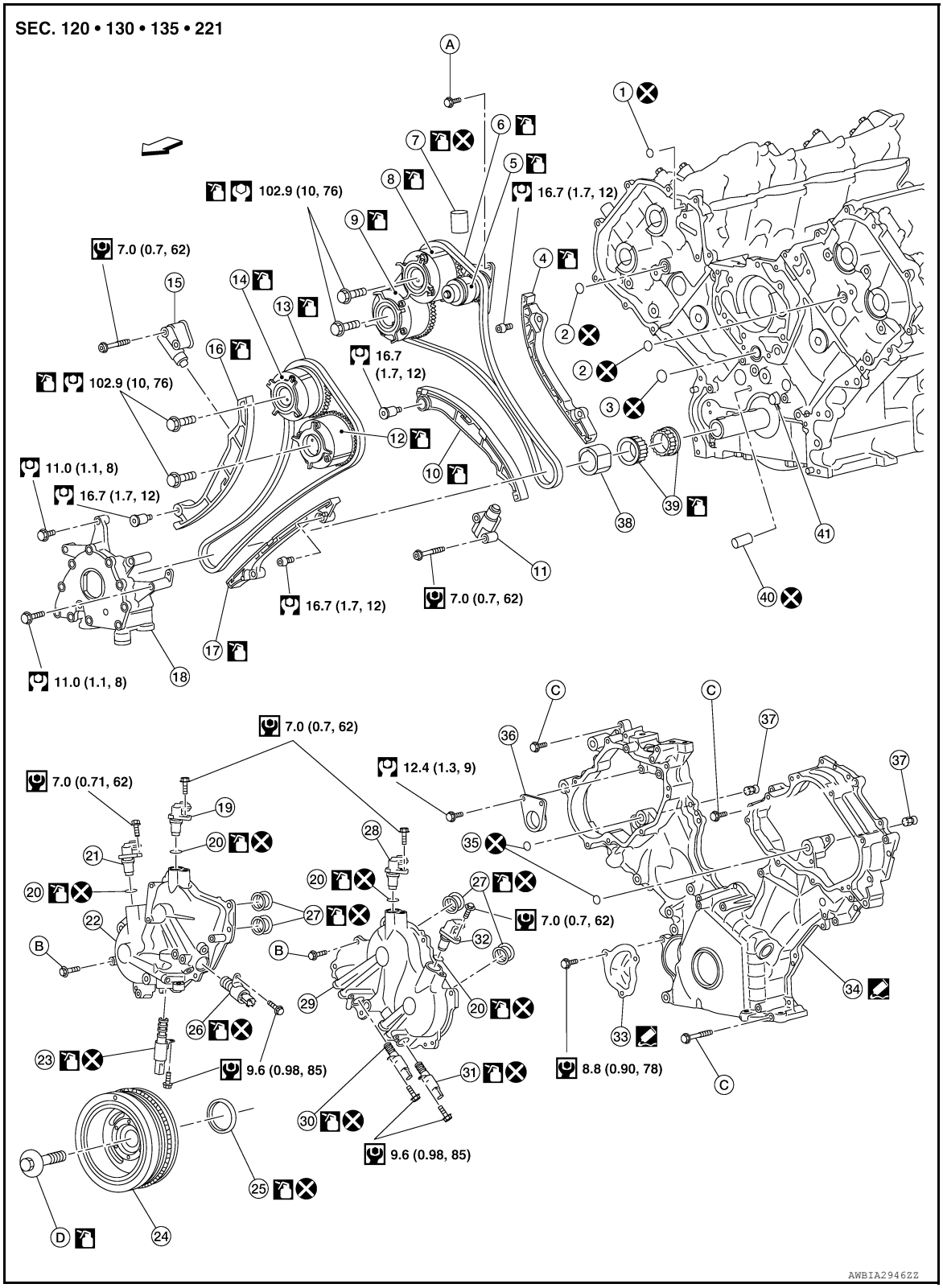
INSPECTION AFTER ASSEMBLY

1. Check the engine oil level and adjust engine oil. Refer to LU-9, "Inspection".
2. Start engine, and check there are no engine oil leaks.
3. Stop engine and wait for 15 minutes.
4. Check the engine oil level again. Refer to LU-9, "Inspection".

TIMING CHAIN

Exploded View

INFOID:0000000014418518



1. O-ring
2. O-ring
3. O-ring
4. Tension guide (bank 2)
5. High pressure fuel pump camshaft
6. Timing chain (bank 2)
7. Lifter
8. Intake camshaft sprocket (bank 2)
9. Exhaust camshaft sprocket (bank 2)

10.	Slack guide (bank 2)	11.	Timing chain tensioner (bank 2)	12.	Exhaust camshaft sprocket (bank 1)
13.	Timing chain (bank 1)	14.	Intake camshaft sprocket (bank 1)	15.	Timing chain tensioner (bank 1)
16.	Slack guide (bank 1)	17.	Tension guide (bank 1)	18.	Oil pump
19.	Intake camshaft position sensor (bank 2)	20.	O-ring	21.	Exhaust camshaft position sensor (bank 2)
22.	Valve timing control cover (bank 2)	23.	Exhaust valve timing control solenoid valve (bank 2)	24.	Crankshaft pulley
25.	Front oil seal	26.	Intake valve timing control solenoid valve (bank 2)	27.	Seal ring
28.	Intake camshaft position sensor (bank 1)	29.	Valve timing control cover (bank 1)	30.	Intake valve timing control solenoid valve (bank 1)
31.	Exhaust valve timing control solenoid valve (bank 1)	32.	Exhaust camshaft position sensor (bank 1)	33.	Timing chain tensioner cover
34.	Front cover	35.	O-ring	36.	Camshaft bracket
37.	Oil filter (for valve timing control solenoid valve)	38.	Oil pump drive spacer	39.	Crankshaft sprocket
40.	Oil jet (bank 2)	41.	Oil jet (bank 1)	A.	Refer to INSTALLATION
B.	Refer to INSTALLATION	C.	Refer to INSTALLATION	D.	Refer to INSTALLATION
⇦	Front				

Removal and Installation

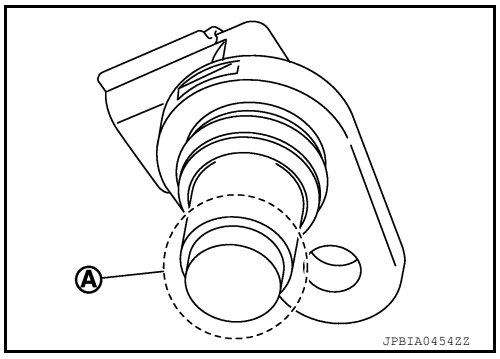
INFOID:0000000014418519

REMOVAL

1. Release fuel pressure. Refer to EC-205, "Work Procedure".
2. Remove oil pan (upper). Refer to EM-71, "Removal and Installation".
3. Remove intake manifold. Refer to EM-35, "Removal and Installation".
4. Remove fan bracket. Refer to CO-22, "Removal and Installation".
5. Remove drive belt auto-tensioner. Refer to EM-25, "Exploded View".
6. Unbolt power steering oil pump and reposition. Refer to ST-66, "Exploded View".
7. Remove alternator, alternator bracket and alternator stay. Refer to CHG-46, "Removal and Installation: VK56VD".
8. Disengage power steering reservoir tank from power steering reservoir tank bracket and then remove power steering reservoir tank bracket. Refer to ST-69, "Exploded View".
9. Remove high pressure fuel pump and lifter. Refer to EM-52, "Exploded View".
   CAUTION:
   Do not reuse lifter.
10. Remove radiator hose (upper) and radiator hose (lower). Refer to CO-13, "Exploded View".
11. Remove water suction pipe. Refer to CO-27, "Exploded View".
12. Remove rocker cover. Refer to EM-38, "Removal and Installation".
13. Remove camshaft position sensors.

    (A) : Keep free from magnetic materials

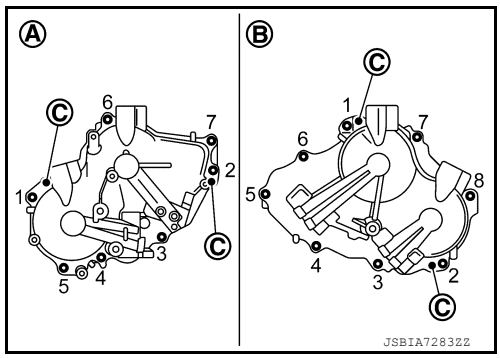
    CAUTION:
    - **Handle carefully to avoid dropping and shocks.**
    - **Do not disassemble.**
    - **Do not allow metal powder to adhere to magnetic part at sensor tip.**
    - **Do not place sensors in a location where they are exposed to magnetism.**



14. Remove valve timing control cover as per the following:

a. Disconnect valve timing control solenoid valve harness connector.

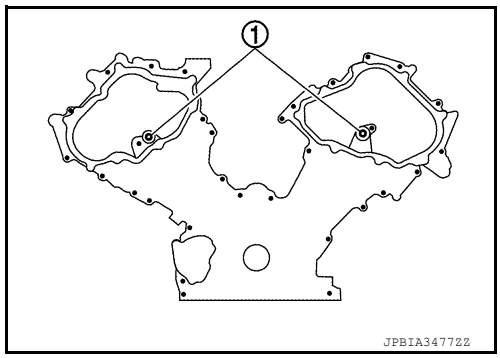
b. Loosen bolts in the reverse sequence as shown.



(A) : Bank 2
(B) : Bank 1
(C) : Dowel pin hole

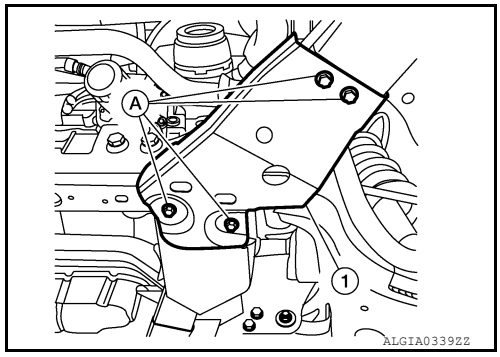
CAUTION:
- **Exercise care not to damage mating surfaces.**
- **Shaft is internally jointed with camshaft sprocket center hole. When removing, keep it horizontal until it is completely disconnected.**

15. Remove intake valve timing control solenoid valve [bank 1 and bank 2 (if necessary)].
CAUTION:
Do not reuse seal ring.
16. Remove O-rings (1) from front cover.
CAUTION:
Do not reuse O-ring.

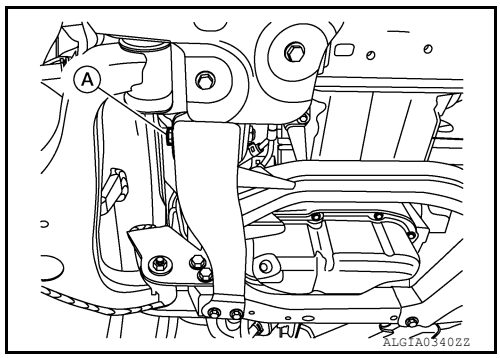


17. Obtain No. 1 cylinder at TDC of its compression stroke. Refer to EM-16, "Inspection".
CAUTION:
Do not rotate crankshaft or camshaft sprockets after this step.
18. Remove front oil seal. Refer to EM-115, "FRONT OIL SEAL : Removal and Installation".
CAUTION:
- **Do not reuse front oil seal.**
- **Be careful not to damage front cover.**
19. Remove water pump pulley. Refer to CO-25, "Exploded View".
20. For Non-XD models equipped with 2WD perform the following steps:

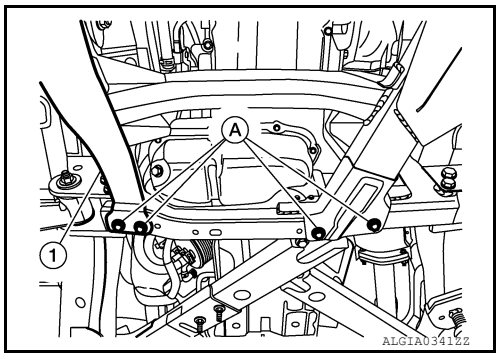
a. Remove bolts (A) and remove front suspension member reinforcement [LH (1)].



b. Remove bolt (A).

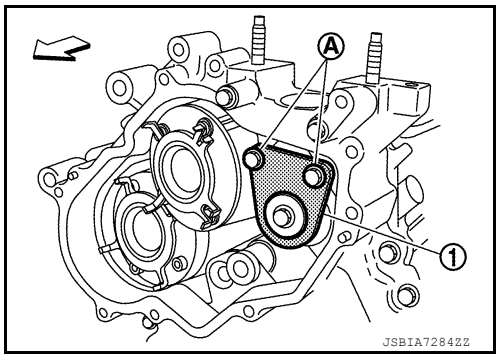


c. Remove bolts (A) and remove diagonal member (1).



21. Remove front cover as per the following:

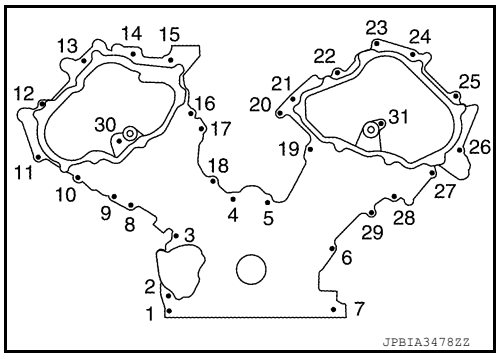
a. Loosen bolts (A) and then remove high pressure fuel pump camshaft bracket (1).



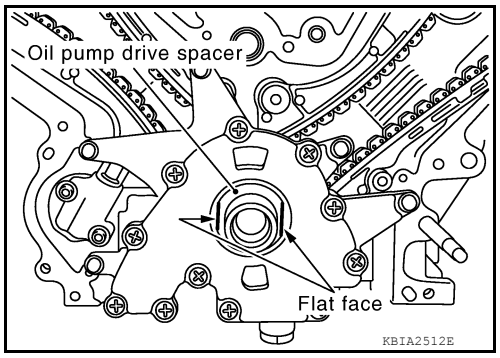
b. Loosen bolts in reverse order as shown in the figure.

c. Insert a suitable tool into the notch at front cover.
- Pry off case by moving a suitable tool.

CAUTION:
- **Exercise care not to damage mating surfaces.**
- **After removal, handle front cover carefully so it does not tilt, cant, or warp under a load.**

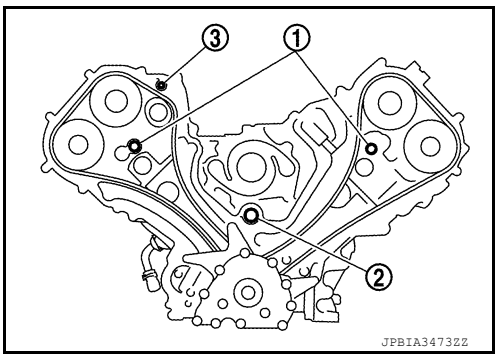


22. Remove the oil pump drive spacer.
- Hold and remove the flat space of the oil pump drive spacer by pulling it forward.



23. Loosen oil pump assembly bolts and remove the oil pump assembly.

24. Remove O-rings (1), (2), (3) from cylinder heads and cylinder block.



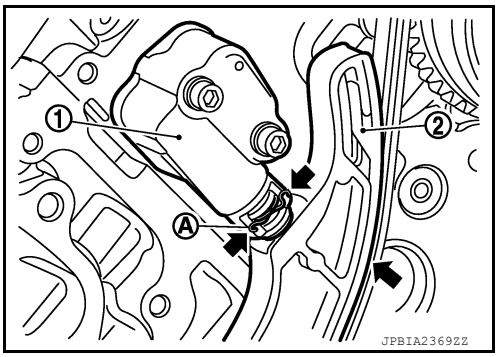
25. Remove oil filter (for valve timing control solenoid valve) (if necessary).
26. Remove timing chain tensioner cover from front cover (if necessary).
    • Use Tool to cut liquid gasket for removal.

Tool : KV10111100 (J-37228)

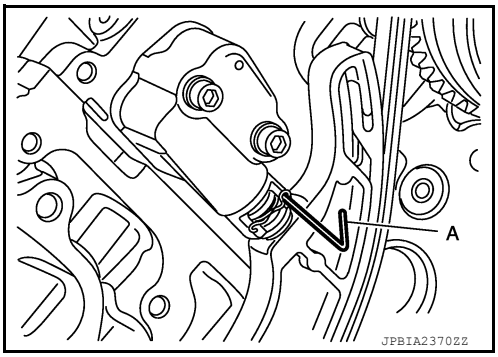
27. Remove timing chain tensioner (bank 1) as per the following:
    NOTE:
    To remove timing chain and related parts, start with those on bank 1. The procedure for removing parts on bank 2 is omitted because it is the same as that for bank 1.

a. Push both sides of spring (A) against spring tension, and then press in plunger with a slack guide (2).

(1) : Timing chain tensioner (bank 1)

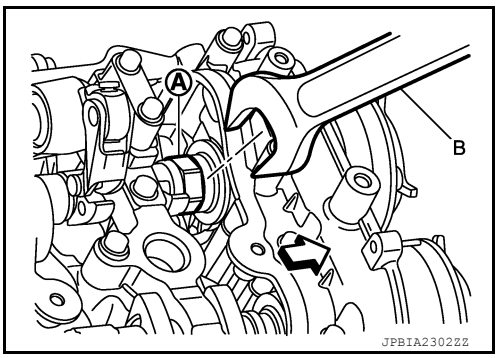


b. Insert a suitable tool (A) into the body hole, and then fix it with the plunger pushed in.
c. Remove bolts and then remove timing chain tension (bank 1).



28. Remove tension guide and slack guide.
29. Remove timing chain and crankshaft sprocket.
    CAUTION:
    After removing timing chain, never turn crankshaft and camshaft separately, or valves will strike the piston head.
30. Remove high pressure fuel pump camshaft.
31. Remove intake camshaft sprocket using the following procedure:

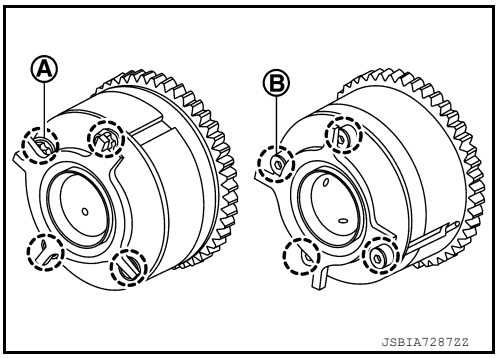
- Secure the hexagonal portion (located in between journal No.1 and journal No. 2) of drive shaft (A) using a suitable tool (B) to loosen bolt.



⇦ : Engine front

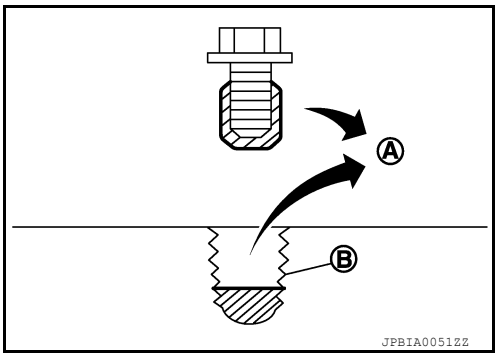
NOTE:
The figure shows an example of bank 2.

CAUTION:
- **Do not loosen the bolt by securing anything other than the camshaft (drive shaft) hexagonal portion or with tensioning the timing chain.**
- **When holding the hexagonal part of camshaft (drive shaft) with a suitable tool, be careful not to allow the suitable tool to cause interference with other parts.**
- **Do not disassemble camshaft sprocket. [Do not loosen Intake bolts (A) and exhaust bolts (B) as shown in the figure.]**



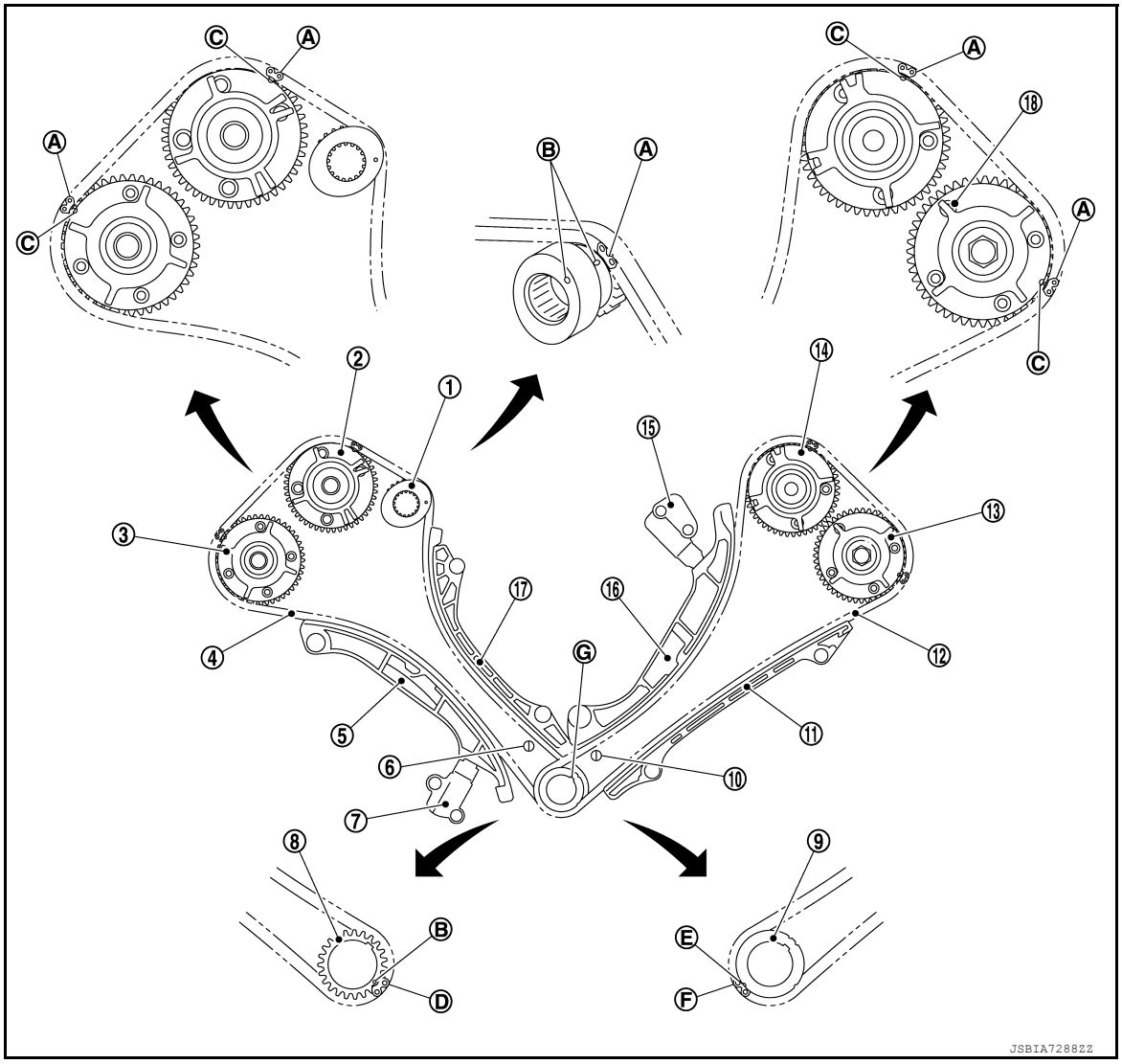
32. To remove the exhaust camshaft sprocket, secure the hexagonal portion of the exhaust camshaft using a suitable tool and loosen the bolt.
33. Use suitable tool to remove all traces of old liquid gasket from front cover and opposite mating surfaces.
    - Remove old liquid gasket from bolt hole and thread.

(A) : Remove old liquid gasket that is stuck
(B) : Bolt hole



INSTALLATION

CAUTION:
Do not reuse O-rings.



1. High pressure fuel pump camshaft	2. Intake camshaft sprocket (bank 2)	3. Exhaust camshaft sprocket (bank 2)
4. Timing chain (bank 2)	5. Slack guide (bank 2)	6. Chain oil jet (bank 2)
7. Timing chain tensioner (bank 2)	8. Crankshaft sprocket (bank 2 side)	9. Crankshaft sprocket (bank 1 side)
10. Chain oil jet (bank 1)	11. Tension guide (bank 1)	12. Timing chain (bank 1)
13. Exhaust camshaft sprocket (bank 1)	14. Intake camshaft sprocket (bank 1)	15. Timing chain tensioner (bank 1)
16. Slack guide (bank 1)	17. Tension guide (bank 2)	18. Dowel pin
A: Matching mark (white link)	B: Matching mark (punched)	C: Matching mark (outer groove)
D: Matching mark (yellow link)	E. Matching mark (notched)	F. Matching mark (orange link)
G. Crankshaft key		

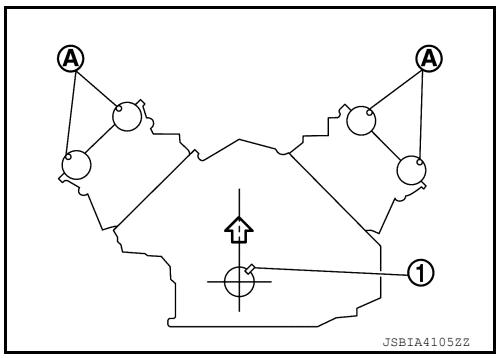
NOTE:
- The above figure shows the relationship between the matching mark on each timing chain and that on the corresponding sprocket, with the components installed.
- Parts with an identification mark (R or L) should be installed on the corresponding bank according to the mark.

- Intake camshaft sprocket, exhaust camshaft sprocket
- Tension guide
- Slack guide

- To install timing chain and related parts, start with those on bank 2. The procedure for installing parts on bank 1 is omitted because it is the same as that for installation on bank 2.

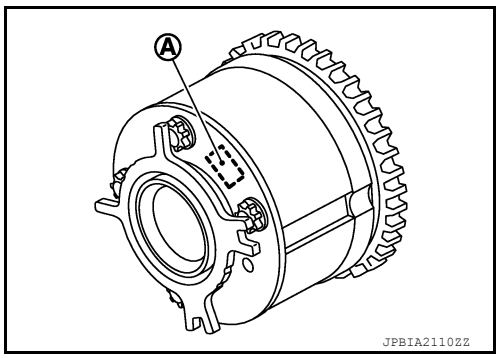
1. Check that crankshaft key (1) and dowel pin (A) of each camshaft are located as shown in the figure.

Camshaft dowel pin
: At cylinder head upper face side in each bank
Crankshaft key
: At cylinder head upper face side in bank 1



NOTE:
Though camshaft does not stop at the position as shown in the figure, for the placement of cam nose, it is generally accepted camshaft is placed for the same direction of the figure.

2. Install camshaft sprockets (INT and EXH).
• Install onto correct side by checking with identification mark (A) on surface.

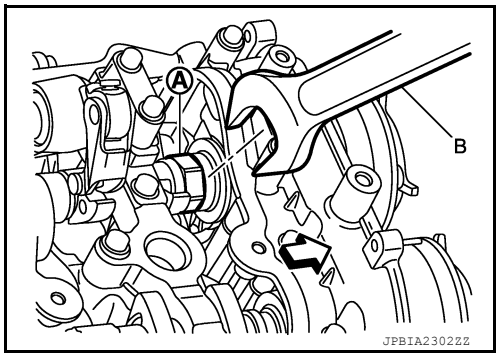


Exhaust side:
• Secure the hexagonal portion of exhaust camshaft using a suitable tool to tighten bolt. Refer to EM-93, "Exploded View".

Intake side:
• Secure the hexagonal portion (located in between journal No.1 and journal No. 2) of drive shaft (A) using a suitable tool (B) to tighten bolt. Refer to EM-93, "Exploded View".

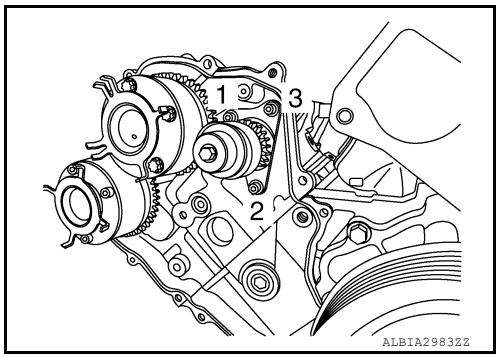
⇦ : Engine front

NOTE:
The figure shows an example of bank 2.



3. Install high pressure fuel pump camshaft and tighten bolts in the sequence shown to the specified torque.

High pressure fuel pump camshaft bolts : 12.4 N·m (1.3 kg-m, 9 ft-lb)

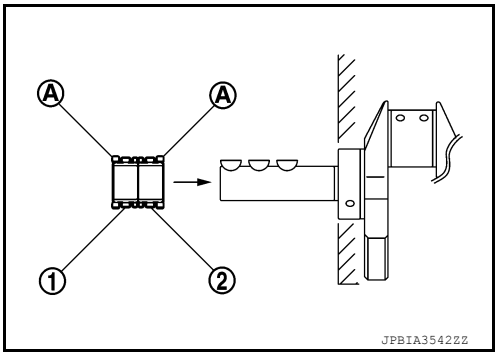


4. Install timing chains as per the following:
a. Install crankshaft sprockets for both banks.

- Install each crankshaft sprocket so that its flange side (the larger diameter side without teeth) (A) faces in the direction shown in the figure.

(1) : Crankshaft sprocket (bank 1 side)
(2) : Crankshaft sprocket (bank 2 side)

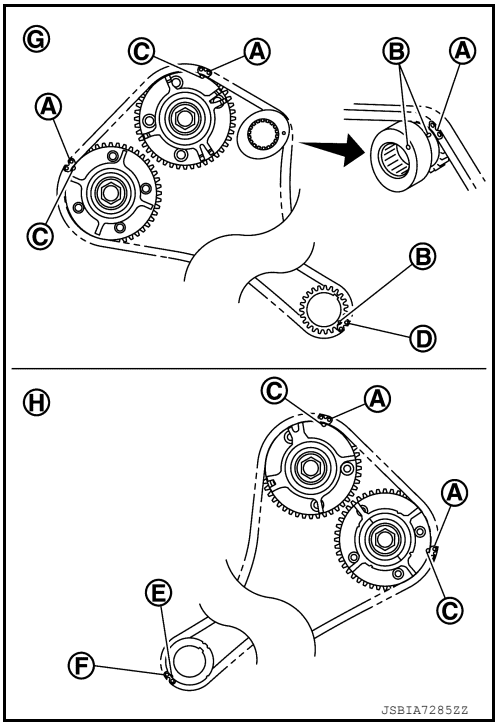
NOTE:
The same parts are used but facing directions are different.



b. Install timing chains.

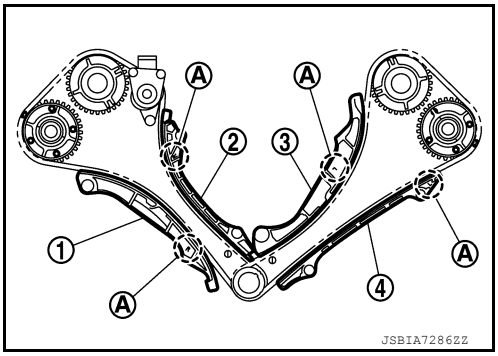
Bank 2 (G):
- Install timing chain so that the matching mark (punched) (B) and the matching mark (outer groove) (C) on camshaft sprocket is aligned with the white link (A) on timing chain, while the matching mark (punched) (B) on crankshaft sprocket is aligned with the yellow link (D) one on timing chain, as shown in the figure.

Bank 1 (H):
- Install timing chain so that the matching mark (punched) (B) and the matching mark (outer groove) (C) on camshaft sprocket is aligned with the white link (A) on timing chain, while the matching mark (notched) (E) on crankshaft sprocket is aligned with the orange link (F) one on timing chain, as shown in the figure.



5. Install slack guides and tension guides onto correct side by checking with identification mark (A) on surface.

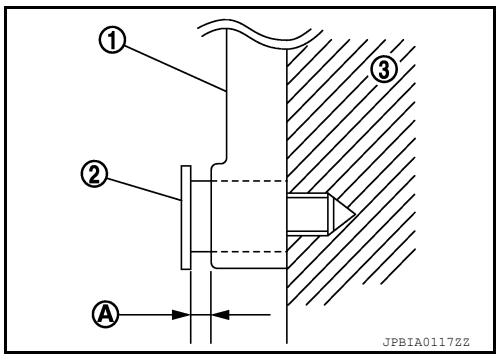
(1) : Slack guide (bank 2)
(2) : Tension guide (bank 2)
(3) : Slack guide (bank 1)
(4) : Tension guide (bank 1)



CAUTION:

Do not overtighten slack guide bolt (2). It is normal for a gap (A) to exist under the bolt seats when bolt are tightened to the specification.

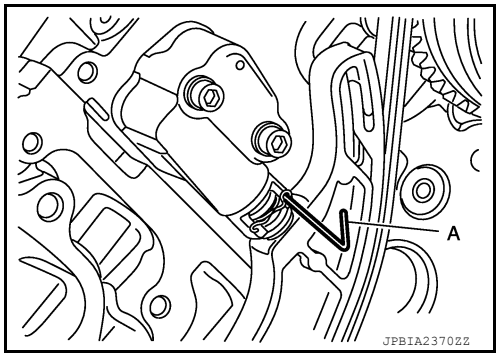
(1) : Slack guide
(3) : Cylinder block



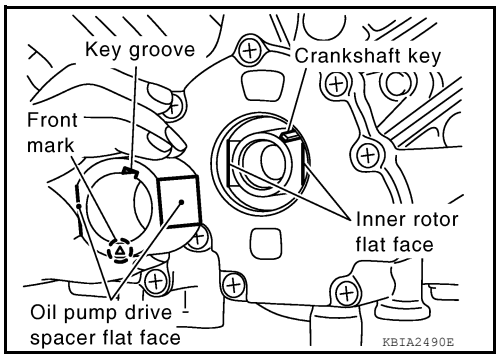
6. Install timing chain tensioner as per the following:

a. Fix the plunger at the most compressed position using a suitable tool (A).
   • Remove any dirt and foreign materials completely from the back and the mounting surfaces of timing chain tensioner.

b. Install chain tensioner and tighten bolts and then remove suitable tool to release plunger.



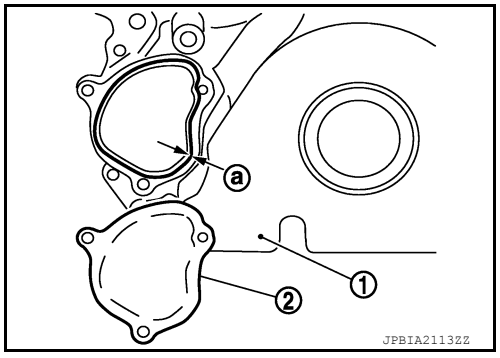
7. Check again that the matching marks on sprockets and timing chain have not slipped out of alignment.
8. Install oil pump. Refer to LU-17, "Exploded View".
9. Install the oil pump drive spacer as follows:
   • When inserting the oil pump drive spacer, align the crankshaft key and the flat face of the inner rotor.
   • If they are not aligned, rotate the oil pump inner rotor by hand.
   • Make sure that each part is aligned and tap lightly until it reaches the end.



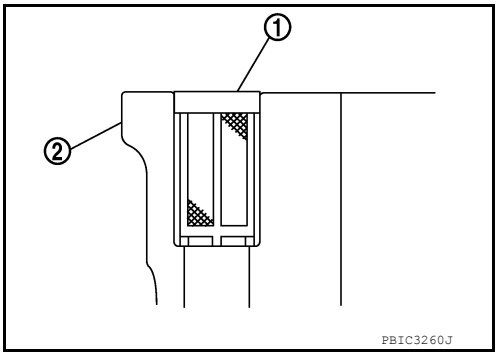
10. Install front oil seal on front cover. Refer to EM-115, "FRONT OIL SEAL : Removal and Installation".
11. Install timing chain tensioner cover (2) to front cover (1).

a : ϕ3.4 - 4.4 mm (0.134 - 0.173 in)

   • Apply a continuous bead of liquid gasket with suitable tool to front cover as shown in the figure.
   Use Genuine RTV silicone sealant or equivalent. Refer to GI-22, "Recommended Chemical Products and Sealants".

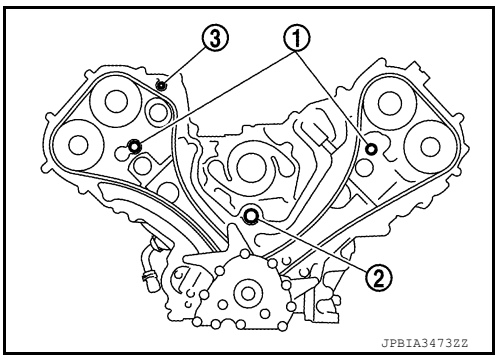


12. Install oil filter (for valve timing control solenoid valve) (1) in the direction shown in the figure, if removed.
    - Check that the oil filter does not protrude from the upper surface of front cover (2) after installation.



13. Install front cover as per the following:

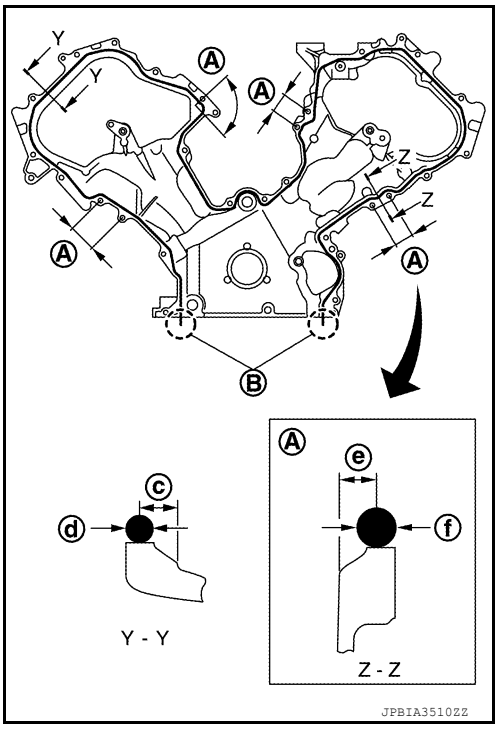
a. Install new O-ring (1), (2), (3) onto cylinder heads and cylinder block.
CAUTION:
Do not reuse O-rings.



b. Apply a continuous bead of liquid gasket with a suitable tool to front cover as shown in the figure.
Use Genuine RTV silicone sealant or equivalent. Refer to GI-22, "Recommended Chemical Products and Sealants".

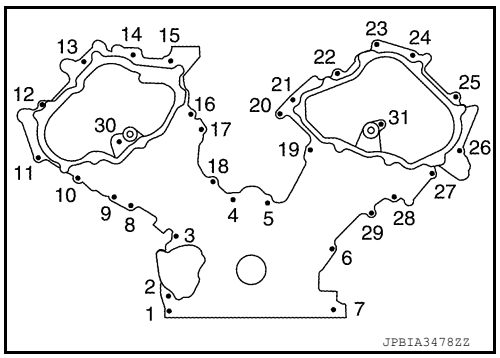
(A) : Junction between cylinder block and cylinder head
(B) : Protrusion
(C) : 4.3 - 5.3 mm (0.169 - 0.209 in)
(D) : ϕ3.4 - 4.4 mm (0.134 - 0.173 in)
(E) : ϕ4.0 - 5.6 mm (0.157 - 0.220 in)
(F) : ϕ4.8 - 5.8 mm (0.189 - 0.228 in)

c. Check again that the matching marks on timing chain and that on each sprocket are aligned. Then, install front cover.
CAUTION:
Be careful not to damage front oil seal by interference with front end of crankshaft.



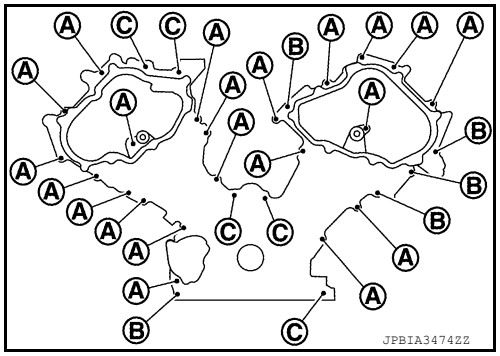
d. Tighten bolts in the sequence shown to the specified torque.

Front cover bolts : 12.8 N·m (1.3 kg-m, 9 ft-lb)



- There are three types of bolts.

A : 20 mm (0.79 in)
B : 50 mm (1.97 in)
C : 80 mm (3.15 in)



e. After all bolts are tightened, retighten them in the sequence shown to the specified torque.
CAUTION:
Be sure to wipe out any excessive liquid gasket leaking onto surface mating with oil pan.

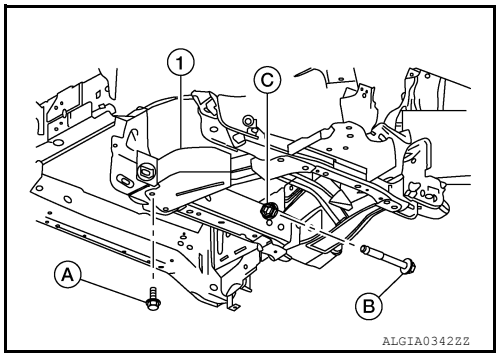
14. For Non-XD models equipped with 2WD, perform the following procedure.

a. Install diagonal member (1) using the following steps.

b. Temporarily install bolt (A) finger tight.

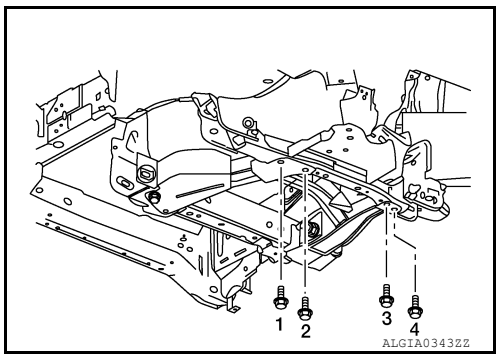
c. Install bolt (B) and nut (C) finger tight, then tighten to specification.

Nut (C) : 210 Nm (21 kg-m, 155 ft-lb)

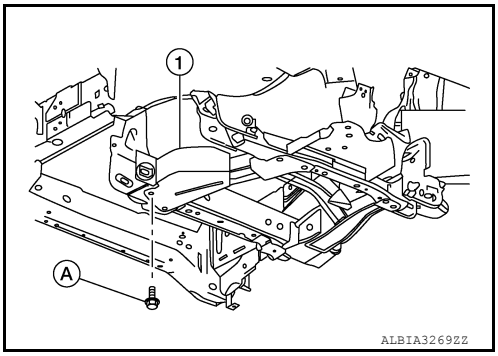


d. Install diagonal member bolts finger tight, then tighten to specification in sequence as shown.

Diagonal member bolts : 80.0 Nm (8.2 kg-m, 59 ft-lb)

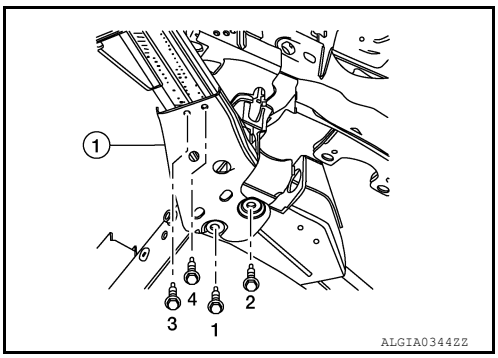


e. Remove bolt (A) from diagonal member (1).

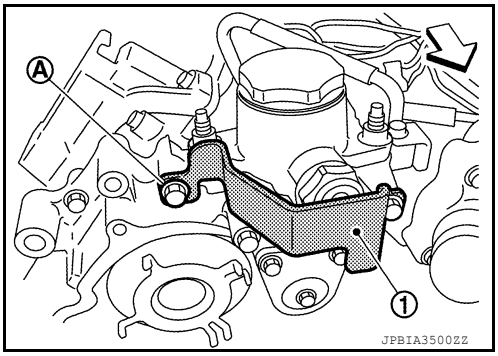


f. Install front frame member reinforcement [LH (1)] bolts finger tight, then tighten to specification in sequence as shown.

Bolts 1-4 : 80.0 Nm (8.2 kg-m, 59 ft-lb)

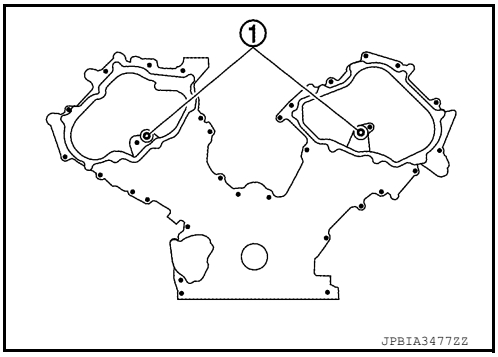


15. Install valve timing control cover as per the following:
    - Bolt (A) of fuel pump connector protector (1) cannot be installed after installing valve timing control cover. Therefore, install fuel pump connector protector in advance, if it is being removed.

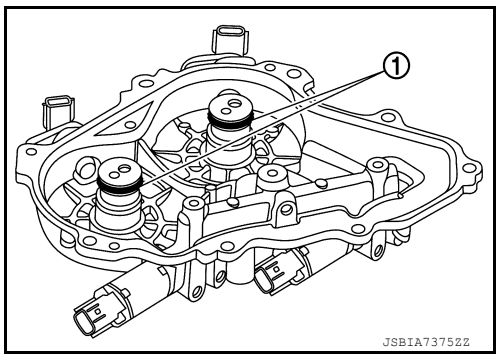


a. Install new O-rings (1) on front cover.

CAUTION:
Do not reuse O-rings.



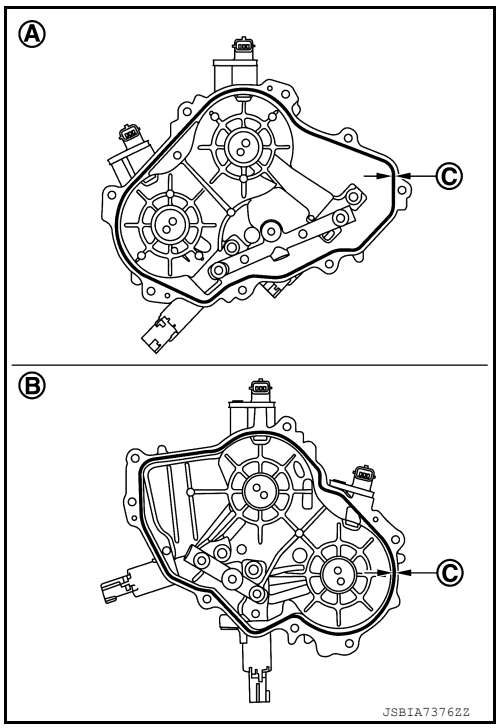
b. Install new seal rings (1) in shaft grooves.
CAUTION:
When replacing seal ring, replace all rings with new ones.



c. Apply a continuous bead of liquid gasket with a suitable tool to valve timing control covers as shown in the figure.

(A) : Bank 1
(B) : Bank 2
(C) : ϕ3.4 - 4.4 mm (0.134 - 0.173 in)

Use Genuine RTV silicone sealant or equivalent. Refer to GI-22, "Recommended Chemical Products and Sealants".

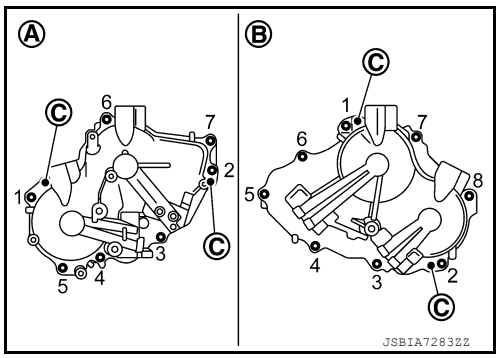


d. Being careful not to move seal ring from the installation groove, align dowel pins on front cover with dowel pin holes (C) to install valve timing control covers.

(A) : Bank 2
(B) : Bank 1

e. Tighten bolts in the sequence shown to the specified torque.

VTC cover bolts : 11.3 N·m (1.2 kg-m, 8 ft-lb)



16. Install camshaft position sensor and valve timing control solenoid valve (RH and LH) to valve timing control cover, if removed.
    • Be sure to tighten bolts with flanges completely seated.
17. Install oil pan (upper). Refer to EM-70, "Exploded View".
18. Install oil pan (lower) and oil strainer. Refer to EM-64, "Exploded View".
19. Install water pump pulley. Refer to CO-25, "Exploded View".
20. Install crankshaft pulley.
    • Fix the crankshaft as instructed in the removal procedure. Refer to EM-115, "FRONT OIL SEAL : Removal and Installation".

a. Install crankshaft pulley, taking care not to damage front oil seal.
b. Apply engine oil onto threaded parts of crankshaft pulley bolt and seating area.

- Lightly tapping its center with plastic hammer, insert crankshaft pulley.

CAUTION:
Do not tap crankshaft pulley on the side surface where belt is installed (outer circumference).

c. Tighten crankshaft pulley bolt.

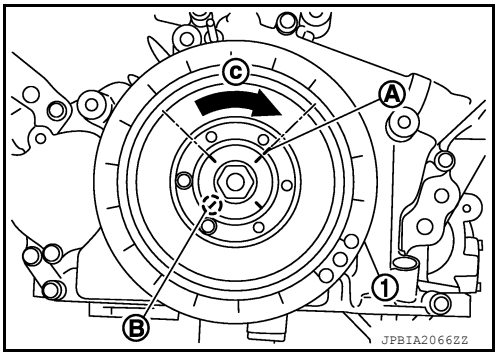
Crankshaft pulley bolt : 205 N·m (21 kg-m, 151 ft-lb)

d. Put a paint mark (A) on crankshaft pulley (1) aligning with angle mark (B) on crankshaft pulley bolt.

e. Tighten crankshaft pulley bolt (clockwise).

Angle tightening : 90° +6°/–0°

- Check the tightening angle by referencing to the notches. The angle between two notches is 90 degrees.



21. Rotate crankshaft pulley in normal direction (clockwise when viewed from engine front) to confirm it turns smoothly.
22. Installation of the remaining components is in the reverse order of removal.

Replacement [Oil Jet (Bank 2)]

INFOID:0000000014418520

When the timing chain becomes enlongated, it can make contact with and deform or damage oil jet (bank 2). Replace the oil jet (bank 2) using the following procedure:

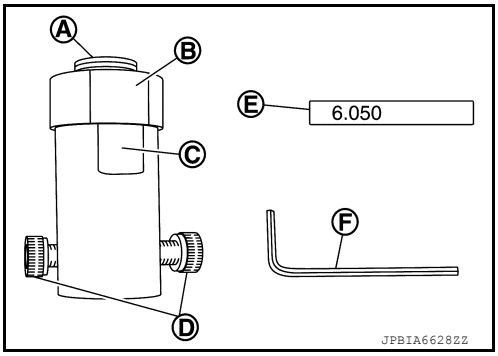
JIGS FOR REPLACEMENT

Check if the following Tools are prepared.

- Remover puller

Tool : — (J-51269-1)

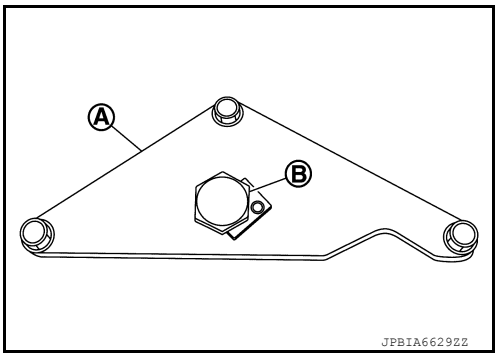
(A) : Tool inner
(B) : Nut
(C) : Tool outer
(D) : Bolt
(E) : Pin gauge (ϕ 6.050 mm)
(F) : Suitable tool



- Alignment fixture

Tool : — (J-51269-2)

(A) : Tool base
(B) : Bolt



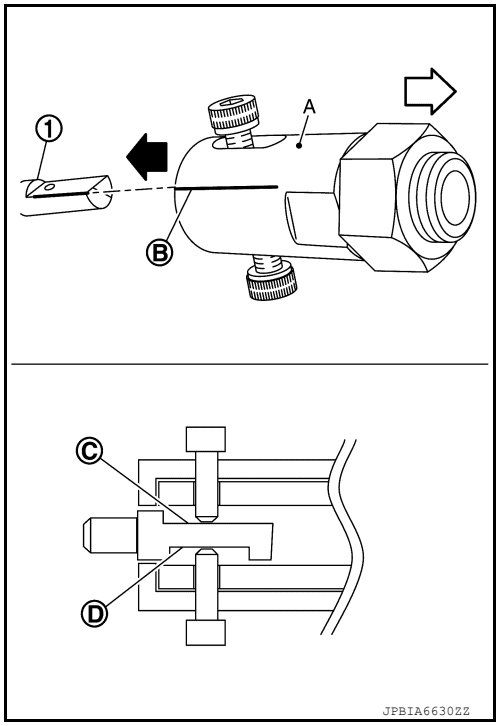
REPLACEMENT PROCEDURE

Removal

1. Turning the base line (B) upwards, insert oil jet [bank 2 (1)] into Tool (A).
CAUTION:
- **There is no base line before service part is setup. (Base line is applied from service part.)**
- **Set Tool so that position matches ground-side (D) and flat side (C) shown in the figure.**

Tool : — (J-51269-1)

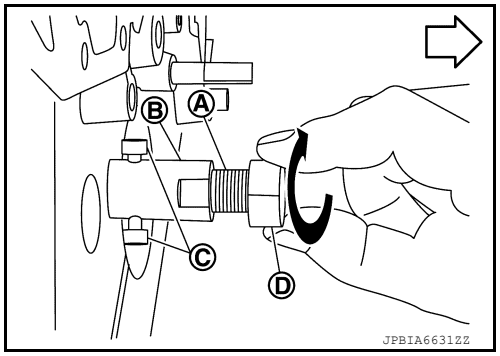
⇦ : Vehicle front



2. Press tool inner (A) into tool outer (B) until it bottoms out and tighten bolts (C).

⇦ : Vehicle front

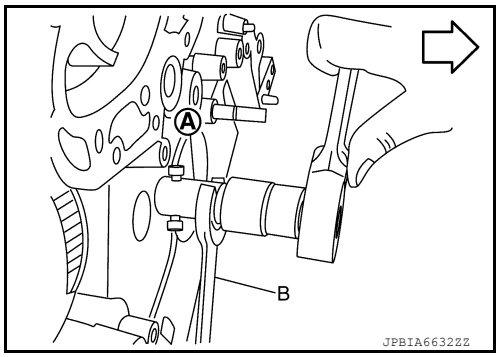
3. Hand tighten nut (D).



4. Hold Tool (A) with a suitable tool (B) and tighten nut to remove oil-jet (bank 2).
CAUTION:
Beware of enlarging the hole diameter caused by tilting the Tool.

Tool : — (J-51269-1)

⇦ : Vehicle front

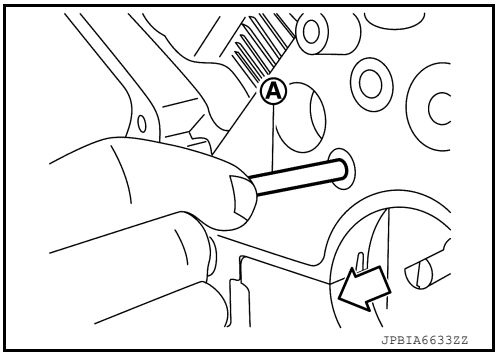


Confirm the Hole Diameter

1. After removing oil jet (bank 2), use Tool (A) to confirm the hole diameter.
NOTE:
If Tool is inserted deeper than 3 mm (0.118 in), replace cylinder block and oil-jet.

Tool : — (J-51269-1)

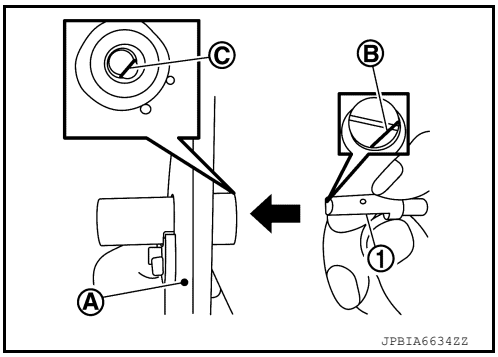
⇦ : Vehicle front



Installation

1. Insert new oil jet [bank 2 (1)] into Tool (A) in the direction shown by arrow.
NOTE:
When inserting new oil jet [bank 2 (1)], be sure that D-cut (B) surface on oil jet and the location plate (C) are parallel to each other.

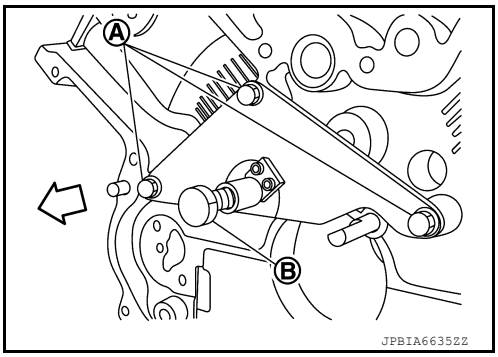
Tool : — (J-51269-2)



2. Hand tighten bolts (A).
3. Hand tighten bolt (B) until you feel the pressure from oil jet (bank 2). Then tighten the bolt two rotations with a suitable tool and center the oil jet (bank 2) and the hole.
CAUTION:
Do not tighten completely until the end of process.
4. Tighten bolts (A).
NOTE:
Make Tool and oil jet (bank 2) are concentric.

Tool : — (J-51269-2)

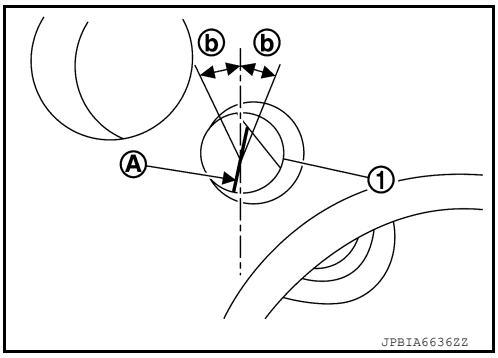
⇦ : Vehicle front



5. Install oil jet (bank 2) by tightening bolt (B) until it stops.
6. Loosen bolts (A) and remove Tool from cylinder block.

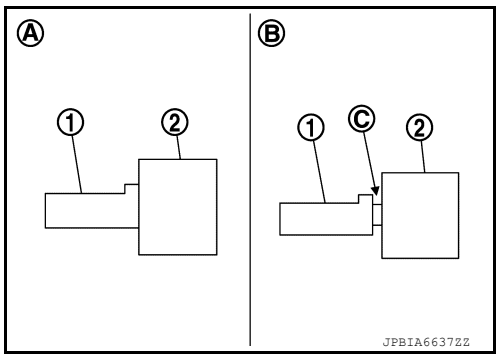
Tool : — (J-51269-2)

7. Confirm the positional limitation of adjustment notch (A) on oil jet [bank 2 (1)] is within ±10° (b).



8. If there is a gap (C) between oil jet [bank 2 (1)] and cylinder block (2) surface, repeat the steps 2 to 6 again.

(A) : OK
(B) : NG



Inspection

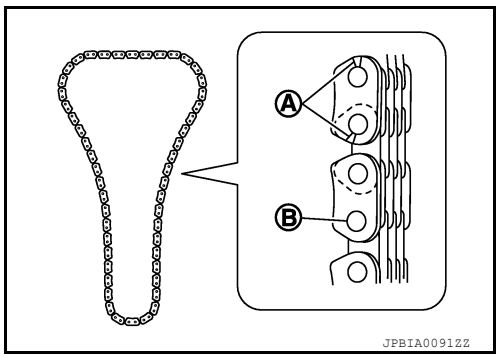
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INSPECTION AFTER DISASSEMBLY

Timing Chain

Check for cracks and any excessive wear at link plates and roller links of timing chain. Replace timing chain if necessary.

(A) : Crack
(B) : Wear



INSPECTION AFTER ASSEMBLY

Inspection for Leakage

The following are procedures for checking fluid leakage, lubricant leakage.

- Before starting engine, check oil/fluid levels including engine coolant and engine oil. If any are less than the required quantity, fill them to the specified level. Refer to MA-13, "VK56VD Gasoline Engine : Fluids and Lubricants".
- Follow the procedure below to check for fuel leakage.
- Turn ignition switch to the “ON” position (with engine stopped). With fuel pressure applied to fuel piping, check for fuel leakage at connection points.
- Start engine. With engine speed increased, check again for fuel leakage at connection points.
- Run engine to check for unusual noise and vibration.

NOTE:
If hydraulic pressure inside chain tensioner drops after removal/installation, slack in guide may generate a pounding noise during and just after the engine start. However, this does not indicate a malfunction. The noise will stop after hydraulic pressure rises.

- Warm up engine thoroughly to check that there is no leakage of fuel, or any oil/fluids including engine oil and engine coolant.
- Bleed air from lines and hoses of applicable lines, such as in cooling system.
- After cooling down engine, again check oil/fluid levels including engine oil and engine coolant. Refill them to the specified level, if necessary.

Summary of the inspection items:

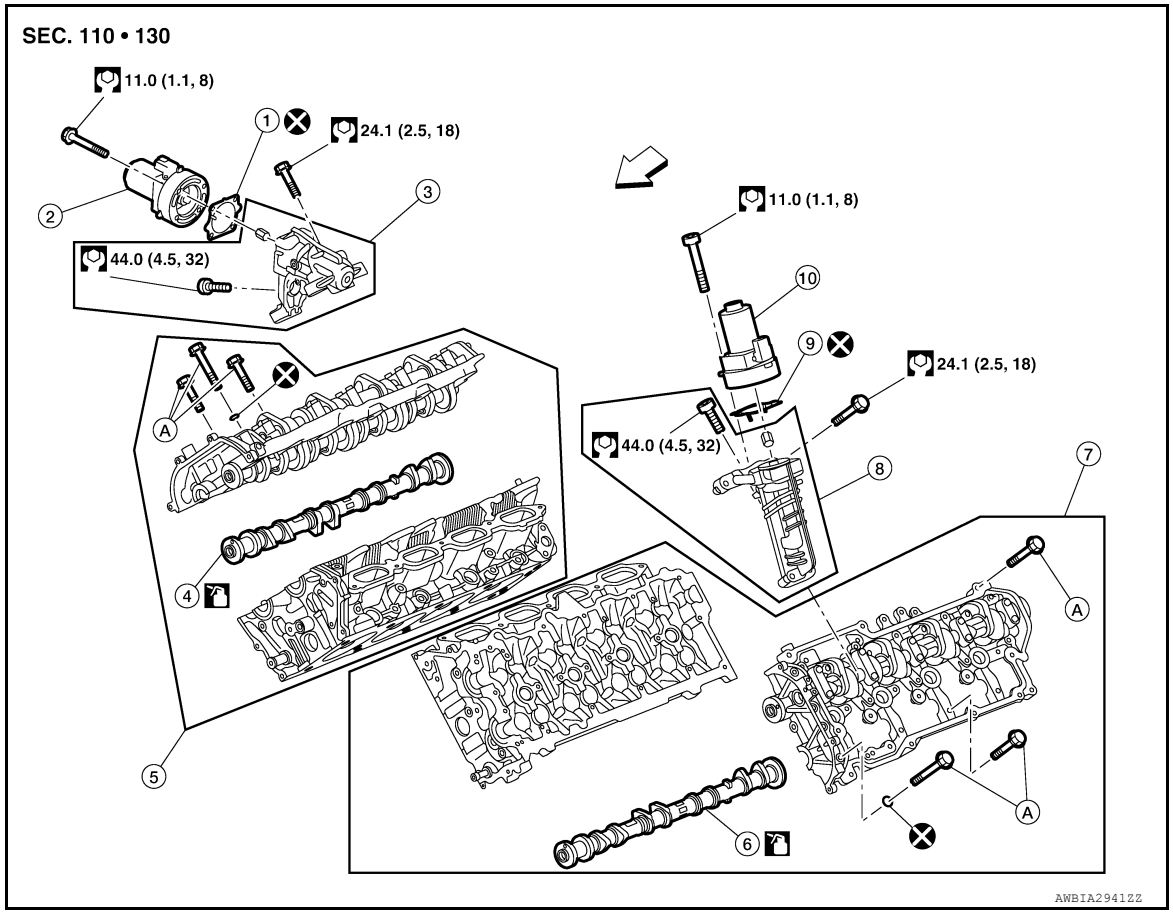
Items		Before starting engine	Engine running	After engine stopped
Engine coolant		Level	Leakage	Level
Engine oil		Level	Leakage	Level
Transmission / transaxle fluid	AT & CVT Models	Leakage	Level / Leakage	Leakage
	MT Models	Level / Leakage	Leakage	Level / Leakage
Other oils and fluids*		Level	Leakage	Level
Fuel		Leakage	Leakage	Leakage

* Power steering fluid, brake fluid, etc.

CAMSHAFT

Exploded View

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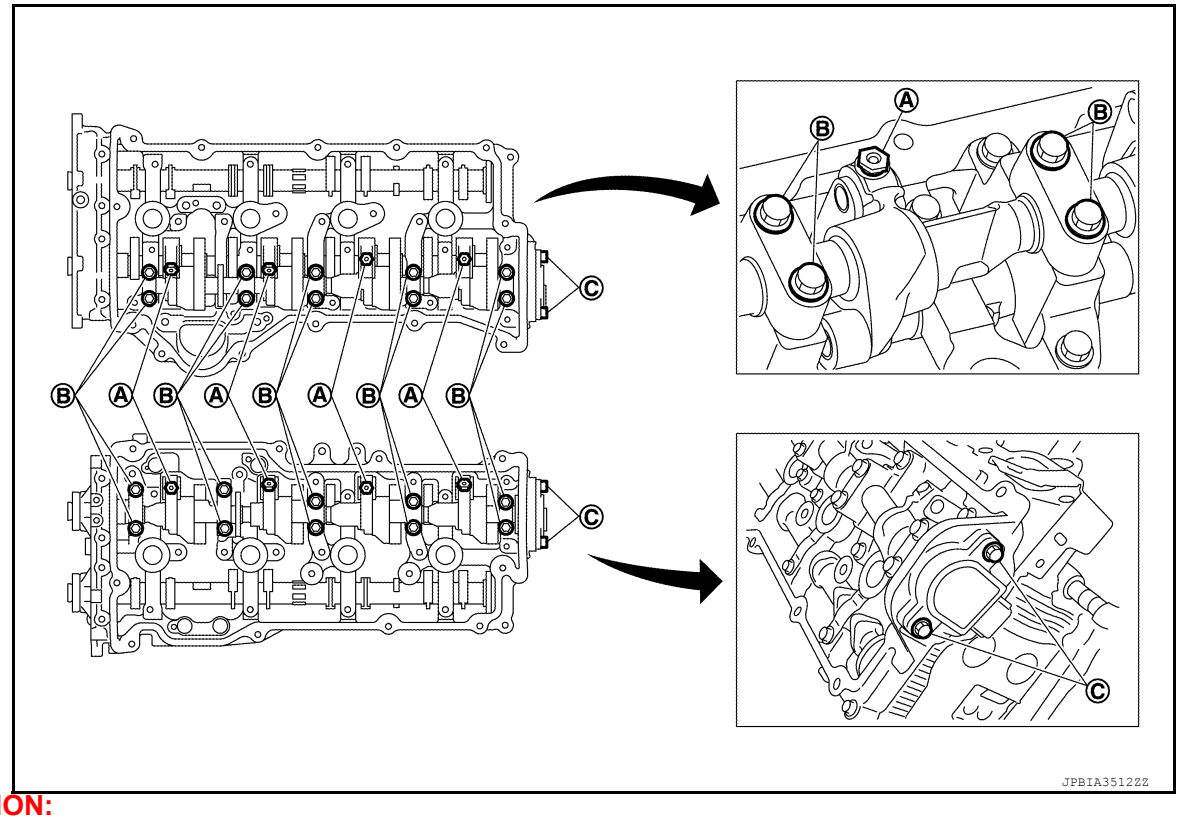


1.	VVEL actuator motor assembly gasket	2.	VVEL actuator motor assembly	3.	VVEL actuator housing assembly (bank 2)
4.	Exhaust camshaft (bank 2)	5.	Cylinder head/VVEL ladder assembly (bank 2)	6.	Exhaust camshaft (bank 1)
7.	Cylinder head/VVEL ladder assembly (bank 1)	8.	VVEL actuator housing assembly (bank 1)	9.	VVEL actuator motor assembly gasket
10.	VVEL actuator motor assembly	A.	Refer to INSTALLATION	⇦	Front

Removal and Installation

INFOID:0000000014418523

REMOVAL



CAUTION:

- **Do not loosen adjusting bolts (A), bolts (black color) (B) of VVEL ladder assembly and bolts (C) of VVEL control shaft position sensor. If loosened, the stroke of cam lift becomes out of adjustment. In such case, replacement of VVEL ladder assembly and cylinder head assembly is required.**
- **Do not loosen the bolts (C) of the VVEL control shaft position sensor. VVEL control shaft position sensor mounting bolts are required to be loosened for adjustment only when using a new VVEL ladder assembly. Refer to EC-202, "Description".**

VVEL control shaft position sensor bolt : 7.0 N·m (0.71 kg-m, 62 in-lb)

NOTE:

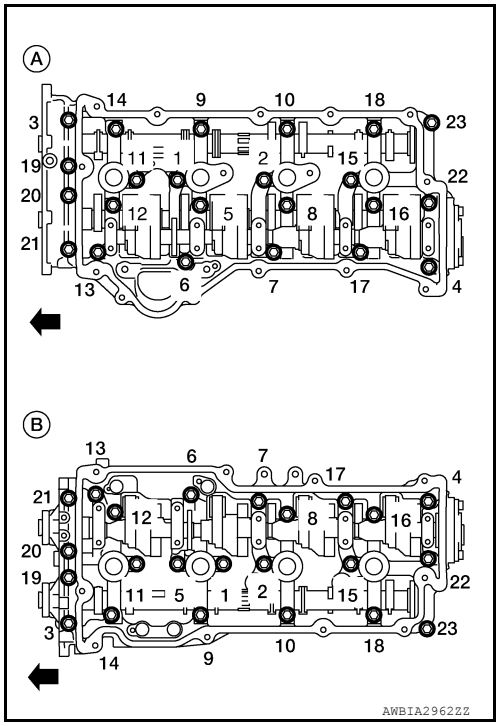
VVEL ladder assembly cannot be replaced as a single part, because it is machined together with cylinder head assembly.

1. Remove front cover, camshaft sprockets, and timing chains. Refer to EM-75, "Removal and Installation".
2. Remove VVEL actuator housing assembly. Refer to EM-41, "Exploded View".
3. Remove VVEL ladder assembly.

- Loosen bolts (gold color) in the reverse sequence as shown.

(A) : Bank 2
(B) : Bank 1
⇦ : Engine front

CAUTION:
- **Do not loosen adjusting bolts and bolts (black color).**
- **When removing VVEL ladder assembly, hold the drive shaft from below so as not to drop it.**
- **Do not drop or damage VVEL ladder assembly, it is machined with cylinder head and is not available separately.**



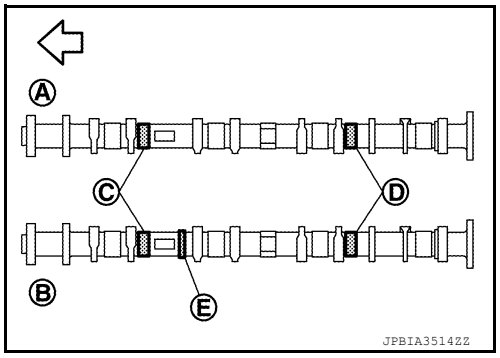
4. Remove exhaust camshaft.
5. Remove valve lifter (if necessary).
   - Identify installation positions, and store them without mixing them up.

INSTALLATION

CAUTION:
Do not reuse washers.

1. Install valve lifter.
   - Install it in the original position.
2. Install exhaust camshaft.
   - Distinction between exhaust camshaft is performed with the identification mark.

⇦ : Engine front



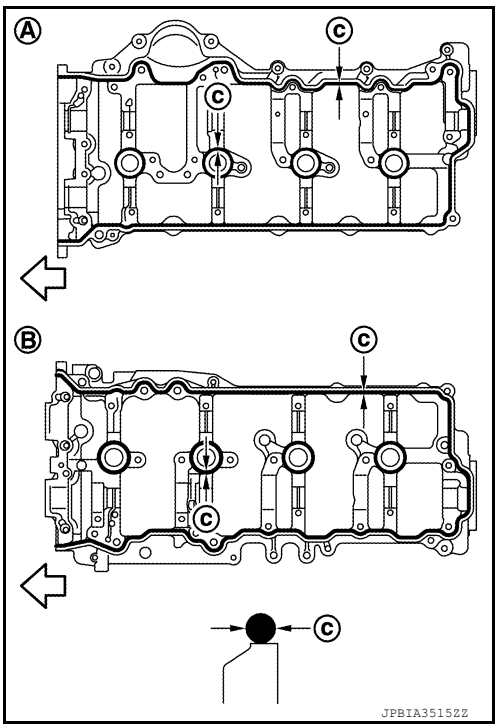
Bank	Paint marks		Identification rib (E)
	M1 (C)	M2 (D)	
Bank 1 (A)	No	White	No
Bank 2 (B)	No	Purple	Yes

3. Install VVEL ladder assembly as per the following:

a. Apply a continuous bead of liquid gasket with a suitable tool to the VVEL ladder assembly as shown in the figure.

(A) : Bank 1
(B) : Bank 2
(C) : ϕ3.4 - 4.4 mm (0.134 - 0.173 in)
⇦ : Engine front

Use Genuine RTV silicone sealant or equivalent. Refer to GI-22, "Recommended Chemical Products and Sealants".

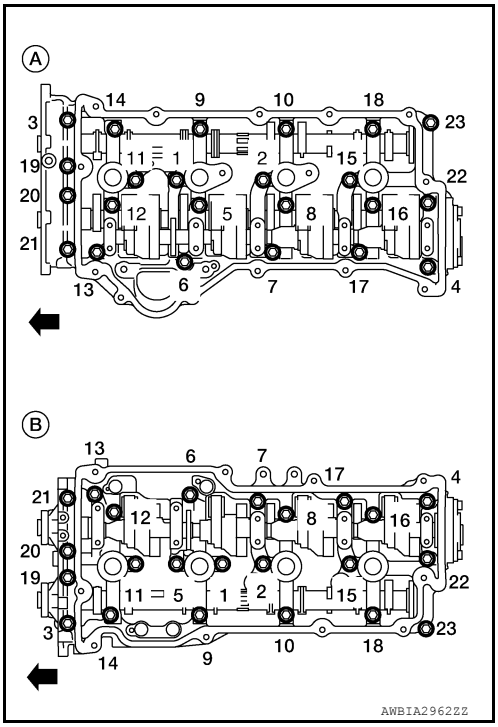


b. Tighten bolts in the sequence shown to the specified torque.

(A) : Bank 2
(B) : Bank 1
⇦ : Engine front

CAUTION:
Do not reuse washers.

Step 1 : 1.96 N·m (0.20 kg-m, 17 in-lb)
Step 2 : 5.88 N·m (0.60 kg-m, 52 in-lb)
Step 3 : 10.4 N·m (1.1 kg-m, 8 ft-lb)



4. Installation of the remaining components is in the reverse order of removal.
   - Inspect valve clearance. Refer to EM-16, "Inspection".
   - When using a new VVEL ladder assembly, adjust VVEL control shaft position sensor. Refer to EC-202, "Description".

Inspection

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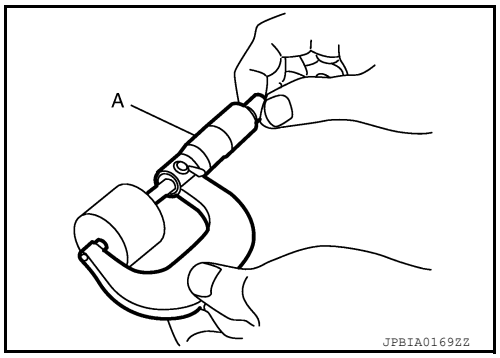
CAMSHAFT VALVE CLEARANCE ADJUSTMENT

- Perform adjustment depending on selected head thickness of valve lifter.

1. Measure the valve clearance. Refer to EM-16, "Inspection".
2. Remove VVEL ladder assembly and exhaust camshaft. Refer to EM-94, "Removal and Installation".
   CAUTION:

Never loosen adjusting bolts and bolts (black color) of VVEL ladder assembly.

3. Remove valve lifter (EXH) or valve lifter (INT) at the locations that are out of the standard.
4. Measure the center thickness of the removed valve lifters with a suitable tool (A).



5. Use the equation below to calculate valve lifter thickness for replacement.

Valve lifter (EXH) thickness calculation: $t = t_1 + (C_1 - C_2)$

t = Valve lifter (EXH) thickness to be replaced

t_1 = Removed valve lifter (EXH) thickness

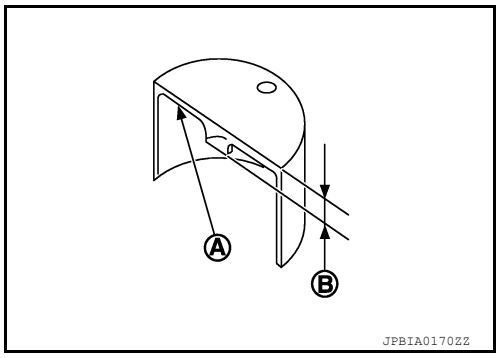
C_1 = Measured valve clearance

C_2 = Standard valve clearance:

Exhaust : 0.33 mm (0.013 in)

- Thickness of new valve lifter can be identified by stamp marks on the reverse side (inside the cylinder).
  Stamp mark 312N or 312n indicates 3.12 mm (0.1228 in) in thickness.

(A) : Stamp
(B) : Thickness of valve lifter



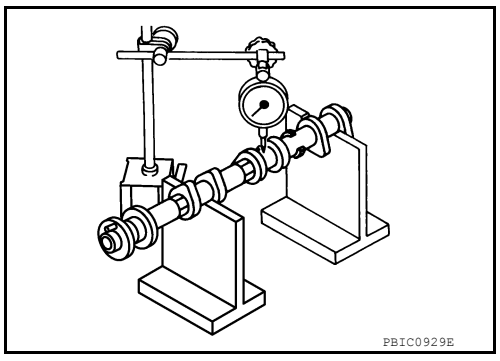
NOTE:
Available thickness of valve lifter: 26 sizes with range 3.00 to 3.50 mm (0.1181 to 0.1378 in) in steps of 0.02 mm (0.0008 in) (when manufactured at factory). Refer to EM-155, "Camshaft".

6. Install selected valve lifter.
7. Install VVEL ladder assembly and exhaust camshaft. Refer to EM-94, "Removal and Installation".
8. Manually turn crankshaft pulley 2 revolutions clockwise.
9. Check that the valve clearances for cold engine are within the specifications by referring to the specified values. Refer to EM-16, "Inspection".
10. Installation of remaining components is in the reverse order of removal.
11. Warm up the engine, and check for unusual noise and vibration.

INSPECTION AFTER DISASSEMBLY (EXHAUST SIDE)

Exhaust Camshaft Runout

1. Put V-block on precise flat table, and support No. 2 and 5 journals of camshaft.
   CAUTION:
   Do not support No. 1 journal (on the side of camshaft sprocket) because it has a different diameter from the other four locations.
2. Set a suitable tool vertically to No. 3 journal.
3. Turn exhaust camshaft to one direction with hands, and measure the camshaft runout on a suitable tool. (Total indicator reading)



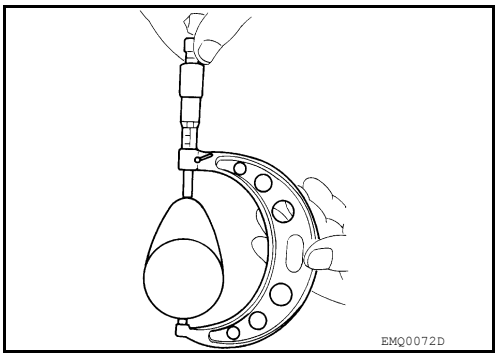
Standard and limit

: Refer to EM-155, "Camshaft".

4. If it exceeds the limit, replace exhaust camshaft.

Exhaust Camshaft Cam Height

- Measure the exhaust camshaft cam height with a suitable tool.



Standard and limit

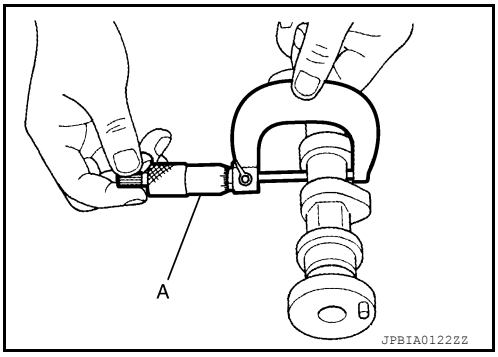
: Refer to EM-155, "Camshaft".

- If wear exceeds the limit, replace exhaust camshaft.

Exhaust Camshaft Journal Oil Clearance

EXHAUST CAMSHAFT JOURNAL DIAMETER

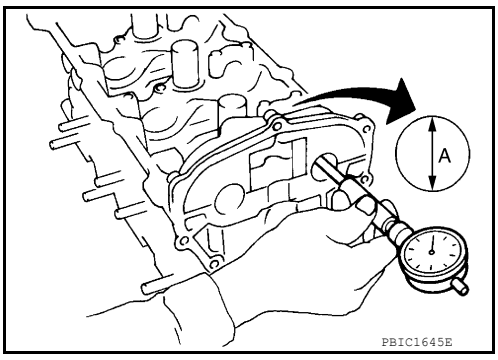
- Measure the outer diameter of exhaust camshaft journal with a suitable tool (A).



Standard : Refer to EM-155, "Camshaft".

VVEL LADDER ASSEMBLY (EXH SIDE) INNER DIAMETER

- Tighten VVEL ladder assembly bolts to the specified torque. Refer to “INSTALLATION”
- Measure inner diameter (A) of VVEL ladder assembly (exhaust side) with a suitable tool.



Standard : Refer to EM-155, "Camshaft".

EXHAUST CAMSHAFT JOURNAL OIL CLEARANCE

- (Oil clearance) = [VVEL ladder assembly (exhaust side) inner diameter] – [Exhaust camshaft journal diameter].

Standard and limit : Refer to EM-155, "Camshaft".

- If the calculated value exceeds the limit, replace either or both exhaust camshaft and VVEL ladder assembly & cylinder head assembly.

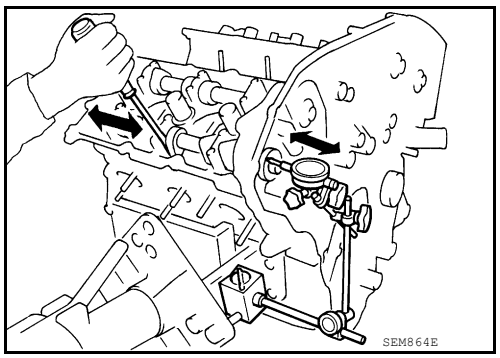
  NOTE:

  VVEL ladder assembly cannot be replaced as a single part, because it is machined together with cylinder head assembly.

Exhaust Camshaft End Play

- Install a suitable tool in thrust direction on front end of camshaft. Measure the end play of a dial indicator when exhaust camshaft is moved forward/backward (in direction of axis).

Standard and limit : Refer to EM-155, "Camshaft".



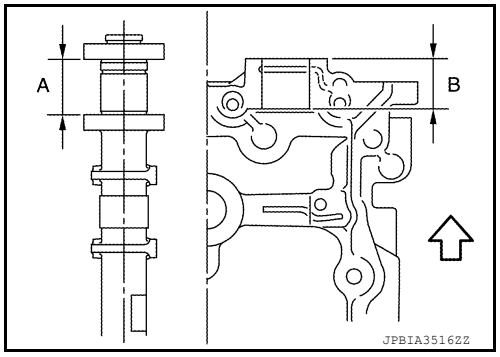
- Measure the following parts if out of the limit.

- Dimension “A” for exhaust camshaft No. 1 journal

Standard : Refer to EM-155, "Camshaft".

- Dimension “B” for cylinder head No. 1 journal bearing

Standard : Refer to EM-155, "Camshaft".



- Refer to the standards above, and then replace exhaust camshaft and/or VVEL ladder assembly & cylinder head assembly.

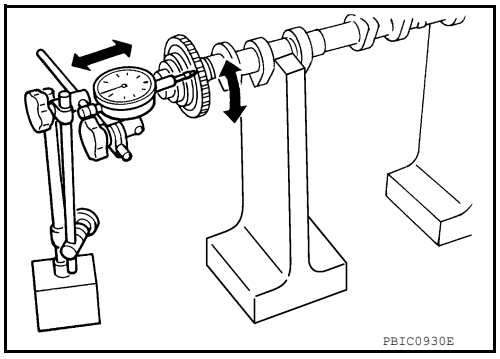
NOTE:
Cylinder head assembly cannot be replaced as a single part, because it is machined together with VVEL ladder assembly.

Exhaust Camshaft Sprocket Runout

1. Put V-block on precise flat table, and support No. 2 and 5 journals of exhaust camshaft.
CAUTION:
Do not support No. 1 journal (on the side of camshaft sprocket) because it has a different diameter from the other four locations.
2. Measure the exhaust camshaft sprocket runout with a suitable tool. (Total indicator reading)

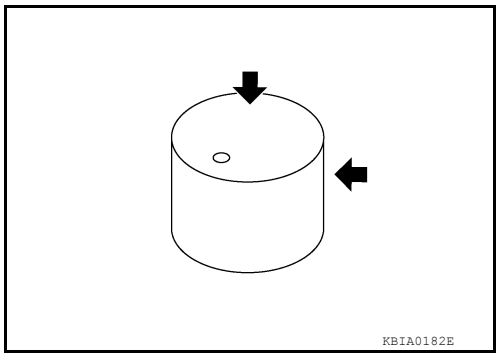
Limit : Refer to EM-155, "Camshaft".

3. If it exceeds the limit, replace exhaust camshaft sprocket.



Valve Lifter (EXH)

- Check if surface of valve lifter has any wear or crack.
- If wear or crack is found, replace valve lifter. Refer to EM-155, "Camshaft".

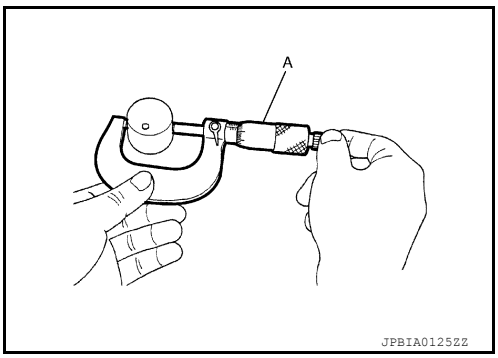


Valve Lifter Clearance (EXH)

VALVE LIFTER OUTER DIAMETER

- Measure the outer diameter at 1/2 height of valve lifter with a suitable tool (A) since valve lifter is in barrel shape.

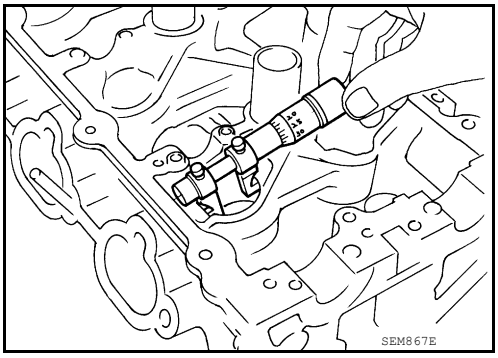
Standard : Refer to EM-155, "Camshaft".



VALVE LIFTER HOLE DIAMETER

- Measure the inner diameter of valve lifter hole of cylinder head with a suitable tool.

Standard : Refer to EM-155, "Camshaft".



VALVE LIFTER CLEARANCE

- (Valve lifter clearance) = (Valve lifter hole diameter) – (Valve lifter outer diameter)

Standard : Refer to EM-155, "Camshaft".

- If the calculated value is out of the standard, referring to each standard of valve lifter outer diameter and valve lifter hole diameter, replace either or both valve lifter and VVEL ladder assembly & cylinder head assembly.

NOTE:
Cylinder head assembly cannot be replaced as a single part, because it is machined together with VVEL ladder assembly.

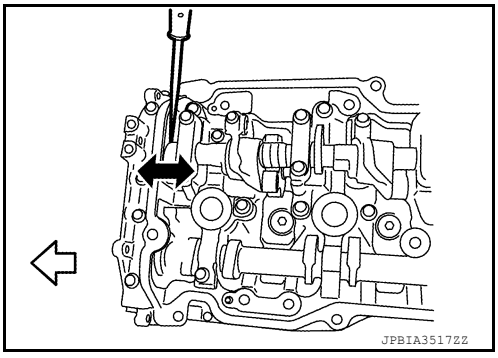
INSPECTION AFTER DISASSEMBLY (INTAKE SIDE)

Drive Shaft End Play

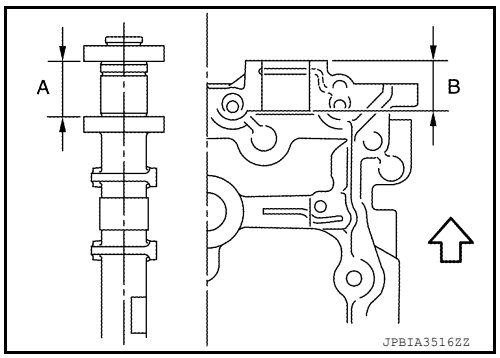
- Install a suitable tool in thrust direction on front end of drive shaft. Measure the end play of a dial indicator when drive shaft is moved forward/backward (in direction of axis).

⇦ : Engine front

Standard and limit : Refer to EM-155, "Camshaft".



- Measure the following parts if out of the limit.



⇦ : Engine front

- Dimension “A” for drive shaft No. 1 journal

Standard : Refer to EM-155, "Camshaft".

- Dimension “B” for cylinder head No. 1 journal bearing

Standard : Refer to EM-155, "Camshaft".

- If it exceeds the limit, replace VVEL ladder assembly & cylinder head assembly.

NOTE:
Cylinder head assembly cannot be replaced as a single part, because it is machined together with VVEL ladder assembly.

Camshaft Sprocket (INT) Runout

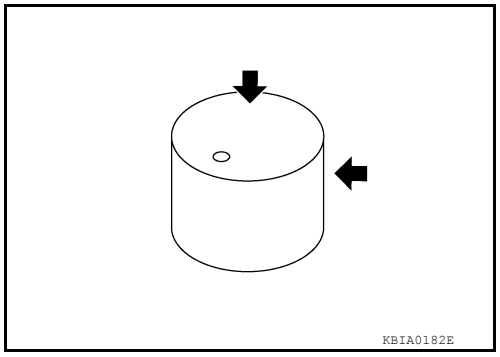
1. Put V-block on precise flat table, and support No. 2 and 5 journals of drive shaft.
CAUTION:
Do not support No. 1 journal (on the side of camshaft sprocket) because it has a different diameter from the other four locations.
2. Measure the camshaft sprocket (INT) runout with a dial indicator. (Total indicator reading)

Limit : Refer to EM-155, "Camshaft".

3. If it exceeds the limit, replace camshaft sprocket (INT).

Valve Lifter (INT)

- Check if surface of valve lifter has any wear or crack.
- If wear or crack is found, replace valve lifter. Refer to EM-155, "Camshaft".

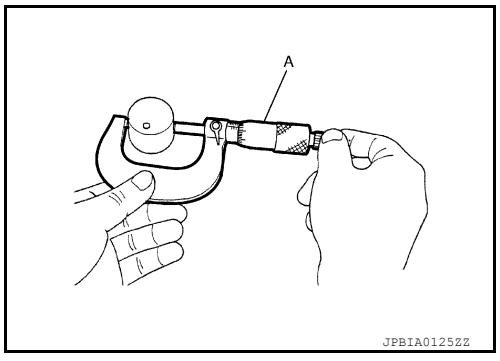


Valve Lifter Clearance (INT)

VALVE LIFTER OUTER DIAMETER

- Measure the outer diameter at 1/2 height of valve lifter (INT) with a suitable tool (A) since valve lifter is in barrel shape.

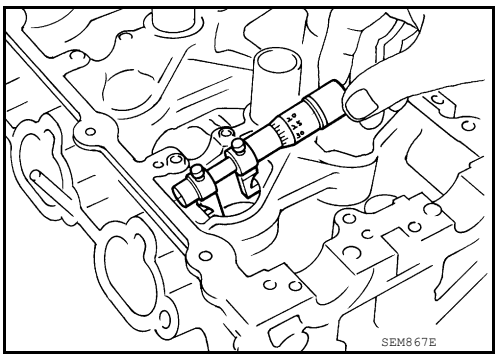
Standard : Refer to EM-155, "Camshaft".



VALVE LIFTER HOLE DIAMETER

- Measure the inner diameter of valve lifter hole of cylinder head with a suitable tool.

Standard : Refer to EM-155, "Camshaft".



VALVE LIFTER CLEARANCE

- (Valve lifter clearance) = (Valve lifter hole diameter) – (Valve lifter outer diameter)

Standard : Refer to EM-155, "Camshaft".

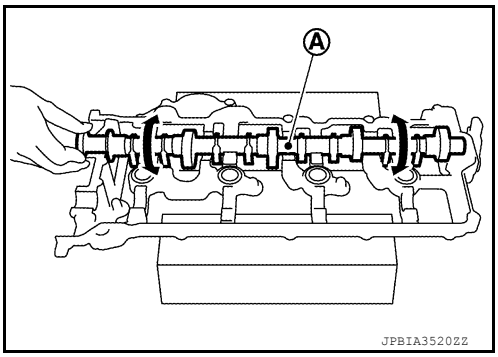
- If the calculated value is out of the standard, replace VVEL ladder assembly & cylinder head assembly.

VVEL Ladder Assembly

DRIVE SHAFT OPERATIONAL CHECK

- Hold the both ends of the drive shaft (A) and rotate it to check that it rotates smoothly.

CAUTION:
Turn VVEL ladder assembly upside down to prevent the drive shaft from dropping off.

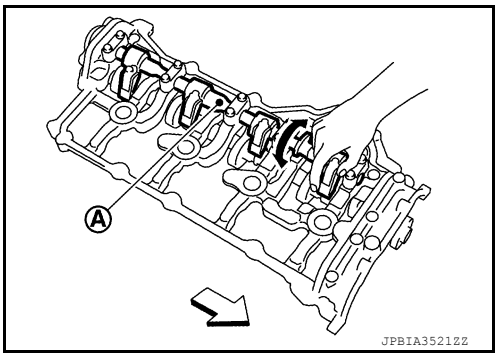


CONTROL SHAFT OPERATIONAL CHECK

- Move control shaft (A) to the small stopper and large stopper to check that the control shaft functions smoothly.

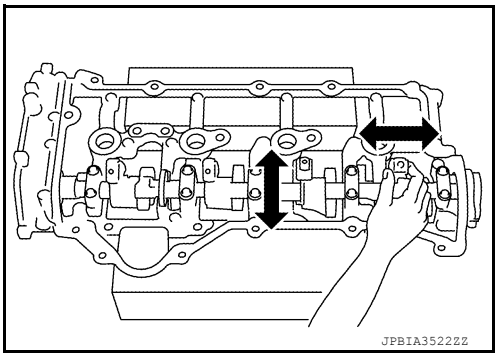
CAUTION:
Turn VVEL ladder assembly upside down to prevent the drive shaft from dropping off.

⇦ : Engine front



RINK CHECK FOR BACK-LASH (BONDING)

- Check that the link and the shaft of drive shaft and control shaft are not fixed.
- Check this by moving drive shaft and control shaft in the axial and rotation directions.



- If there is an unusualness related to the above three items, replace VVEL ladder assembly & cylinder head assembly.

NOTE:
VVEL ladder assembly cannot be replaced as a single part, because it is machined together with cylinder head assembly.

INSPECTION AFTER ASSEMBLY

Inspection of Camshaft Sprocket (INT) Oil Groove

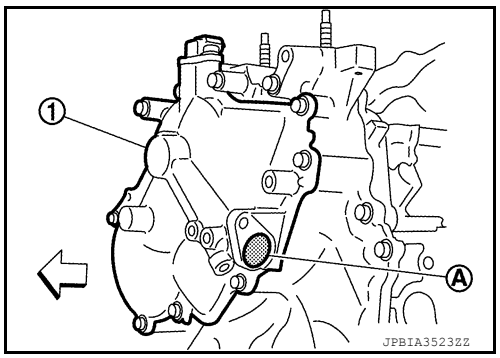
CAUTION:

- **Perform this inspection only when DTC P0011, P0021 are detected in self-diagnostic results of CONSULT and it is directed according to inspection procedure of EC section. Refer to EC-244, "DTC Description".**
- **Check when engine is cold to prevent burns from the splashing engine oil.**

1. Check engine oil level. Refer to LU-9, "Inspection".
2. Perform the following procedure to prevent the engine from being unintentionally started while checking.

a. Release the fuel pressure. Refer to EC-205, "Work Procedure".
b. Disconnect ignition coil and injector harness connectors.

3. Remove valve timing control solenoid valve. Refer to EM-74, "Exploded View".
4. Crank engine, and then check that engine oil comes out from valve timing control solenoid valve hole (A). End crank after checking.



(1) : Valve timing control cover (bank 2)

WARNING:
Be careful not to touch rotating parts (drive belt, idler pulley, and crankshaft pulley, etc.).
CAUTION:

- **Prevent splashing by using a shop cloth to prevent the worker from injury from engine oil and to prevent engine oil contamination.**
- **Prevent splashing by using a shop cloth to prevent engine oil from being splashed to engine and vehicle. Especially, be careful not to apply engine oil to rubber parts of drive belt, engine mounting insulator, etc. Wipe engine oil out immediately if it is splashed.**

5. Perform the following inspection if engine oil does not come out from valve timing control solenoid valve oil hole of the valve timing control cover.
   - Remove oil filter, and then clean it. Refer to EM-74, "Exploded View".
   - Clean oil groove between oil strainer and valve timing control solenoid valve. Refer to LU-7, "Engine Lubrication System" and LU-8, "Engine Lubrication System Schematic".
6. Remove components between valve timing control solenoid valve and camshaft sprocket, and then check each oil groove for clogging.
   - Clean oil groove if necessary. Refer to LU-7, "Engine Lubrication System" and LU-8, "Engine Lubrication System Schematic".
7. After inspection, installation is in the reverse order of removal

Inspection for Leakage

The following are procedures for checking fluid leakage, lubricant leakage.

- Before starting engine, check oil/fluid levels including engine coolant and engine oil. If any are less than the required quantity, fill them to the specified level. Refer to MA-13, "VK56VD Gasoline Engine : Fluids and Lubricants".
- Follow the procedure below to check for fuel leakage.

- Turn ignition switch to the “ON” position (with engine stopped). With fuel pressure applied to fuel piping, check for fuel leakage at connection points.
- Start engine. With engine speed increased, check again for fuel leakage at connection points.

- Run engine to check for unusual noise and vibration.

NOTE:
If hydraulic pressure inside chain tensioner drops after removal/installation, slack in guide may generate a pounding noise during and just after the engine start. However, this does not indicate a malfunction. The noise will stop after hydraulic pressure rises.

- Warm up engine thoroughly to check that there is no leakage of fuel, or any oil/fluids including engine oil and engine coolant.
- Bleed air from lines and hoses of applicable lines, such as in cooling system.
- After cooling down engine, again check oil/fluid levels including engine oil and engine coolant. Refill them to the specified level, if necessary.

Summary of the inspection items:

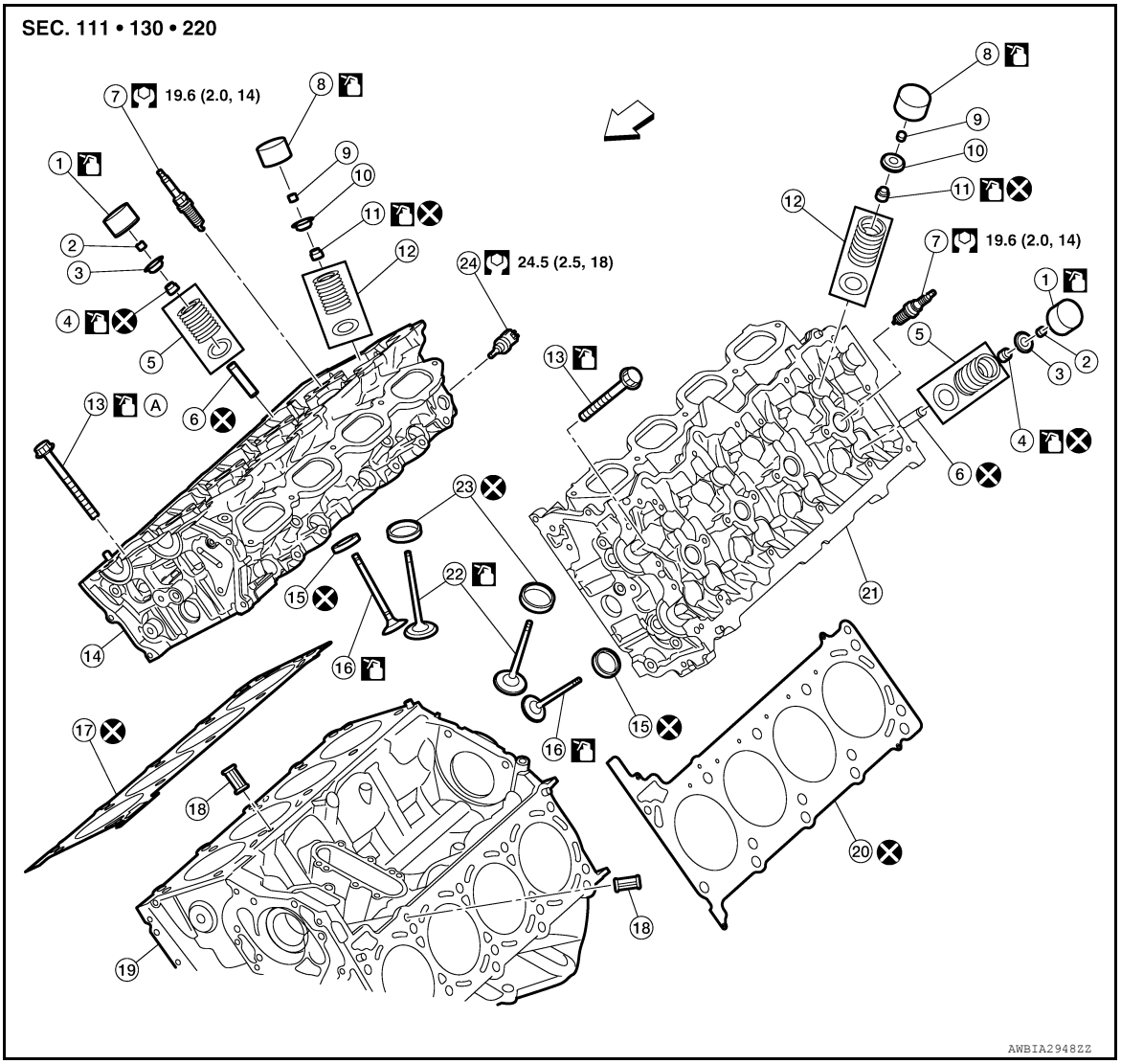
Items		Before starting engine	Engine running	After engine stopped
Engine coolant		Level	Leakage	Level
Engine oil		Level	Leakage	Level
Transmission / transaxle fluid	AT & CVT Models	Leakage	Level / Leakage	Leakage
	MT Models	Level / Leakage	Leakage	Level / Leakage
Other oils and fluids*		Level	Leakage	Level
Fuel		Leakage	Leakage	Leakage

* Power steering fluid, brake fluid, etc.

CYLINDER HEAD

Exploded View

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1. Valve lifter (EXH)	2. Valve collet (EXH)	3. Valve spring retainer (EXH)
4. Valve oil seal (EXH)	5. Valve spring (with valve spring seat) (EXH)	6. Valve guide (EXH)
7. Spark plug	8. Valve lifter (INT)	9. Valve collet (INT)
10. Valve spring retainer (INT)	11. Valve oil seal (INT)	12. Valve spring (with valve spring seat) (INT)
13. Cylinder head bolt	14. Cylinder head (bank 2)	15. Valve seat (EXH)
16. Valve (EXH)	17. Cylinder head gasket (bank 2)	18. Oil filter (for VVEL ladder assembly)
19. Cylinder block	20. Cylinder head gasket (bank 1)	21. Cylinder head (bank 1)
22. Valve (INT)	23. Valve seat (INT)	24. Engine coolant temperature sensor 1
A. Refer to INSTALLATION	⇦ Front	

CAUTION:

A high degree of precision is required for a valve on the intake side. Do not remove the valve related parts unless necessary.

NOTE:

Cylinder head (bank 1/bank 2) cannot be replaced as a single part because it is machined together with VVEL ladder assembly.

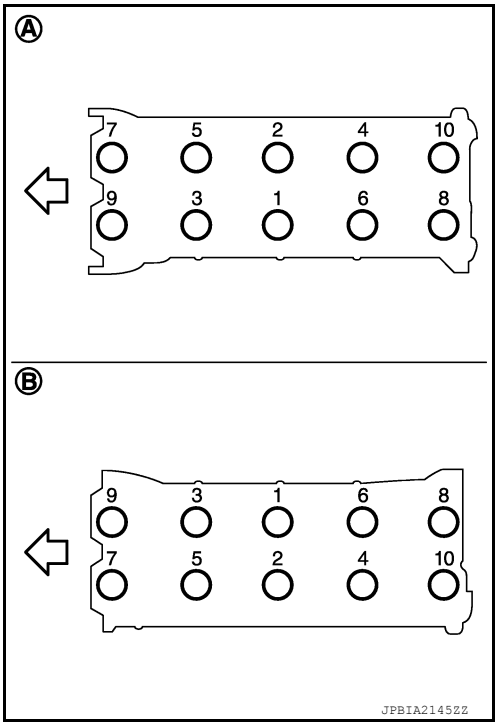
Removal and Installation

INFOID:0000000014418526

REMOVAL

1. Remove the following parts:
   - Camshaft (EXH) and VVEL ladder assembly: Refer to EM-75, "Removal and Installation".
   - Exhaust manifold and three way catalyst: Refer to EM-45, "Removal and Installation - XD Models" (XD Models) or EM-48, "Removal and Installation - Non-XD Models" (Non-XD Models).
   - Multi-way control valve: Refer to CO-29, "Removal and Installation".
   - Water pipe and heater pipe: Refer to CO-27, "Exploded View".
   - Spark plug: Refer to EM-28, "Exploded View".
   - Fuel injectors and fuel rails: Refer to EM-57, "Exploded View".
2. Disconnect water bypass hose (bank 1) and water bypass hose (bank 2) from cylinder heads.
3. Disconnect engine coolant temperature sensor 1 harness connector on rear of cylinder head (bank 2).
4. Disconnect knock sensors harness connectors from cylinder head (bank 1) and cylinder head (bank 2).
5. Remove cylinder head.
   - Loosen bolts in the reverse of the sequence as shown.

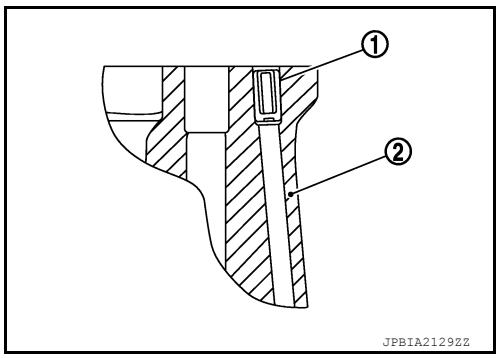
(A) : Bank 2
(B) : Bank 1
⇦ : Engine front



6. Remove cylinder head gaskets.
   CAUTION:
   Do not reuse gaskets.
7. Remove the following from cylinder heads (if necessary):
   - Oil filter (for VVEL ladder assembly)
   - Engine coolant temperature sensor 1
8. Remove valve lifter (if necessary).
   - Identify installation positions, and store them without mixing them up.

INSTALLATION

1. Install oil filter (for VVEL ladder assembly) (1) in the direction shown in the figure, if removed.
   - Check that the oil filter does not protrude from the upper surface of cylinder block (2) after installation.



2. Install engine coolant temperature sensor 1 and tighten to the specified torque.

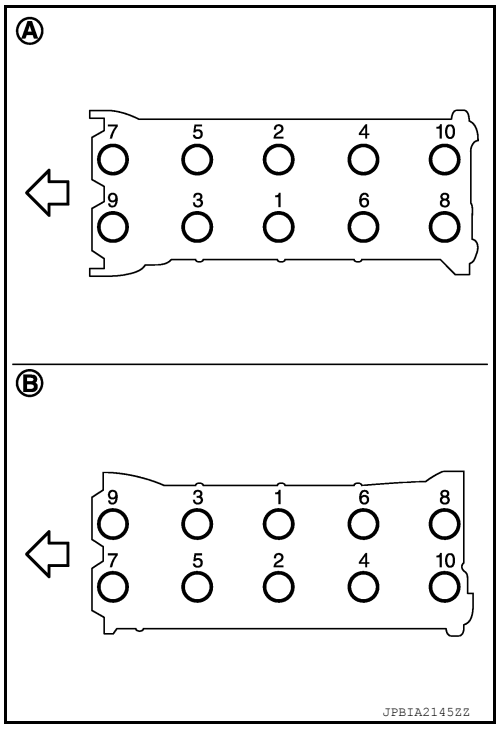
   Engine coolant temperature sensor 1 : 24.5 N·m (2.5 kg-m, 18 ft-lb)

3. Install new cylinder head gaskets.
   CAUTION:
   Do not reuse gaskets.
4. Install cylinder head as per the following:
   CAUTION:
   - **If cylinder head bolts are re-used, check their outer diameters before installation. Refer to EM-112, "Inspection".**
   - **Before installing cylinder head, inspect cylinder head distortion. Refer to EM-112, "Inspection".**
   - Tighten cylinder head bolts in the sequence shown to the specified torque.

   NOTE:
   Apply new engine oil to threads and seat surfaces of cylinder head bolts.

   (A) : Bank 2
   (B) : Bank 1
   ⇦ : Engine front

   Step 1 : Tighten 40.0 N·m (4.1 kg-m, 30 ft-lb)
   Step 2 : Tighten 75°
   Step 3 : Loosen 0 N·m (0 kg-m, 0 ft-lb)
   Step 4 : Tighten 40.0 N·m (4.1 kg-m, 30 ft-lb)
   Step 5 : Tighten 90°
   Step 6 : Tighten 90°

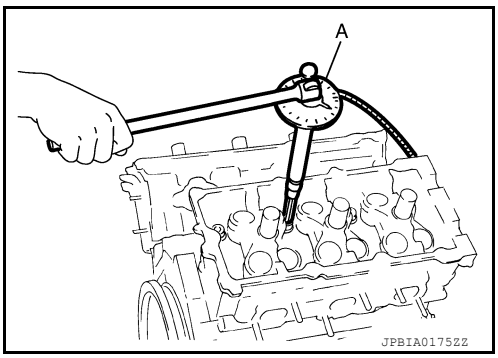


a. **CAUTION:**

Check the tightening angle using Tool (A). Do not make judgment by visual inspection.

- Check tightening angle indicated on the angle wrench indicator plate.

Tool : KV10112100 (BT8653-A)



5. Install valve lifter.
   - Install it in the original position.
6. Installation of the remaining components is in the reverse order of removal.

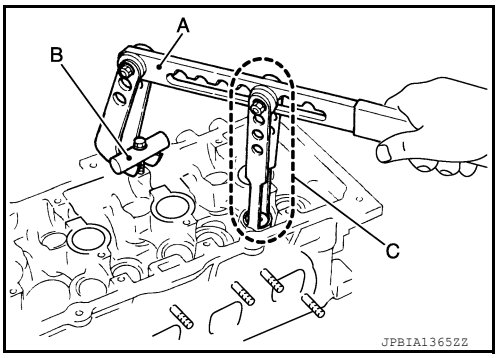
Disassembly and Assembly

INFOID:0000000014418527

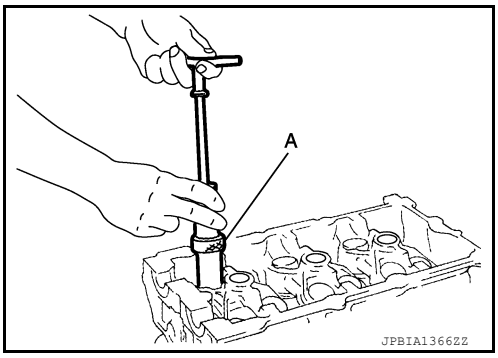
DISASSEMBLY

1. Remove valve collet.
   - Compress valve spring with suitable tool (A/B/C). Remove valve collet with a magnet hand.

   CAUTION:
   When working, take care not to damage valve lifter holes.



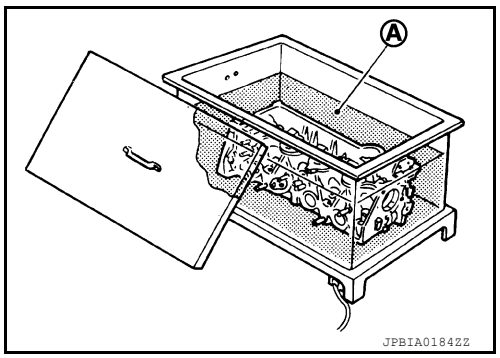
2. Remove valve spring retainer and valve spring (with valve spring seat).
3. Push valve stem to combustion chamber side, and remove valve.
   - Identify installation positions, and store them without mixing them up.
4. Remove valve oil seal using suitable tool (A).



5. Remove valve seat (EXH) and valve seat (INT), if valve seat (EXH) or valve seat (INT) must be replaced.
   - Bore out old seat until it collapses. Boring should not continue beyond the bottom face of the seat recess in cylinder head. Set the machine depth stop to ensure this. Refer to EM-157, "Cylinder Head".

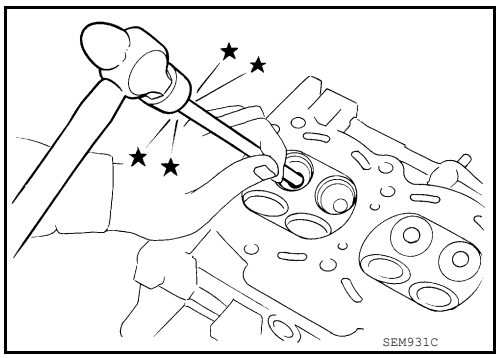
   CAUTION:
   Prevent to scratch cylinder head by excessive boring.
6. Remove valve guide (EXH), if valve guide (EXH) must be replaced.

a. To remove valve guide (EXH), heat cylinder head to 110 to 130°C (230 to 266°F) by soaking in heated oil (A).



b. Drive out valve guide (EXH) with a press [under a 20 kN (2 ton, 2.2 US ton, 2.0 lmp ton) pressure] or a hammer and suitable tool.

WARNING:
Cylinder head contains heat. When working, wear protective equipment to avoid getting burned.

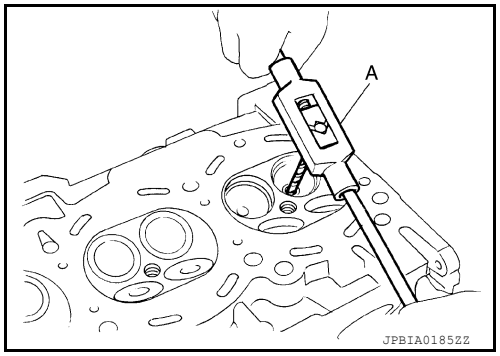


ASSEMBLY

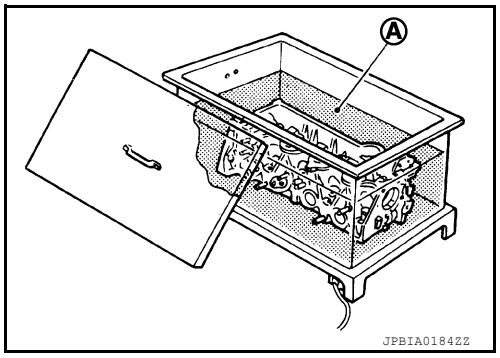
1. Install valve guide (EXH), if removed.
Replace with oversized [0.2 mm (0.008 in)] valve guide (EXH).

a. Using a suitable tool (A), ream cylinder head valve guide (EXH) hole.

Oversize (service) [0.2 mm (0.008 in)]:
: Refer to EM-157, "Cylinder Head".



b. Heat cylinder head to 110 to 130°C (230 to 266°F) by soaking in heated oil (A).

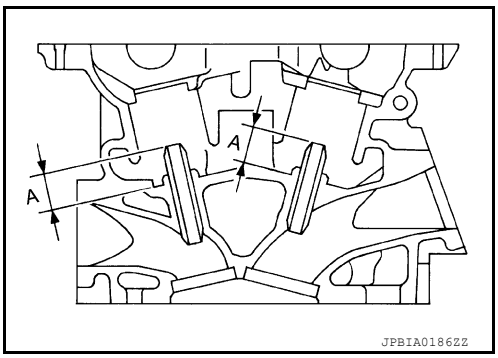


c. Using the suitable tool, press valve guide (EXH) from camshaft side to the dimensions as shown in the figure.

Projection (A)

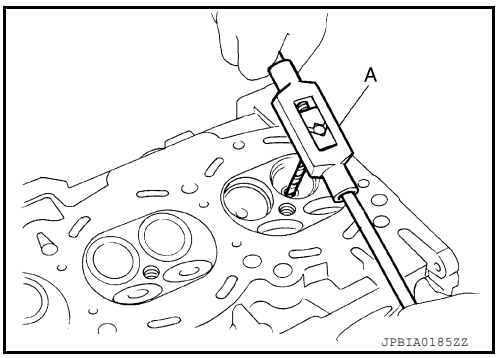
: Refer to EM-157, "Cylinder Head".

WARNING:
Cylinder head contains heat. When working, wear protective equipment to avoid getting burned.



d. Using the suitable tool (A), apply reamer finish to valve guide (EXH).

Standard : Refer to EM-157, "Cylinder Head".



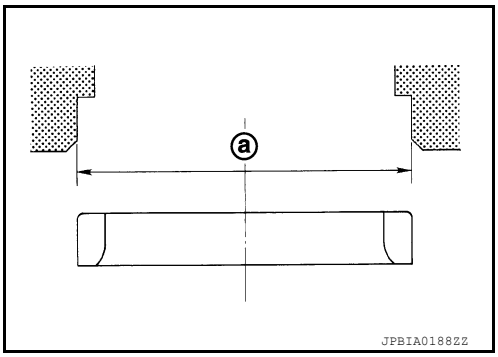
2. Install valve seat (EXH) or valve seat (INT), if removed.
Replace with oversize [0.5 mm (0.020 in)] valve seat (EXH).

a. Ream cylinder head recess diameter (a) for service valve seat (EXH) or valve seat (INT).

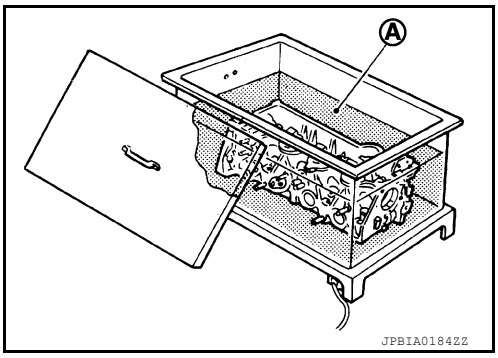
Oversize (service) [0.5 mm (0.020 in)]:

: Refer to EM-157, "Cylinder Head".

- Be sure to ream in circles concentric to valve guide center. This enables valve to fit correctly.



b. Heat cylinder head to 110 to 130°C (230 to 266°F) by soaking in heated oil (A).

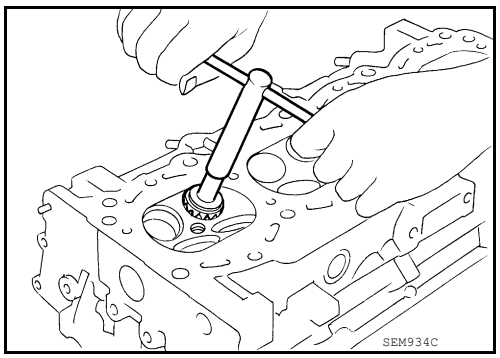


c. Provide valve seats (EXH) or valve seat (INT) cooled well with dry ice. Force fit valve seat (EXH) or valve seat (INT) into cylinder head.

WARNING:
Cylinder head contains heat. When working, wear protective equipment to avoid getting burned.
CAUTION:
Avoid directly touching cold valve seats.

d. Using a suitable tool, finish seat to the specified dimensions. Refer to EM-157, "Cylinder Head".

CAUTION:
When using the valve seat cutter, firmly grip cutter handle with both hands. Then, press on the contacting surface all around the circumference to cut in a single drive. Improper pressure on cutter or cutting many different times may result in staged valve seat.



e. Using compound, grind to adjust valve fitting.

f. Check again for normal contact. Refer to EM-112, "Inspection".

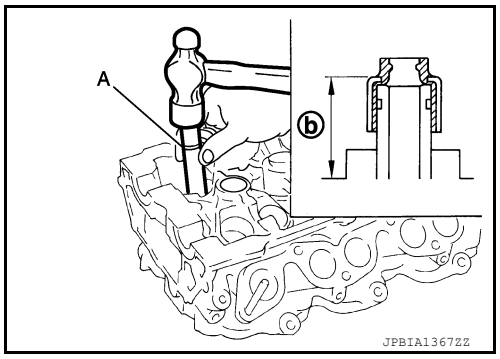
3. Install new valve oil seals as per the following:

a. Apply new engine oil on new valve oil seal joint and seal lip.

b. Using a suitable tool (A), press fit valve seal to height (b) shown in figure.

Height (b)

Intake, Exhaust : 14.3 - 14.9 mm (0.563 - 0.587 in)



4. Install valve.

NOTE:
Larger diameter valves are for intake side.

5. Install valve spring (with valve spring seat).
   - Install narrow pitch (B) end [paint mark (C)] to cylinder head side (valve spring seat side).

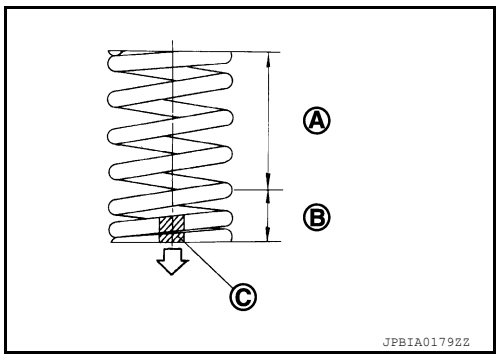
(A) : Wide pitch

⇦ : Cylinder head side

Paint mark color

Intake : Orange

Exhaust : White

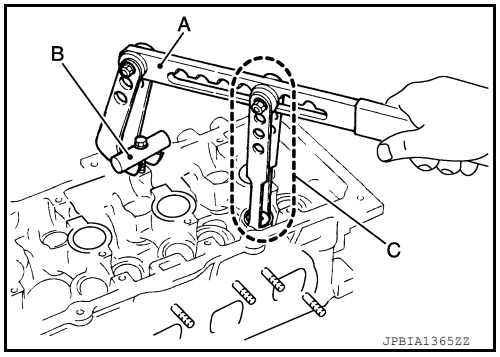


6. Install valve spring retainer.

7. Install valve collet.
   - Compress valve spring with a suitable tool (A/B/C). Install valve collet with a magnet hand.

CAUTION:
When working, take care not to damage valve lifter holes.

   - Tap valve stem edge lightly with plastic hammer after installation to check its installed condition.



Inspection

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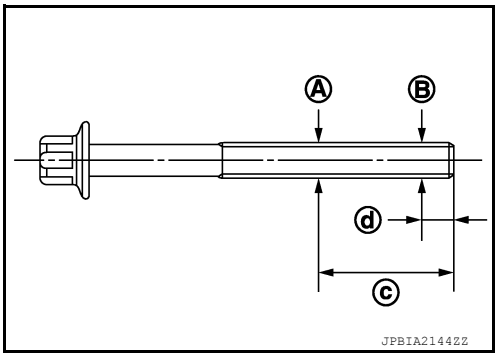
INSPECTION AFTER DISASSEMBLY

Cylinder Head Bolts Outer Diameter

- Cylinder head bolts are tightened by plastic zone tightening method. Whenever the size difference between (B) and (A) exceeds the limit, replace them with new one.

Limit [(B) - (A)] : Refer to EM-157, "Cylinder Head".

- If reduction of outer diameter appears in a position other than (A), use it as (A) point.



Cylinder Head Distortion

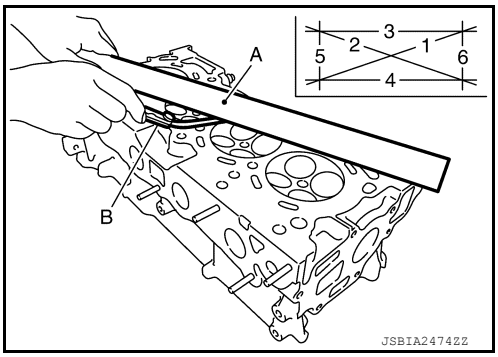
NOTE:

When performing this inspection, cylinder block distortion should be also checked. Refer to EM-137, "Inspection".

1. Using a suitable tool, wipe out oil, scale, gasket, sealant and carbon deposits from surface of cylinder head.
   CAUTION:
   Do not allow gasket fragments to enter engine oil or engine coolant passages.
2. At each of several locations on bottom surface of cylinder head, measure the distortion in six locations

Limit : Refer to EM-157, "Cylinder Head".

- If it exceeds the limit, replace VVEL ladder assembly & cylinder head assembly.
  NOTE:
  Cylinder head assembly cannot be replaced as a single part, because it is machined together with VVEL ladder assembly.



Valve Dimensions

- Check the dimensions of each valve. For the dimensions, refer to EM-157, "Cylinder Head".
- If dimensions are out of the standard.
  - Replace valve and check valve seat contact. Refer to "VALVE SEAT CONTACT".

Valve Guide Clearance

Valve Stem Diameter

- Measure the diameter of valve stem with suitable tool (A).

Standard : Refer to EM-157, "Cylinder Head".

Valve Guide Inner Diameter

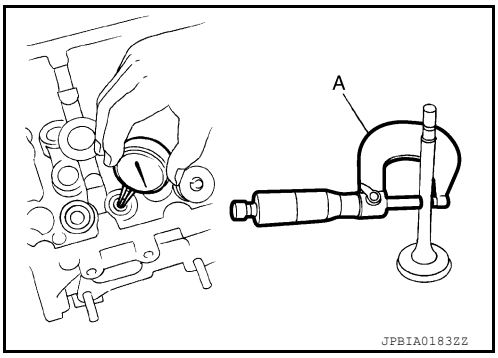
- Measure the inner diameter of valve guide with suitable tool.

Standard : Refer to EM-157, "Cylinder Head".

Valve Guide Clearance

- (Valve guide clearance) = (Valve guide inner diameter) – (Valve stem diameter)

Standard : Refer to EM-157, "Cylinder Head".



- If the calculated value exceeds the limit.
  - Replace valve (EXH) and/or valve guide (EXH). Refer to EM-105, "Exploded View". (Exhaust side)

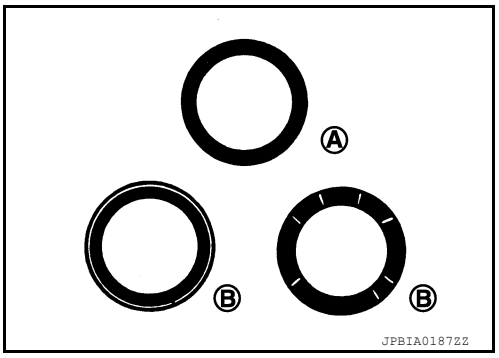
- Replace valve (INT) and/or VVEL ladder assembly & cylinder head assembly. Refer to EM-105, "Exploded View". (Intake side)

NOTE:
Since the valve guide (INT) cannot be replaced by the piece, VVEL ladder assembly & cylinder head assembly replacement are required.

Valve Seat Contact

- After confirming that the dimensions of valve guides and valves are within the specifications, perform this procedure.
- Apply prussian blue (or white lead) onto contacting surface of valve seat to check the condition of the valve contact on the surface.
- Check if the contact area band is continuous all around the circumference.

(A) : OK
(B) : NG



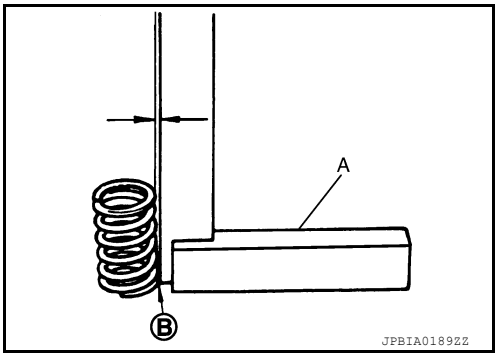
- If not, grind to adjust valve fitting and check again. If the contacting surface still has “NG” conditions even after the re-check, replace valve seat. Refer to EM-105, "Exploded View".

Valve Spring (with valve spring seat) Squareness

- Set a suitable tool (A) along the side of valve spring (with valve spring seat) and rotate spring. Measure the maximum clearance between the top of spring and try square.

(B) : Contact

Limit : Refer to EM-157, "Cylinder Head".

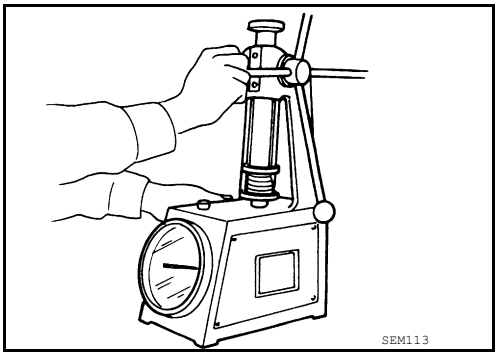


- If it exceeds the limit.
- Replace valve spring (with valve spring seat). Refer to EM-105, "Exploded View".

Valve Spring Dimensions and Valve Spring Pressure Load

- Check the valve spring (with valve spring seat) pressure at specified spring height.

Standard
: Refer to EM-157, "Cylinder Head".



- If the installation load or load with valve open is out of the standard.
- Replace valve spring (with valve spring seat). Refer to EM-105, "Exploded View".

INSPECTION AFTER ASSEMBLY

Inspection for Leakage

The following are procedures for checking fluid leakage, lubricant leakage.

- Before starting engine, check oil/fluid levels including engine coolant and engine oil. If any are less than the required quantity, fill them to the specified level. Refer to MA-13, "VK56VD Gasoline Engine : Fluids and Lubricants".
- Follow the procedure below to check for fuel leakage.
- Turn ignition switch to the “ON” position (with engine stopped). With fuel pressure applied to fuel piping, check for fuel leakage at connection points.
- Start engine. With engine speed increased, check again for fuel leakage at connection points.
- Run engine to check for unusual noise and vibration.

NOTE:
If hydraulic pressure inside chain tensioner drops after removal/installation, slack in guide may generate a pounding noise during and just after the engine start. However, this does not indicate a malfunction. The noise will stop after hydraulic pressure rises.

- Warm up engine thoroughly to check that there is no leakage of fuel, or any oil/fluids including engine oil and engine coolant.
- Bleed air from lines and hoses of applicable lines, such as in cooling system.
- After cooling down engine, again check oil/fluid levels including engine oil and engine coolant. Refill them to the specified level, if necessary.

Summary of the inspection items:

Items		Before starting engine	Engine running	After engine stopped
Engine coolant		Level	Leakage	Level
Engine oil		Level	Leakage	Level
Transmission / transaxle fluid	AT & CVT Models	Leakage	Level / Leakage	Leakage
	MT Models	Level / Leakage	Leakage	Level / Leakage
Other oils and fluids*		Level	Leakage	Level
Fuel		Leakage	Leakage	Leakage

* Power steering fluid, brake fluid, etc.

OIL SEAL

FRONT OIL SEAL

FRONT OIL SEAL : Removal and Installation

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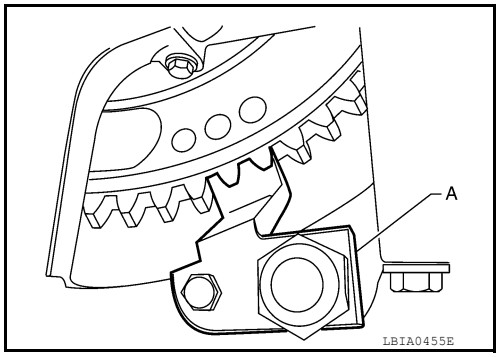
REMOVAL

1. Remove the following parts:
   - Drive belt: Refer to EM-23, "Removal and Installation".
   - Cooling fan: Refer to CO-22, "Removal and Installation".
2. Remove crankshaft pulley as per the following:

a. Remove rear plate cover. Refer to EM-64, "Exploded View".

b. Set Tool (A) as shown in the figure.

Tool : KV10120100 (J-47245)

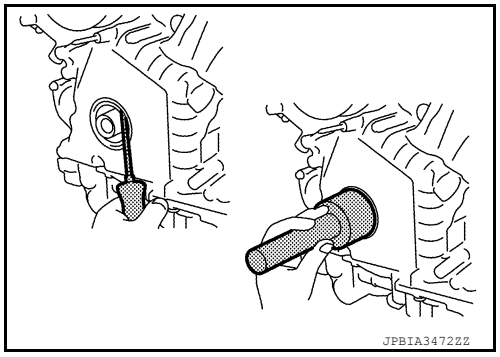


c. Loosen crankshaft pulley bolt, and then pull crankshaft pulley with both hands to remove it.

CAUTION:
Do not remove crankshaft pulley bolt. Keep loosened crankshaft pulley bolt in place to protect removed crankshaft pulley from dropping.

3. Remove front oil seal using a suitable tool.

CAUTION:
- **Do not reuse front oil seal.**
- **Be careful not to damage front cover and crankshaft.**

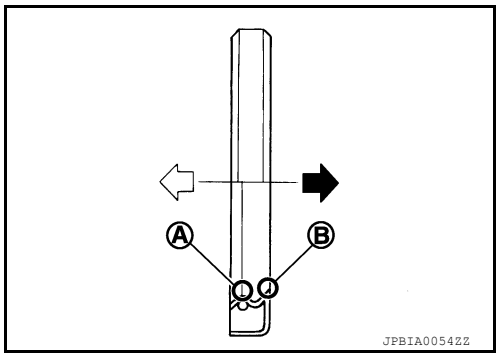


INSTALLATION

1. Install front oil seal on front cover.

⇦ : Engine inside

⬅ : Engine outside



- Apply new engine oil to both oil seal lip (A) and dust seal lip (B).
- Install it so that each seal lip is oriented as shown in the figure.

CAUTION:
Be careful not to scratch or make burrs on circumference of oil seal.

- Using a suitable drift, press-fit oil seal until it becomes flush with front cover end face.
- Check the garter spring is in position and seal lips are not inverted.

2. Installation of the remaining components is in the reverse order of removal.

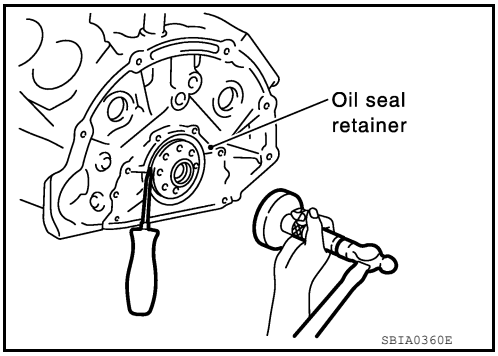
REAR OIL SEAL

REAR OIL SEAL : Removal and Installation

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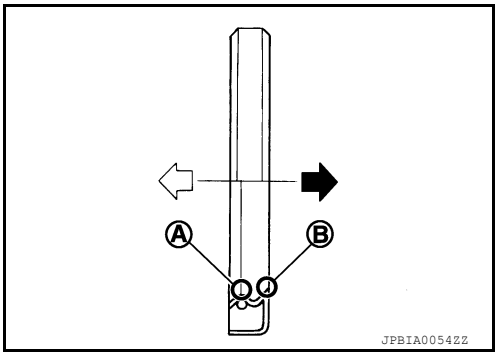
REMOVAL

1. Remove transmission assembly. Refer to TM-506, "2WD : Removal and Installation" (2WD models) or TM-511, "4WD : Removal and Installation" (4WD models).
2. Remove drive plate. Refer to EM-128, "Exploded View".
3. Remove rear oil seal with a suitable tool.
   CAUTION:
   - **Do not reuse rear oil seal.**
   - **Be careful not to damage crankshaft and cylinder block.**



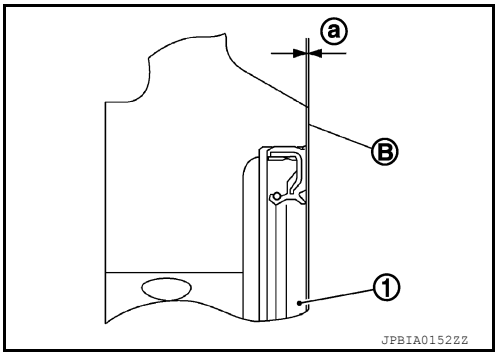
INSTALLATION

1. Install rear oil seal.
   - Install rear oil seal so that each seal lip is oriented as shown in the figure.



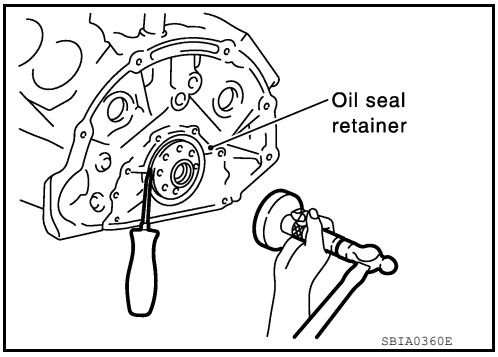
(A) : Oil seal lip
(B) : Dust seal lip
⇦ : Engine inside
⬅ : Engine outside

- Press in rear oil seal (1) to the position as shown in the figure.



(B) : Rear oil seal retainer rear end face
(A) : 0 - 0.5 mm (0 - 0.020 in)

- Using a suitable drift, press-fit until the height of rear oil seal is level with the mounting surface.
- Check the garter spring is in position and seal lips are not inverted.
  CAUTION:
  - **Be careful not to damage crankshaft and cylinder block.**
  - **Press-fit straight and avoid causing burrs or tilting oil seal.**

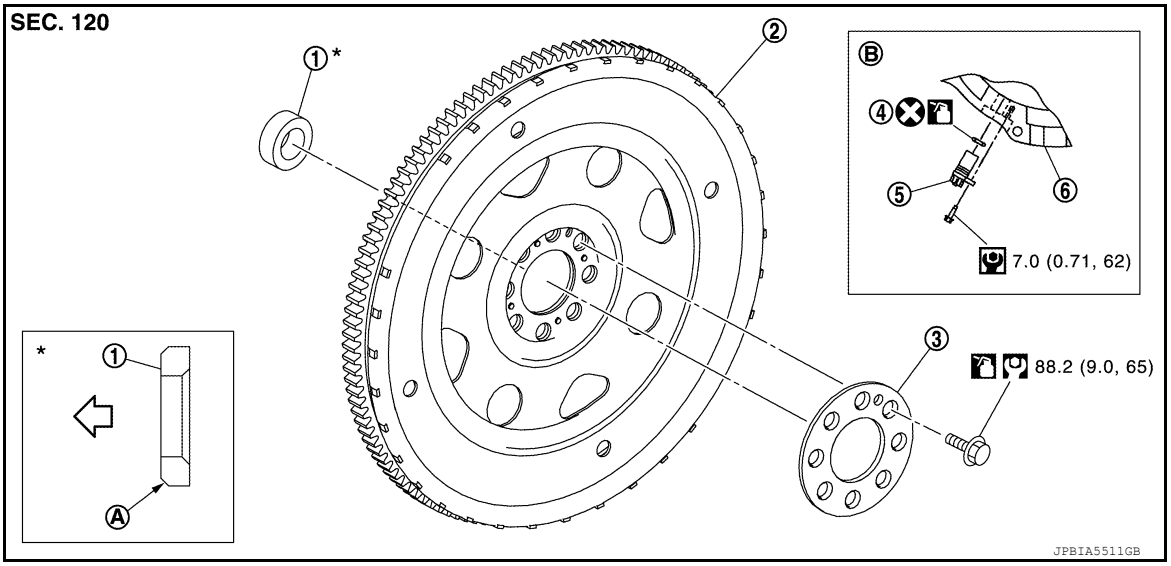


2. Installation of the remaining components is in the reverse order of removal.

DRIVE PLATE

Exploded View

INFOID:0000000014418531



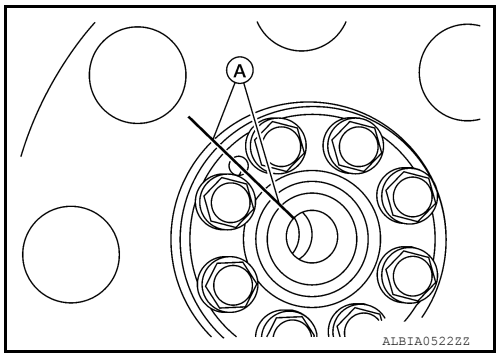
1. Pilot converter
2. Drive plate
3. Reinforcement plate
4. O-ring
5. Crankshaft position sensor (POS)
6. Transmission
A. Chamfered
B. Installed on transmission
⇦ Crankshaft side

Removal and Installation

INFOID:0000000014418532

REMOVAL

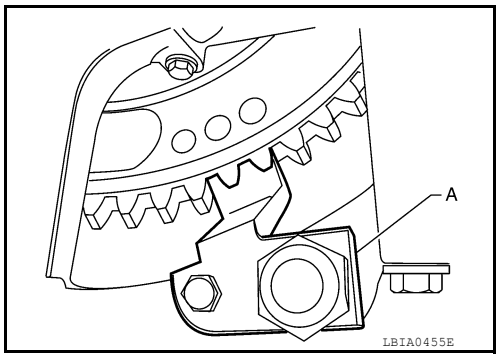
1. Remove transmission assembly. Refer to TM-506, "2WD : Removal and Installation" (2WD models) or TM-511, "4WD : Removal and Installation" (4WD models).
2. Before removing the drive plate, put a match mark (A) on the crankshaft and drive plate for alignment during installation.



3. Remove drive plate as par the following procedure.

a. Set the Tool (A) as shown in the figure.

Tool : KV10120100 (J-47245)



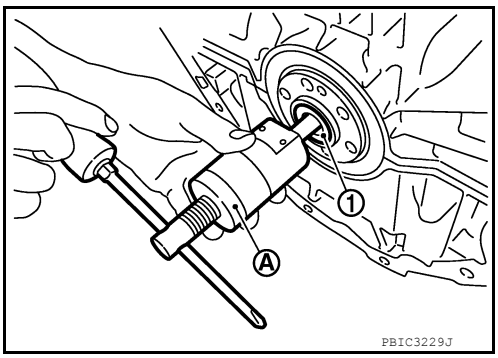
b. Loosen the bolts diagonally, and then pull drive plate with both hands to remove it.

CAUTION:

- **Do not disassemble them.**
- **Do not place them with signal plate facing down.**
- **When handling signal plate, take care not to damage or scratch them.**
- **Handle signal plate in a manner that prevents them from becoming magnetized.**

- **Take care not to damage the periphery of the sensing area.**
- **Any dropped drive plate shall not be used. (The drive plate to which the sensing area shall not be placed on the floor.)**
- **Do not touch drive plate with bare hands. Always use urethane coating gloves or skin gloves when removing these parts.**
- **Do not use torn glove.**

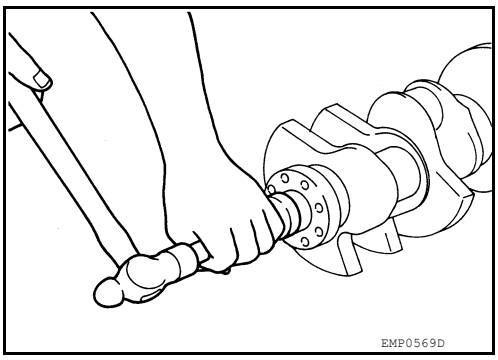
4. Remove pilot converter (1) using a suitable tool (A) (if necessary).



INSTALLATION

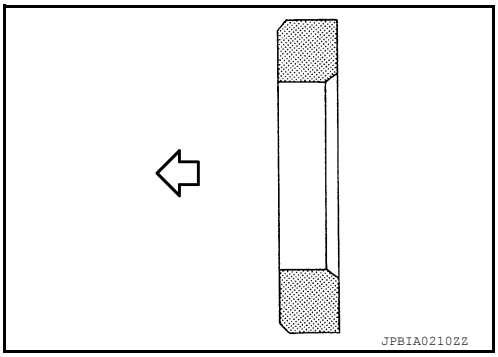
1. Install pilot converter to the crankshaft using suitable tool, if removed.
   - With a drift of the following outer diameter, press-fit as far as it will go.

     Pilot converter : Approx. 35 mm (1.38 in)



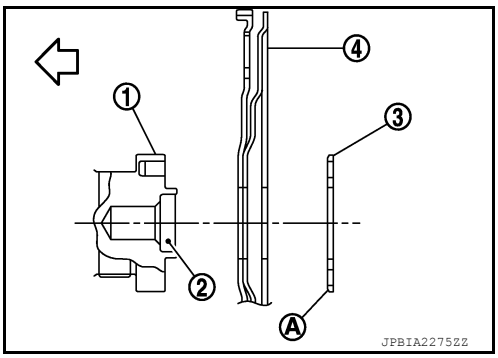
   - Press-fit pilot converter with its chamfering side facing crankshafts shown in the figure.

     ⇦ : Crankshaft side



2. Install drive plate in the reverse order of removal.
   - Install drive plate (4) and reinforcement plate (3) as shown in the figure.

     (2) : Pilot converter
     (A) : Rounded
     ⇦ : Engine front



   - When installing drive plate to crankshaft (1), be sure to correctly align crankshaft side dowel pin and drive plate side dowel pin hole.
     CAUTION:
     If these are not aligned correctly, engine runs roughly and "MIL" illuminates.
   - Holding ring gear with Tool.

     Tool : KV10120100 (J-47245)

- Tighten the bolts crosswise over several times.

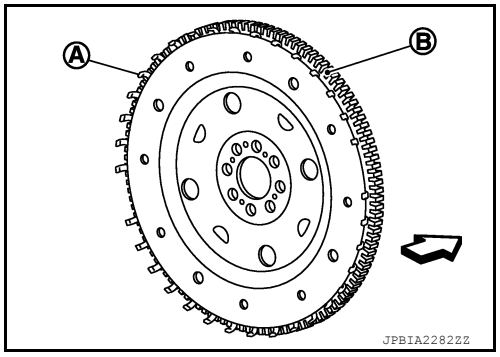
3. Installation of the remaining components is in the reverse order of removal.

Inspection

INFOID:0000000014418533

DRIVE PLATE DEFLECTION

- Check drive plate and signal plate (A) for deformation or damage.



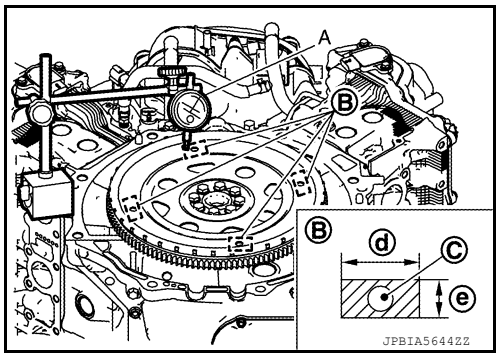
(B) : Ring gear

⇦ : Engine front

CAUTION:

- **Do not disassemble drive plate.**
- **Do not place drive plate with signal plate facing down.**
- **When handling signal plate, take care not to damage or scratch it.**
- **Handle signal plate in a manner that prevents it from becoming magnetized.**

- If damage is found, replace drive plate.
- Measure the deflection of drive plate contact surface to torque converter with a suitable tool (A).
- Measure the deflection at the area (B).



(C) : Hole of torque converter bolt

(D) : 34 mm (1.34 in)

(E) : 21 mm (0.83 in)

Limit : 0.35 mm (0.0138 in) or less.

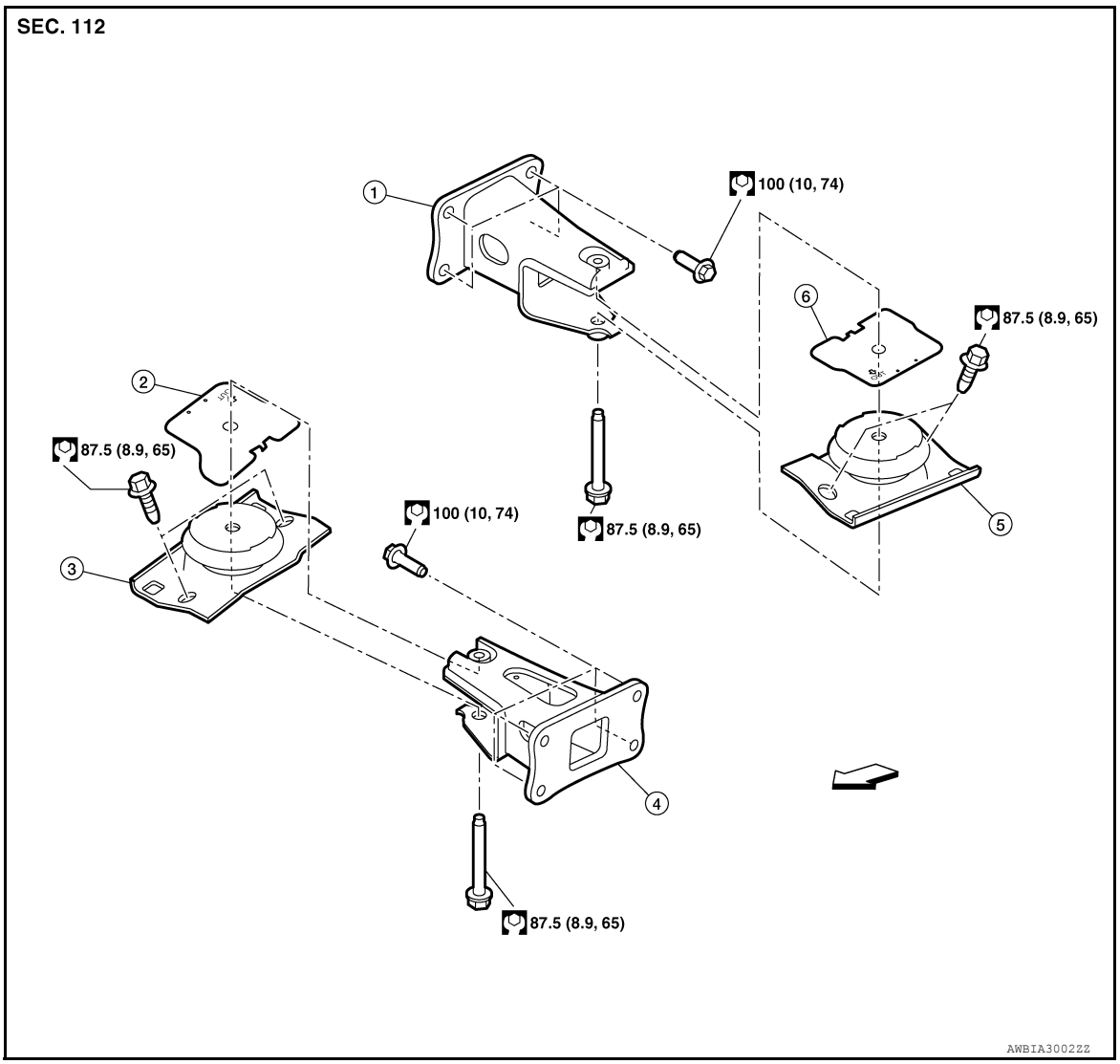
- If measured value is out of the standard, replace drive plate.

UNIT REMOVAL AND INSTALLATION

ENGINE ASSEMBLY

Exploded View

INFOID:0000000014418534



1. Engine mounting bracket (LH)
2. Heat shield plate (RH)
3. Engine mounting insulator (RH)
4. Engine mounting bracket (RH)
5. Engine mounting insulator (LH)
6. Heat shield plate (LH)

⇦ Front

Removal and Installation

INFOID:0000000014418535

WARNING:
- **Situate the vehicle on a flat and solid surface.**
- **Place chocks at the front and back of rear wheels.**
- **For engines not equipped with engine slingers, attach proper slingers and bolts described in PARTS CATALOG.**

CAUTION:
- **Always be careful to work safely, and avoid forceful or uninstructed operations.**
- **Do not start working until exhaust system and engine coolant are cool enough.**
- **If items or work required are not covered by the engine section, refer to the applicable sections.**
- **Always use the support point specified for lifting.**

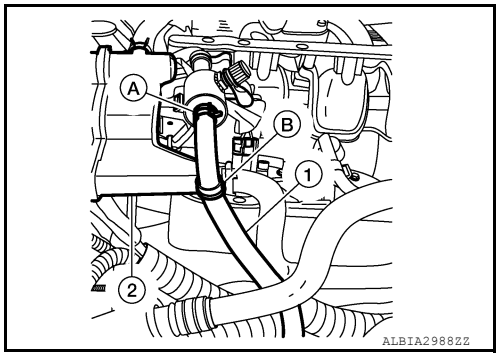
- **Use either 2-pole lift type or separate type lift as much as possible. If board-on type is used for unavoidable reasons, support at rear axle jacking point with transmission jack or similar tool before starting work, in preparation for the backward shift of the center of gravity.**
- **For supporting points for lifting and jacking point at rear axle, refer to GI-29, "XD MODELS : Garage Jack and Safety Stand".**

NOTE:

- When removing components such as hoses, tube/lines, etc., cap or plug openings to prevent fluid from spilling.

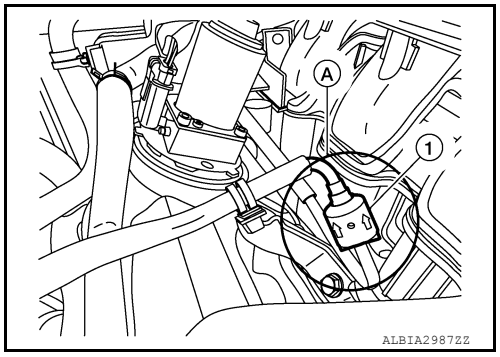
REMOVAL

1. Disconnect battery. Refer to PG-185, "Battery Disconnect".
2. Release fuel pressure. Refer to EC-205, "Work Procedure".
3. Drain engine coolant. Refer to CO-11, "Changing Engine Coolant".
4. Remove hood assembly. Refer to DLK-144, "HOOD ASSEMBLY : Removal and Installation".
5. Remove cowl top extension. Refer to EXT-36, "Removal and Installation - Cowl Top Extension".
6. Remove air cleaner and air duct. Refer to EM-31, "Removal and Installation".
7. Remove radiator. CO-14, "Removal and Installation - XD Models" or CO-17, "Removal and Installation - Non-XD Models".
8. Remove cooling fan coupling. CO-22, "Exploded View".
9. Disconnect clamp (B) from air duct (2).
10. Remove clamp (A) and disconnect EVAP hose (1) from air duct.



11. Disconnect quick connector (A) with the following procedure.

a. Remove quick connector cap (1) from quick connector connection.



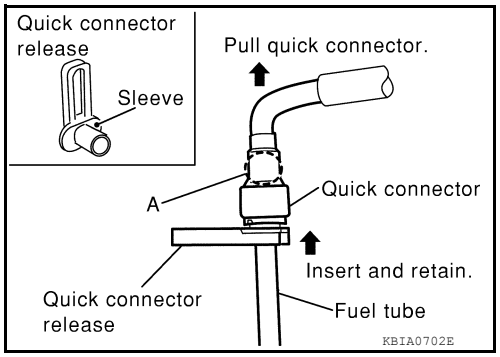
b. With the sleeve side of Tool facing quick connector, install Tool onto fuel tube.

c. Insert Tool into quick connector until sleeve contacts and goes no further. Hold Tool on that position.

CAUTION:

Inserting quick connector release hard will not disconnect quick connector. Hold quick connector release where it contacts and goes no further.

Tool : — (J-45488)

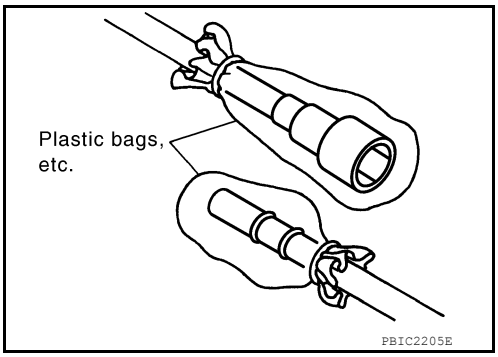


d. Draw and pull out quick connector straight from fuel tube.

CAUTION:

- **Pull quick connector holding (A) position as shown in the figure.**
- **Do not pull with lateral force applied. O-ring inside quick connector may be damaged.**

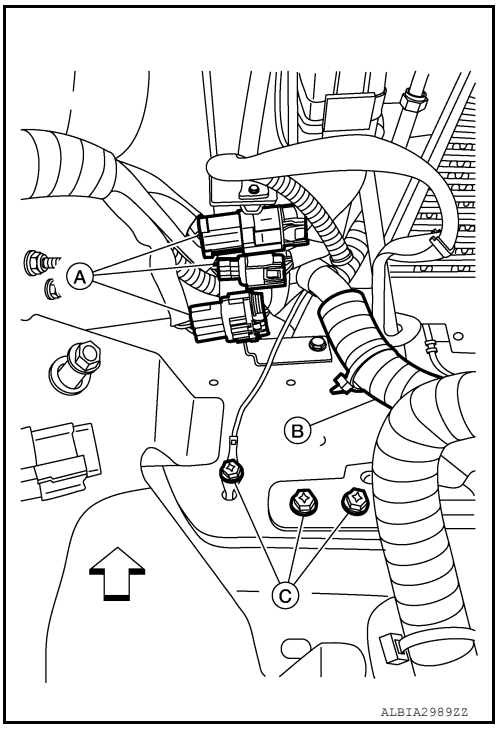
- **Prepare container and cloth beforehand because fuel will leak out.**
- **Avoid fire and sparks.**
- **Keep parts away from heat source. Especially, be careful when welding is performed around them.**
- **Do not expose parts to battery electrolyte or other acids.**
- **Do not bend or twist connection between quick connector and fuel feed hose (with damper) during installation/removal.**
- **To keep clean the connecting portion and to avoid damage and foreign materials, cover them completely with plastic bags, etc. or a similar item.**



12. Disconnect VVEL control module harness connector. Refer to PG-7, "Harness Connector".
13. Disconnect harness connectors (A) for engine harness [LH (B)].
14. Remove screws (C).

⇦ : Front

15. Disconnect harness retainers and reposition engine harness (LH).

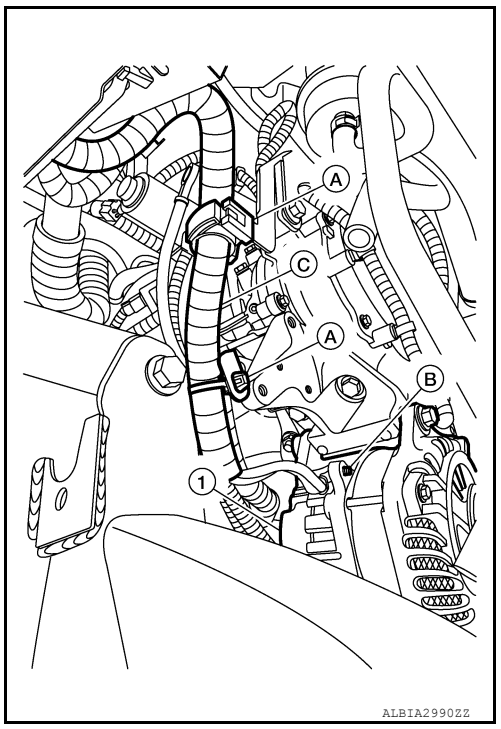


16. Remove wheel and tire. Refer to WT-69, "Removal and Installation".
17. Remove fender protector. Refer to EXT-41, "Removal and Installation - Front Fender Protector".

18. Remove the alternator harness (C) from the engine assembly using the following procedure:

a. Disconnect harness clips (A) from the engine.

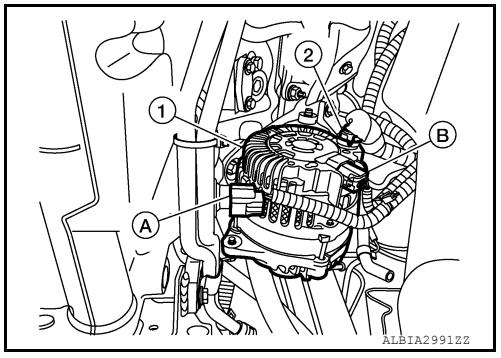
b. Remove bolt (B) from alternator (1).



c. Disconnect oil pressure sensor harness connector (A).

d. Remove "B" terminal nut (2).

e. Disconnect the harness connector (B) from the alternator (1).



19. Disconnect A/T fluid cooler hose A and A/T fluid cooler hose B from A/T fluid warmer. Refer to TM-498, "Exploded View - XD Models" or TM-499, "Exploded View - Non-XD Models".

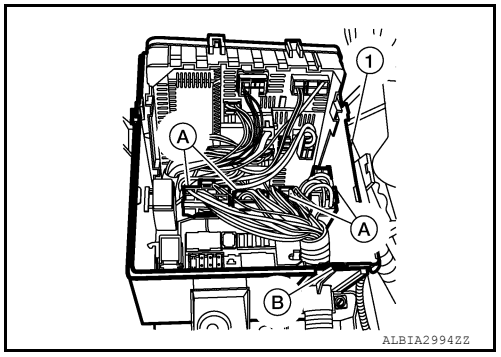
20. Remove clips securing A/T fluid cooler tube A and A/T fluid cooler tube D to engine assembly. Refer to TM-498, "Exploded View - XD Models" or TM-499, "Exploded View - Non-XD Models".

21. Release relay box from mount and set aside.

22. Remove IPDM E/R lid.

23. Remove cover (B) from IPDM E/R (1).

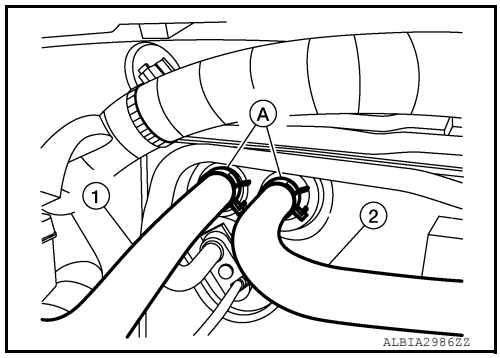
24. Disconnect harness connectors (A) from IPDM E/R and remove engine harness (RH) from IPDM E/R.



25. Disconnect ECM harness connectors. Refer to PG-7, "Harness Connector".

26. Remove fusible link cover and remove battery positive cables. Refer to PG-193, "Removal and Installation".

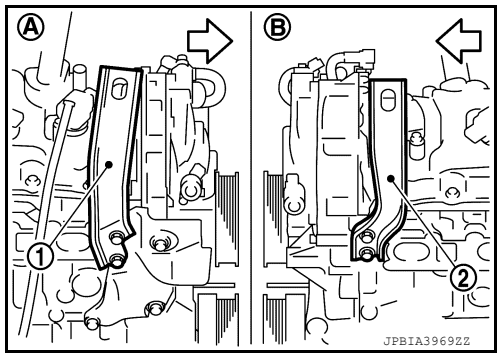
27. Unbolt power steering oil pump and set aside without disconnecting power steering suction hose or power steering pressure hose. Refer to ST-68, "Removal and Installation - VK56VD".
28. Disengage power steering reservoir from bracket and set aside. Refer to ST-69, "Exploded View".
29. Remove the high-pressure flexible hose and low-pressure flexible hose from the compressor. Refer to HA-40, "Exploded View".
30. Remove clamps (A) and remove heater hose [inlet (1)] and heater hose [outlet (2)] from heater core.



31. Remove the transmission assembly. Refer to TM-506, "2WD : Removal and Installation" (2WD) or TM-511, "4WD : Removal and Installation" (4WD).
32. Remove the front final drive. Refer to DLN-191, "Removal and Installation" (XD 4WD Models only) or DLN-220, "Removal and Installation" (Non-XD 4WD Models only).
33. Install engine slinger on both front right and front left sides of the engine.

Slinger bolts: : 45.0 N·m (4.6 kg-m, 33 ft-lb)

(A) : Engine front slinger (bank 2)
(B) : Engine front slinger (bank 1)



34. Lift using a hoist and secure the engine in position.
35. Remove engine mounting bracket (LH, RH) and engine mounting insulator (LH, RH).
36. Remove the engine from the vehicle, avoid interference with the vehicle body.
CAUTION:
Before and during lifting, always check that any harnesses are left connected.

INSTALLATION

Installation is in the reverse order of removal.

CAUTION:
- **When replacing an engine or transmission you must make sure the dowels are installed correctly during re-assembly. Improper alignment caused by missing dowels may cause vibration, oil leaks or breakage of drivetrain components.**
- **Perform ADDITIONAL SERVICE WHEN REPLACING ECM. Refer to EC-194, "Description".**

Inspection

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INSPECTION AFTER INSTALLATION

Inspection for Leakage

The following are procedures for checking fluid leakage, lubricant leakage.
- Before starting engine, check oil/fluid levels including engine coolant and engine oil. If any are less than the required quantity, fill them to the specified level. Refer to MA-13, "VK56VD Gasoline Engine : Fluids and Lubricants".
- Follow the procedure below to check for fuel leakage.
- Turn ignition switch to the “ON” position (with engine stopped). With fuel pressure applied to fuel piping, check for fuel leakage at connection points.

- Start engine. With engine speed increased, check again for fuel leakage at connection points.
- Run engine to check for unusual noise and vibration.

NOTE:

If hydraulic pressure inside chain tensioner drops after removal/installation, slack in guide may generate a pounding noise during and just after the engine start. However, this does not indicate a malfunction. The noise will stop after hydraulic pressure rises.

- Warm up engine thoroughly to check that there is no leakage of fuel, or any oil/fluids including engine oil and engine coolant.
- Bleed air from lines and hoses of applicable lines, such as in cooling system.
- After cooling down engine, again check oil/fluid levels including engine oil and engine coolant. Refill them to the specified level, if necessary.

Summary of the inspection items:

Items		Before starting engine	Engine running	After engine stopped
Engine coolant		Level	Leakage	Level
Engine oil		Level	Leakage	Level
Transmission / transaxle fluid	AT & CVT Models	Leakage	Level / Leakage	Leakage
	MT Models	Level / Leakage	Leakage	Level / Leakage
Other oils and fluids*		Level	Leakage	Level
Fuel		Leakage	Leakage	Leakage
Exhaust gases		—	Leakage	—

*: Power steering fluid, brake fluid, etc.

UNIT DISASSEMBLY AND ASSEMBLY

ENGINE STAND SETTING

Setting

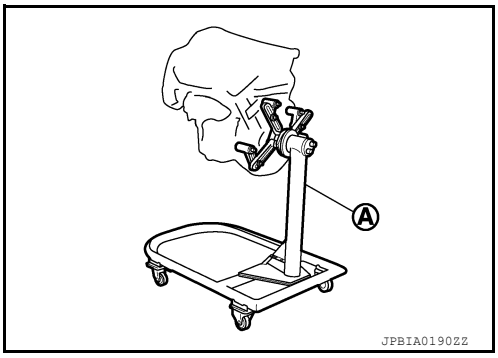
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NOTE:
Explained here is how to disassemble with engine stand supporting transmission surface. When using a different type of engine stand, note the difference in the steps, etc.

1. Remove the engine assembly from the vehicle. Refer to EM-120, "Removal and Installation".
2. Remove crankshaft pulley. Refer to EM-115, "FRONT OIL SEAL : Removal and Installation".
   NOTE:
   The drive plate is fixed with Tool. Loosen the crankshaft pulley bolt before installing the engine stand.

   Tool : KV10120100 (J-47245)
3. Remove the parts that may restrict installation of engine to a widely used engine stand.
   • Drive plate: Refer to EM-117, "Exploded View".
4. Lift the engine with hoist to install it onto the widely used engine stand.
   CAUTION:
   Use an engine stand that has a load capacity [240 kg (529 lb) or more] large enough for supporting the engine weight.
   • If the load capacity of the stand is not adequate, remove the following parts beforehand to reduce the potential risk of overturning the stand.
   - Remove intake manifold. Refer to EM-35, "Exploded View".
   - Remove fuel injector and fuel tube assembly. Refer to EM-57, "Exploded View".
   - Remove ignition coil. Refer to EM-34, "Exploded View".
   - Remove rocker cover. Refer to EM-38, "Exploded View".
   - Remove exhaust manifold. Refer to EM-45, "Exploded View".
   - Other removable brackets.

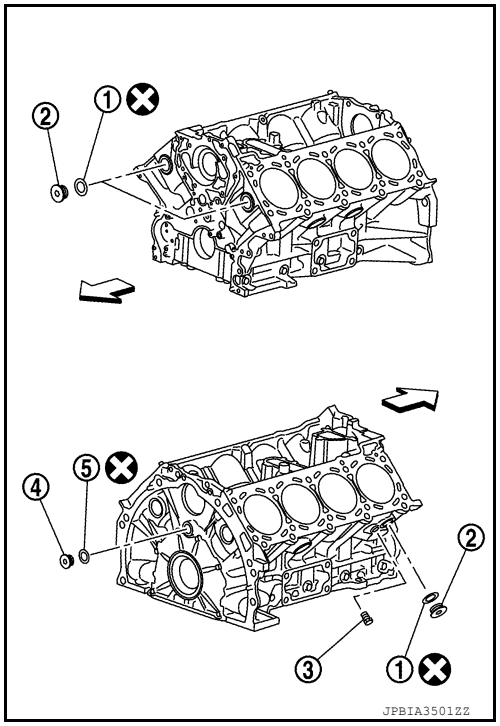
   NOTE:
   The figure shows an example of widely used engine stand (A) that can hold mating surface of transmission with drive plate removed.
   CAUTION:
   Before removing the hanging chains, check the engine stand is stable and there is no risk of overturning.



5. Drain engine oil. Refer to LU-10, "Draining".

6. Drain engine coolant by removing water drain plug (3) from cylinder block as shown in the figure.

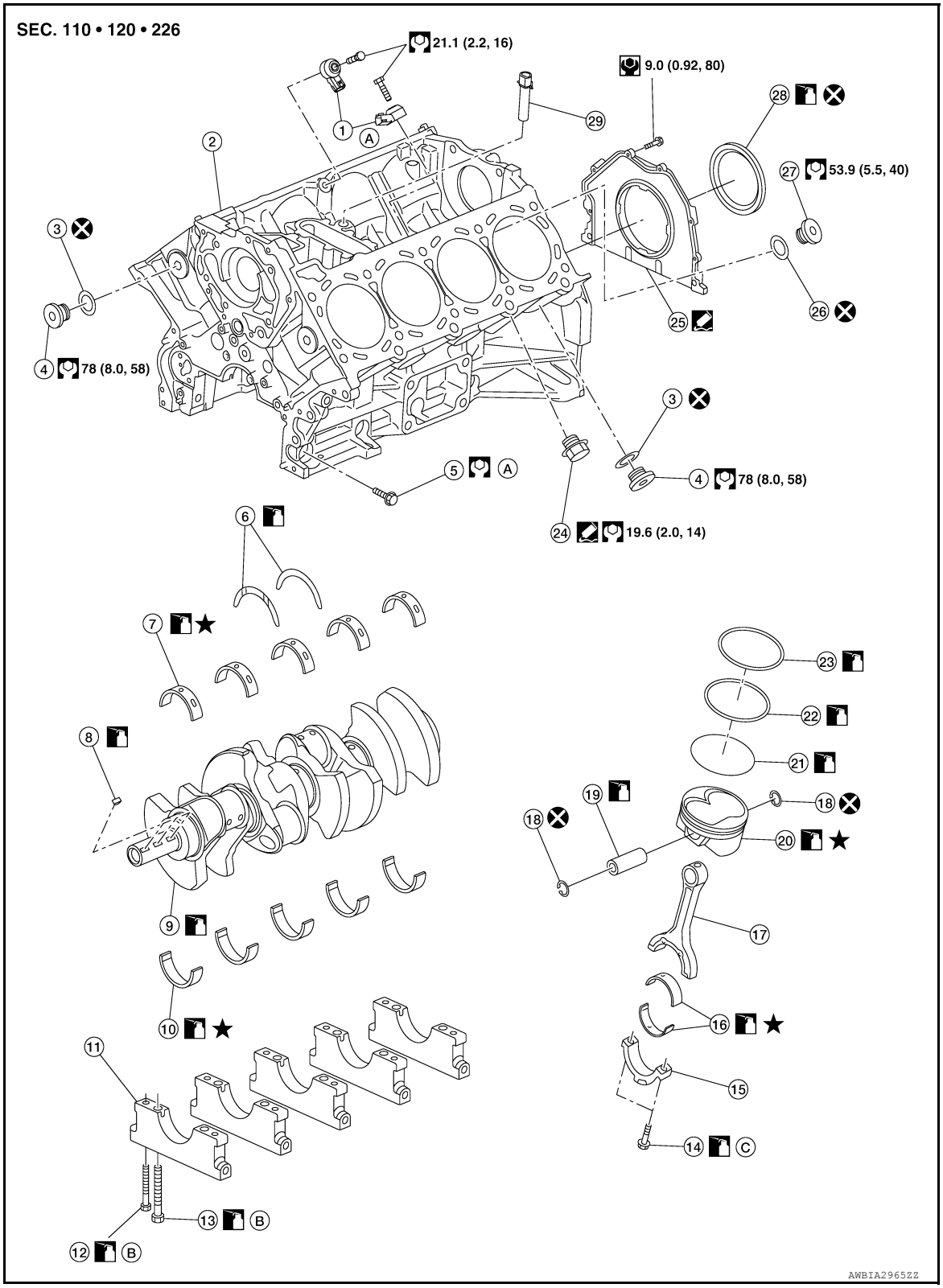
(1) : Washer
(2) : Plug (engine coolant)
(4) : Plug (engine oil)
(5) : Washer
⇦ : Engine front



CYLINDER BLOCK

Exploded View

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1. Knock sensor
2. Cylinder block
3. Washer
4. Drain plug
5. Main bearing side bolt
6. Thrust bearing
7. Main bearing (upper)
8. Crankshaft key
9. Crankshaft

10. Main bearing (lower)
11. Main bearing cap
12. Main bearing cap sub bolt
13. Main bearing cap bolt
14. Connecting rod cap bolt
15. Connecting rod cap
16. Connecting rod bearing
17. Connecting rod
18. Snap ring
19. Piston pin
20. Piston
21. Oil ring
22. Second ring
23. Top ring
24. Water drain plug
25. Rear oil seal retainer
26. Washer
27. Drain plug
28. Rear oil seal
29. Cylinder block heater (if equipped)
A. Refer to INSTALLATION
B. Refer to INSTALLATION
C. Refer to INSTALLATION

Disassembly and Assembly

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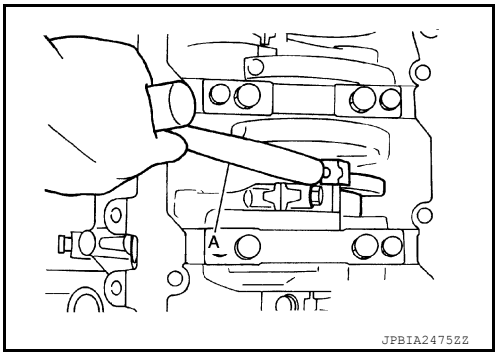
DISASSEMBLY

NOTE:
Explained here is how to disassemble with engine stand supporting transmission surface. When using a different type of engine stand, note the difference in the steps, etc.

1. Attach engine on a suitable engine stand. Refer to EM-126, "Setting".
2. Remove the following parts (if not already removed):
   - Intake manifold, refer to EM-35, "Exploded View".
   - Oil pan (upper), refer to EM-70, "Exploded View".
   - Front cover and timing chain, refer to EM-74, "Exploded View".
   - Cylinder head, refer to EM-105, "Exploded View".
   - Starter, refer to STR-38, "Removal and Installation - For VK56VD".
3. Remove all drain plugs.
4. Remove cylinder block heater (if equipped).
5. Remove knock sensor.
   CAUTION:
   Carefully handle knock sensor avoiding shocks.
6. Remove oil filter (for VVEL ladder assembly) from cylinder block (if necessary). Refer to EM-105, "Exploded View".
7. Remove piston and connecting rod assembly using the following procedure:
   - Before removing piston and connecting rod assembly, check the connecting rod side clearance. Refer to EM-137, "Inspection".

   CAUTION:
   Be careful not to drop connecting rod bearing, and to scratch the surface.

a. Position crankshaft pin corresponding to connecting rod to be removed onto the bottom dead center.
b. Loosen bolts and remove connecting rod bearing cap.
c. Using a suitable tool (A) to push piston and connecting rod assembly out to the cylinder head side.
   CAUTION:
   Be careful not to damage the cylinder wall and crankshaft pin, resulting from an interference of the connecting rod big end.

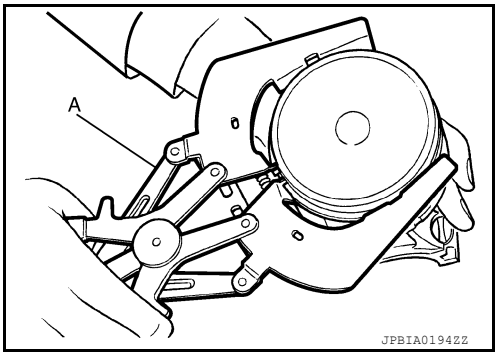


8. Remove connecting rod bearings from connecting rod and connecting rod bearing cap.
   CAUTION:
   - **Be careful not to drop connecting rod bearing and to scratch the surface.**
   - **Identify installation positions and store them without mixing them up.**
9. Remove piston rings from piston.
   - Before removing piston rings, check the piston ring side clearance. Refer to EM-137, "Inspection".

- Use a suitable tool (A) and remove piston rings.

CAUTION:

- **When removing piston rings, be careful not to damage piston.**
- **Be careful not to damage piston rings by expanding them excessively.**

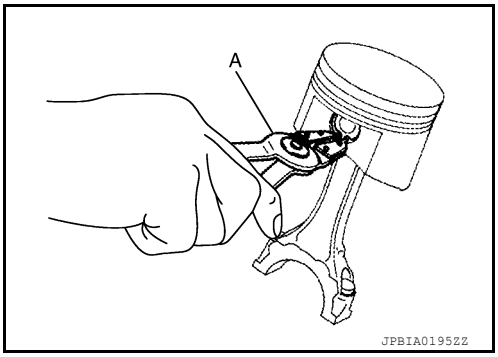


10. Remove piston from connecting rod as per the following:

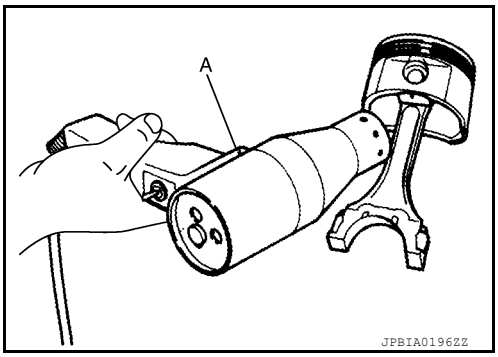
a. Using a suitable tool (A), remove snap rings.

CAUTION:

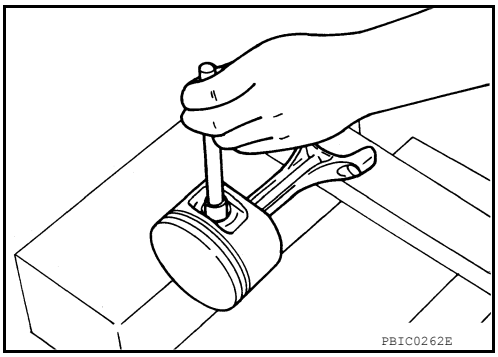
Do not reuse snap rings.



b. Heat piston to 60 to 70°C (140 to 158°F) with a suitable tool (A).



c. Push out piston pin using a suitable tool that has an outer diameter of approximately 20 mm (0.79 in).



11. Remove bolts and remove rear oil seal and rear oil seal retainer assembly from cylinder block.
    - Insert suitable tool between rear end of crankshaft counter weight and rear oil seal retainer and separate liquid gasket to remove.

    CAUTION:

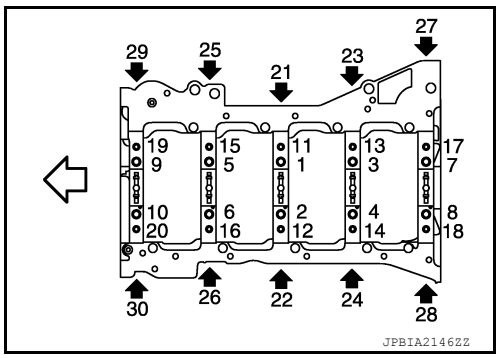
    Be careful not to damage the mating surfaces.
12. Using suitable tool, remove rear oil seal from rear oil seal retainer (if necessary).
13. Remove main bearing cap as per the following:
    - Before loosening cylinder block bolts, measure the crankshaft end play. Refer to EM-137, "Inspection".

a. Loosen side bolts starting from No. 30 to 21 to remove.

⇦ : Engine front

b. Loosen main bearing cap sub bolts starting from No. 20 to 11 to remove.

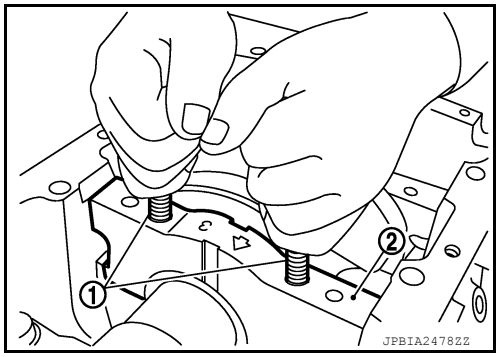
c. Loosen main bearing cap bolts starting from No. 10 to 1 to remove.



d. Remove the main bearing cap.
- Insert bolts (1) into bolt holes, and then remove main bearing cap (2) by lifting up and rocking main bearing cap forward and backward.

CAUTION:
Be careful not to damage the mounting surface.

14. Remove main bearings from main bearing caps.



15. Remove crankshaft.
16. Remove main bearings and thrust bearings from main bearing cap and cylinder block.

CAUTION:
- **Be careful not to drop main bearing, and to scratch the surface.**
- **Identify installation positions, and store them without mixing them up.**

ASSEMBLY

CAUTION:
Do not reuse washers.

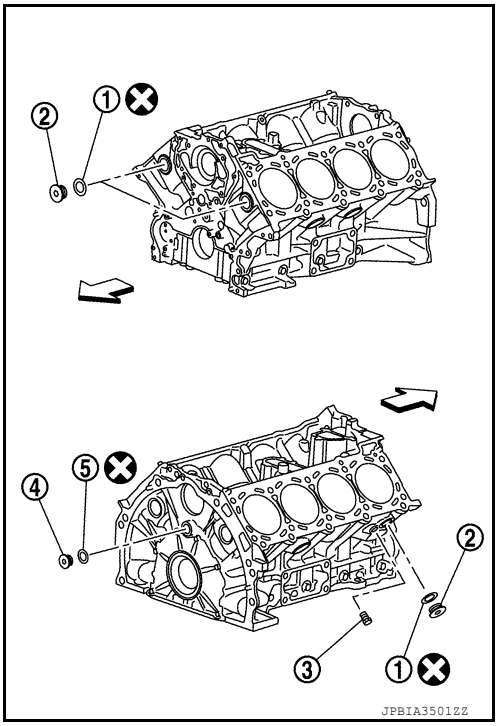
1. Fully air-blow engine coolant and engine oil passages in cylinder block, cylinder bore and crankcase to remove any foreign material.

CAUTION:
Use goggles to protect your eyes.

2. Install each plug to cylinder block as shown in the figure.
CAUTION:
Do not reuse washers (1/5).
NOTE:
Apply sealant to the thread of water drain plug (3) and thread of plug (4).
Use Genuine RTV silicone sealant or equivalent. Refer to GI-22, "Recommended Chemical Products and Sealants".

Plug (2)	**: 78.0 N·m (8.0 kg-m, 58 ft-lb)**
Water drain plug (3)	**: 19.6 N·m (2.0 kg-m, 14 ft-lb)**
Plug (4)	**: 53.9 N·m (5.5 kg-m, 40 ft-lb)**

⇦ : Engine front



3. Install main bearings and thrust bearings using the following procedure:
CAUTION:
Be careful not to drop main bearing, and to scratch the surface.

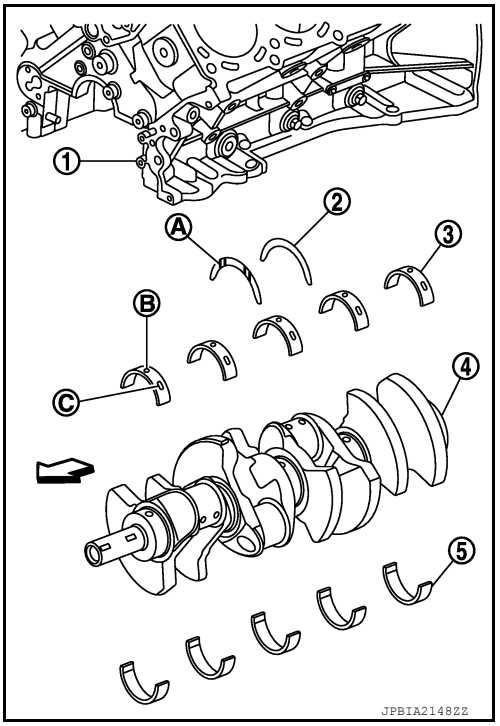
a. Remove dust, dirt, and engine oil on bearing mating surfaces of cylinder block and main bearing caps.

b. Install thrust bearings (2) to both sides of the No. 3 journal housing on cylinder block (1).

(3) : Main bearing (upper) (cylinder block side)
(4) : Crankshaft
(5) : Main bearing (lower) (main bearing cap side)
⇦ : Engine front

- Install thrust bearings with the oil groove (A) facing crankshaft arm (outside).

c. Install main bearings paying attention to the direction.
- Main bearing with oil hole (B) and groove (C) goes on cylinder block. The one without them goes on main bearing cap.
- Before installing main bearings, apply engine oil to the bearing surface (inside). Do not apply engine oil to the back surface, but thoroughly clean it.
- When installing, align main bearing stopper protrusion to cut-out of cylinder block and main bearing.
- Ensure the oil holes on cylinder block and those on the corresponding bearing are aligned.



4. Install crankshaft to cylinder block.
- While turning crankshaft by hand, check that it turns smoothly.

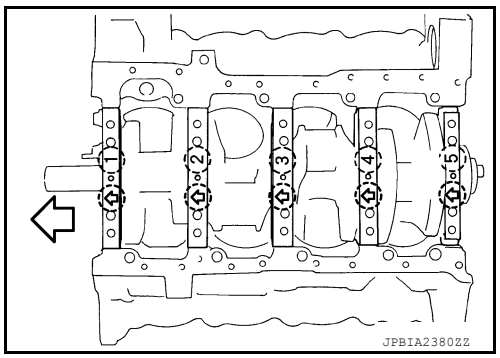
5. Install main bearing caps as per the following:

- Align the identification number to the journal position to install.

⇦ : Engine front

- Install it with the front mark (indicated by stamping) facing the front of engine.
- Using a suitable tool, tap them lightly to seat them on the installation position.

NOTE:
Main bearing cap cannot be replaced as a single parts, because it is machined together with cylinder block.



6. Install each main bearing cap bolts as per the following:

CAUTION:
If main bearing cap bolts and sub bolts are re-used, check their outer diameters before installation. Refer to EM-137, "Inspection".

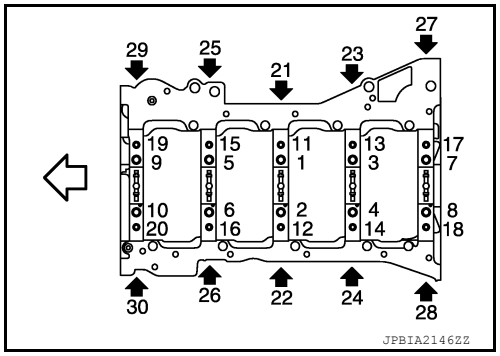
a. Apply new engine oil to threads and seat surfaces of main bearing cap bolts and sub bolts.

b. Tighten all bolts in order of (No. 1 - 30) temporarily.

⇦ : Engine front

c.

	Bolts	
Step 1	**(1-10)**	**: 39.2 N·m (4.0 kg-m, 29 ft-lb)**
Step 2	**(11-20)**	**: 29.4 N·m (3.0 kg-m, 22 ft-lb)**
Step 3	**(1-10)**	**: Tighten 40°**
Step 4	**(11-20)**	**: Tighten 30°**
Step 5	**(21-30)**	**: 49.2 N·m (5.0 kg-m, 36 ft-lb)**



CAUTION:
Use Tool to check tightening angle. Do not make judgment by visual inspection.

Tool : KV10112100 (BT8653-A)

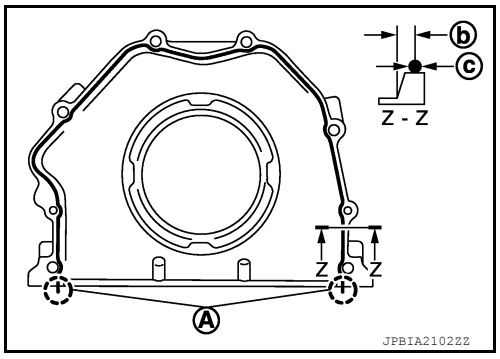
- After installing bolts, check that crankshaft can be rotated smoothly by hand.
- Check the crankshaft end play. Refer to EM-159, "Cylinder Block".

7. Install rear oil seal retainer.

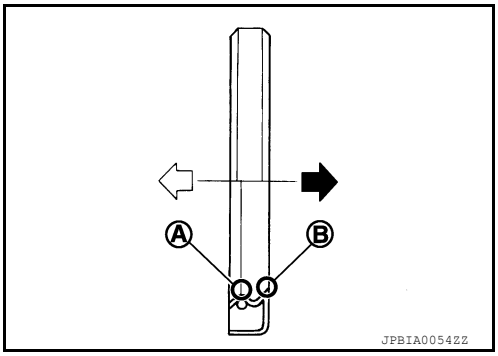
- Apply a continuous bead of liquid gasket with a suitable tool to rear oil seal retainer as shown in the figure.

(A) : Protrusion
(B) : 4.0 - 5.6 mm (0.157 - 0.220 in)
(C) : ϕ3.4 - 4.4 mm (0.134 - 0.173 in)

Use Genuine RTV silicone sealant or equivalent. Refer to GI-22, "Recommended Chemical Products and Sealants".



8. Install rear oil seal on rear oil seal retainer.



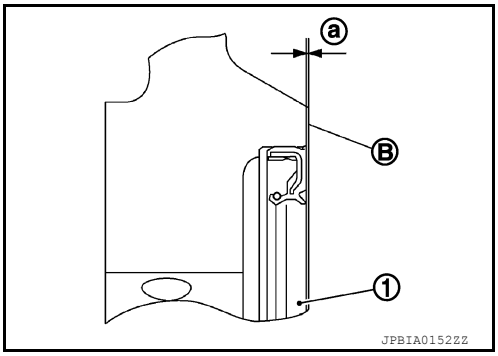
⇦ : Engine inside

⬅ : Engine outside

- Apply new engine oil to both oil seal lip (A) and dust seal lip (B).
- Install it so that each seal lip is oriented as shown in the figure.

CAUTION:
Be careful not to scratch or make burrs on circumference of oil seal.

- Press in rear oil seal (1) to the position as shown using a suitable tool.

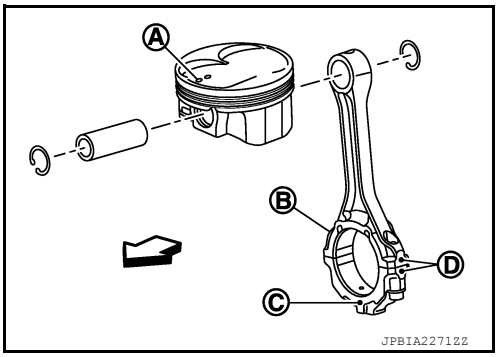


(A) : 0 - 0.5 mm (0 - 0.020 in)

(B) : Rear oil seal retainer rear end face

- Check the garter spring is in position and seal lips are not inverted.

9. Install piston to connecting rod as per the following:
   - Assemble so that the front mark (A) on the piston head and the cylinder number (D) on connecting rod are positioned as shown in the figure.



(B) : Oil hole

(C) : Front mark

⇦ : Engine front

a. Using a suitable tool, install new snap ring to the groove of piston rear side.
   - Insert it fully into groove to install.

CAUTION:
Do not reuse snap rings.

b. Install piston to connecting rod.
   - Using a suitable tool, heat piston until piston pin can be pushed in by hand without excess force [approximately 60 to 70°C (140 to 158°F)]. From the front to the rear, insert piston pin into piston and connecting rod.

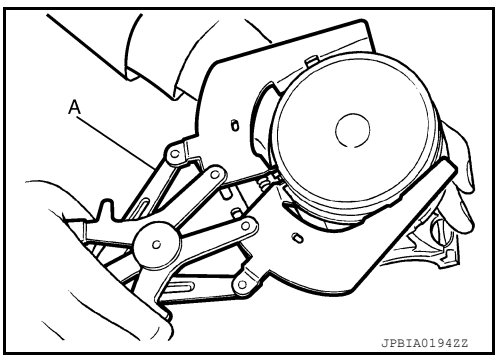
c. Install new snap ring to the groove of the piston front side.
   - Insert it fully into groove to install.

CAUTION:
Do not reuse snap rings.

   - After installing, check that connecting rod moves smoothly.

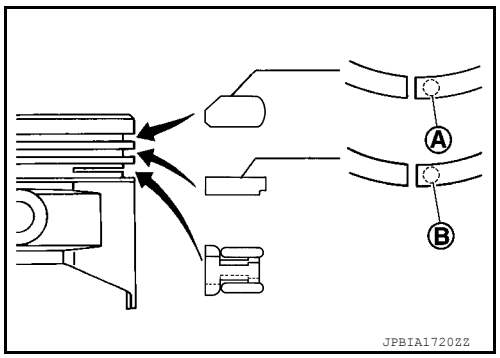
10. Using a suitable tool (A), install piston rings.

CAUTION:
- **When installing piston rings, be careful not to damage piston.**
- **Be careful not to damage piston rings by expending them excessively.**



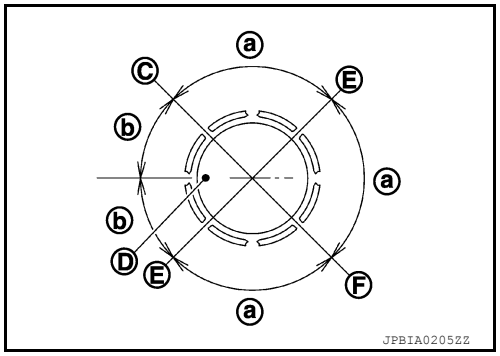
- If there is stamped mark on ring, mount it with marked side up.

Stamped mark:
Top ring (A) : 1 K
Second ring (B) : 2 K



- Position each ring with the gap as shown in the figure referring to the piston front mark (D).

(A) : 90 degrees
(B) : 45 degrees
(C) : Top ring gap
(E) : Oil ring upper or lower rail gap (either of them)
(F) : Second ring and oil ring spacer gap



- Check the piston ring side clearance. Refer to EM-137, "Inspection".

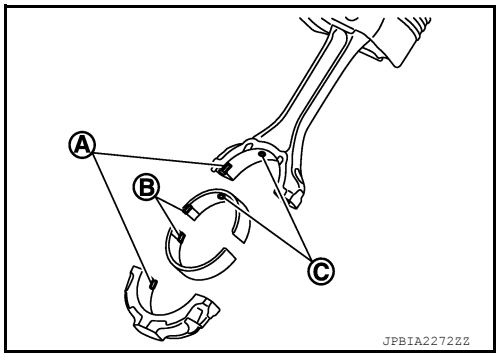
11. Install connecting rod bearings to connecting rod and connecting rod bearing cap.

CAUTION:
Be careful not to drop connecting rod bearing, and to scratch the surface.

- Before installing connecting rod bearings, apply engine oil to the bearing surface (inside).

WARNING:
Do not apply engine oil to connecting rod side of bearings.

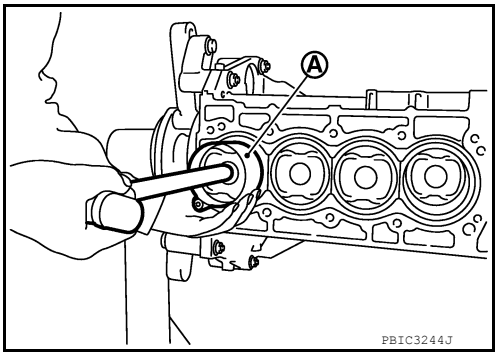
- Make sure connecting rod bearing to connecting rod bearing surface is free of debris.
- When installing, align connecting rod bearing stopper protrusion (B) with cutout (A) of connecting rods and connecting rod bearing caps to install.
- Ensure the oil hole (C) on connecting rod and that on the corresponding bearing are aligned.



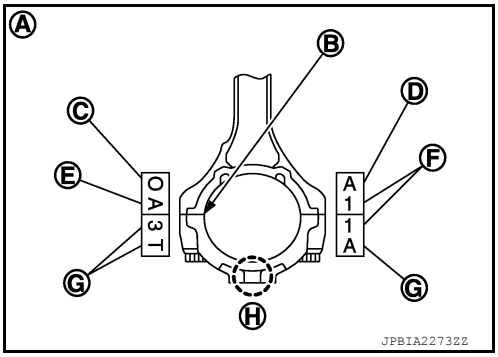
12. Install piston and connecting rod assembly to crankshaft.
- Position crankshaft pin corresponding to connecting rod to be installed onto the bottom dead center.
- Apply engine oil sufficiently to the cylinder bore, piston and crankshaft pin journal.
- Match the cylinder position with the cylinder number on connecting rod to install.
- Be sure that front mark on piston crown is facing the front of the engine.

- Using a suitable tool (A), install piston with the front mark on the piston crown facing the front of the engine.

CAUTION:
Be careful not to damage the cylinder wall and crankshaft pin, resulting from an interference of the connecting rod big end.



13. Install connecting rod bearing cap.
- Match the stamped cylinder number marks on connecting rod with those on connecting rod bearing cap to install.



(A) : Sample codes
(B) : Bearing stopper groove
(C) : Small-end diameter grade
(D) : Big-end diameter grade
(E) : Weight grade
(F) : Cylinder No.
(G) : Management code

- Be sure that front mark (H) on connecting rod bearing cap is facing the front of the engine.

14. Tighten connecting rod bolts as per the following:

a. Inspect the outer diameter of connecting rod bolt. Refer to EM-137, "Inspection".

b. Apply engine oil to the threads and seats of connecting rod bolts.

c. Tighten connecting rod bolts using the following procedure:

Step 1 : Tighten 29.4 N·m (3.0 kg-m, 21.7 ft-lb)
Step 2 : Loosen 0 N·m (0 kg-m, 0 ft-lb)
Step 3 : Tighten 19.6 N·m (2.0 kg-m, 14.5 ft-lb)
Step 4 : Tighten 90° +5°/-0°

CAUTION:
Always use Tool to check tightening angle. Do not make judgment by visual inspection.

Tool : KV10112100 (BT8653-A)

- After tightening connecting rod bolts, check that crankshaft rotates smoothly.
- Check the connecting rod side clearance. Refer to EM-137, "Inspection".

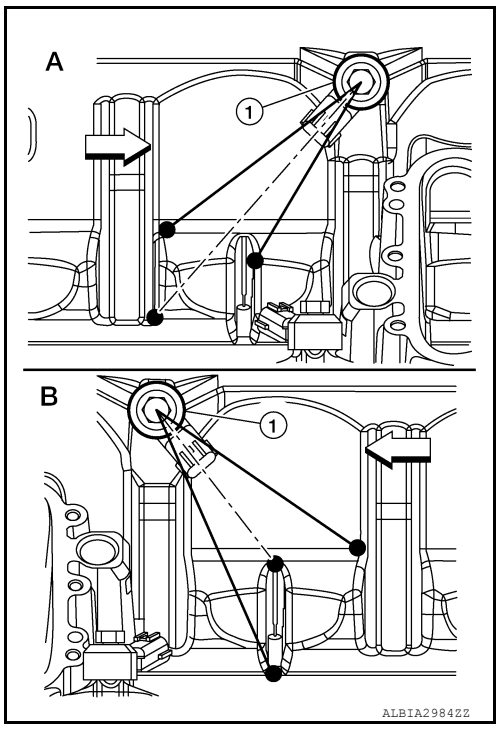
15. Install knock sensors (1).
    - Install knock sensors as shown.

      (A) : Bank 1
      (B) : Bank 2
      ⇦ : Engine front

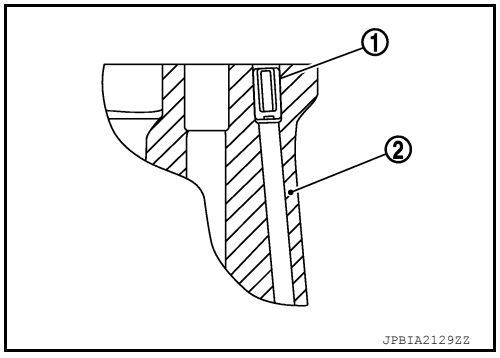
    - After installing knock sensor, connect harness connector and lay it out to front of the engine.

    CAUTION:
    - **Do not tighten bolts while holding connector.**
    - **If any impact by dropping is applied to knock sensor, replace it with new one.**

    NOTE:
    - Check that there is no foreign material on the cylinder block mating surface and the back surface of knock sensor.
    - Check that knock sensor does not interfere with other parts.



16. Install oil filter [for VVEL ladder assembly (1)] in the direction shown.
    NOTE:
    Check that oil filter does not protrude from upper surface of cylinder block (2) after installation.



17. Assembly of the remaining components is in the reverse order of disassembly.

Inspection

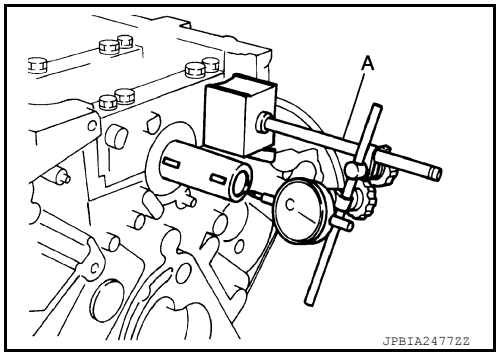
INFOID:0000000014418540

CRANKSHAFT END PLAY

- Measure the clearance between thrust bearings and crankshaft arm when crankshaft is moved fully forward or backward with a suitable tool (A).

  Standard and limit : Refer to EM-159, "Cylinder Block".

- If the measured value exceeds the limit, replace thrust bearings, and measure again. If it still exceeds the limit, replace crankshaft also.

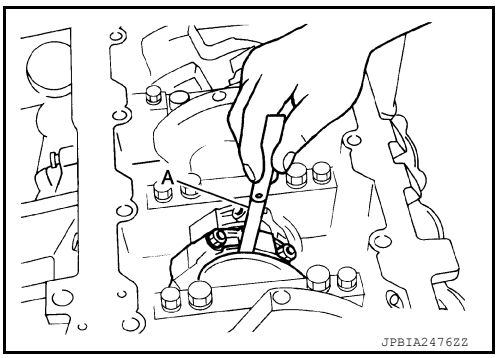


CONNECTING ROD SIDE CLEARANCE

- Measure the side clearance between connecting rod and crankshaft arm with a suitable tool (A).

Standard and limit : Refer to EM-159, "Cylinder Block".

- If the measured value exceeds the limit, replace connecting rod, and measure again. If it still exceeds the limit, replace crankshaft also.

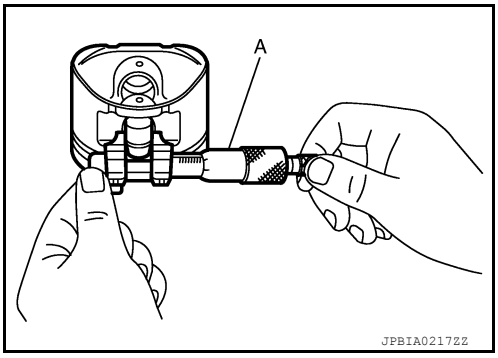


PISTON TO PISTON PIN OIL CLEARANCE

Piston Pin Hole Diameter

Measure the inner diameter of piston pin hole with a suitable tool (A).

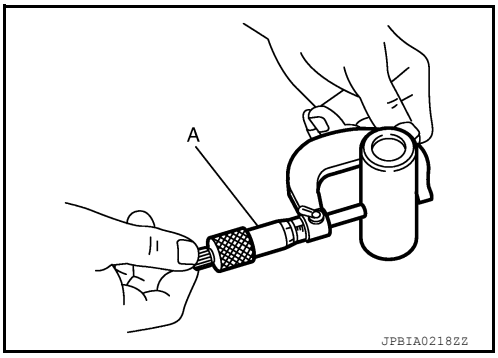
Standard : Refer to EM-159, "Cylinder Block".



Piston Pin Outer Diameter

Measure the outer diameter of piston pin with a suitable tool (A).

Standard : Refer to EM-159, "Cylinder Block".



Piston to Piston Pin Oil Clearance

(Piston to piston pin oil clearance) = (Piston pin hole diameter) – (Piston pin outer diameter)

Standard : Refer to EM-159, "Cylinder Block".

- If the calculated value is out of the standard, replace piston and piston pin assembly.
- When replacing piston and piston pin assembly, refer to EM-147, "Description".

NOTE:
Piston is available together with piston pin as assembly.

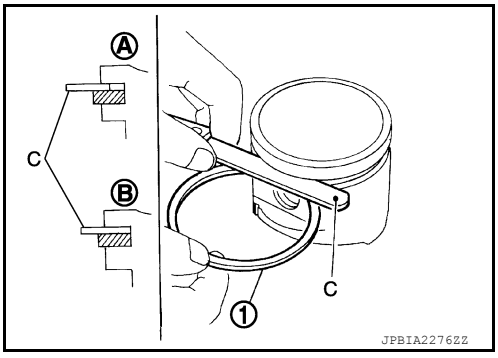
PISTON RING SIDE CLEARANCE

- Measure the side clearance of piston ring (1) and piston ring groove with a suitable tool (C).

(A) : OK
(B) : NG

Standard and limit : Refer to EM-159, "Cylinder Block".

- If the measured value exceeds the limit, replace piston ring, and measure again. If it still exceeds the limit, replace piston also.

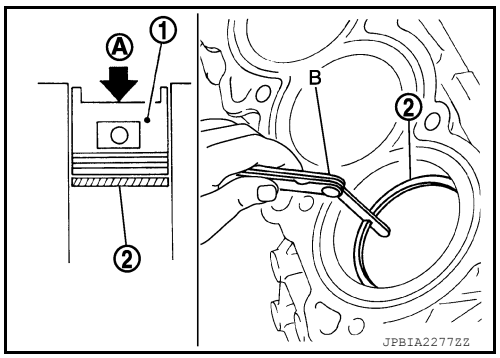


PISTON RING END GAP

- Check that the cylinder bore inner diameter is within the specification.
- Lubricate with new engine oil to piston (1) and piston ring (2), and then insert piston ring until middle of cylinder with piston and measure the piston ring end gap with a suitable tool (B).

(A) : Press-fit

Standard and limit : Refer to EM-159, "Cylinder Block".



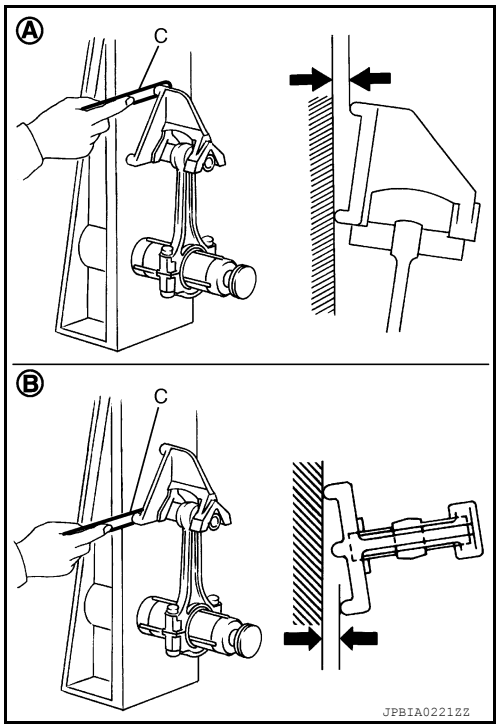
- If the measured value exceeds the limit, replace piston ring, and measure again. If it still exceeds the limit, re-bore cylinder and use oversize piston and piston rings.

CONNECTING ROD BEND AND TORSION

- Check with a connecting rod aligner.

(A) : Bend
(B) : Torsion
(C) : Suitable tool

Bend limit : Refer to EM-159, "Cylinder Block".
Torsion limit

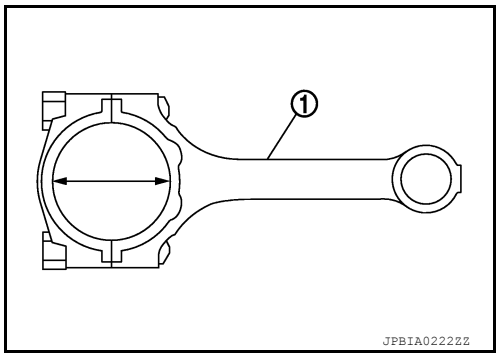


- If it exceeds the limit, replace connecting rod assembly.

CONNECTING ROD BIG END DIAMETER

- Install connecting rod bearing cap without installing connecting rod bearing, and tighten connecting rod bolts to the specified torque. Refer to EM-129, "Disassembly and Assembly" for the tightening procedure.

(1) : Connecting rod



- Measure the inner diameter of connecting rod big end with a suitable tool.

Standard : Refer to EM-159, "Cylinder Block".

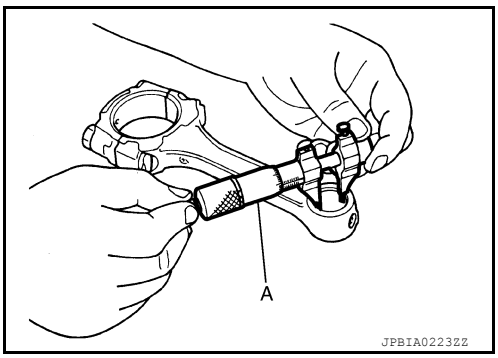
- If out of the standard, replace connecting rod assembly.

CONNECTING ROD BUSHING OIL CLEARANCE

Connecting Rod Bushing Inner Diameter

Measure the inner diameter of connecting rod bushing with a suitable tool (A).

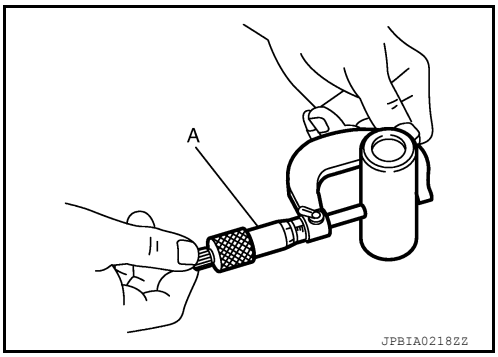
Standard : Refer to EM-159, "Cylinder Block".



Piston Pin Outer Diameter

Measure the outer diameter of piston pin with a suitable tool (A).

Standard : Refer to EM-159, "Cylinder Block".



Connecting Rod Bushing Oil Clearance

(Connecting rod bushing oil clearance) = (Connecting rod bushing inner diameter) – (Piston pin outer diameter)

Standard and limit : Refer to EM-159, "Cylinder Block".

- If the calculated value exceeds the limit, replace connecting rod assembly and/or piston and piston pin assembly.
- If replacing piston and piston pin assembly, refer to EM-147, "Description".
- If replacing connecting rod assembly, refer to EM-148, "Connecting Rod Bearing" to select the connecting rod bearing.

CYLINDER BLOCK DISTORTION

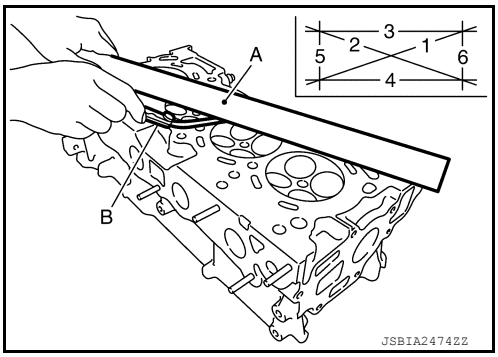
- Using a suitable tool, remove gasket on the cylinder block surface, and also remove engine oil, scale, carbon, or other contamination.

  CAUTION:

  Be careful not to allow gasket flakes to enter engine oil or engine coolant passages.
- Measure for distortion at the six locations shown in the illustration using a straight edge (A) and suitable tool (B).

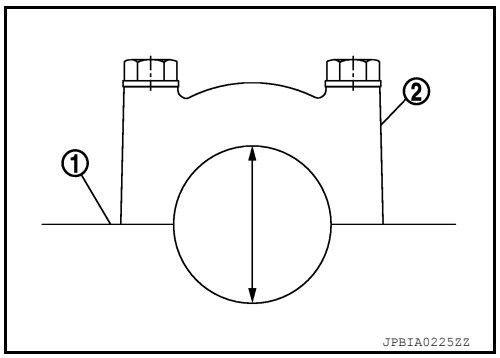
Limit : Refer to EM-159, "Cylinder Block".

- If it exceeds the limit, replace cylinder block.



MAIN BEARING HOUSING INNER DIAMETER

- Install main bearing cap (2) without installing main bearings, and tighten main bearing cap bolts to the specified torque. Refer to EM-129, "Disassembly and Assembly" for the tightening procedure.
- Measure the inner diameter of main bearing housing with a suitable tool.



Standard : Refer to EM-159, "Cylinder Block".

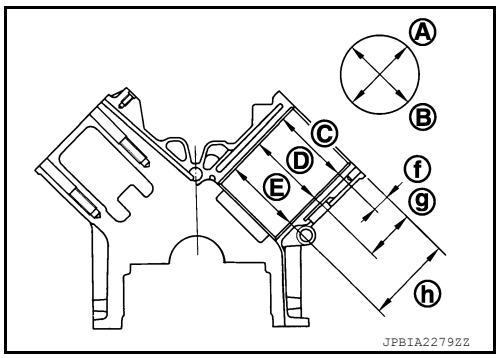
- If out of the standard, replace cylinder block (1) and main bearing cap as assembly.

NOTE:
Cylinder block cannot be replaced as a single part, because it is machined together with main bearing cap.

PISTON TO CYLINDER BORE CLEARANCE

Cylinder Bore inner Diameter

- Using a bore gauge, measure cylinder bore for wear, out-of-round and taper at six different points on each cylinder. [(A) and (B) directions at (C), (D) and (E)] is in longitudinal direction of engine.



(F) : 10 mm (0.39 in)
(G) : 60 mm (2.36 in)
(H) : 120 mm (4.72 in)

Wear limit:
Out-of-round (Difference between “A” and “B”): Refer to EM-159, "Cylinder Block".
Taper limit (Difference between “C” and “E”):

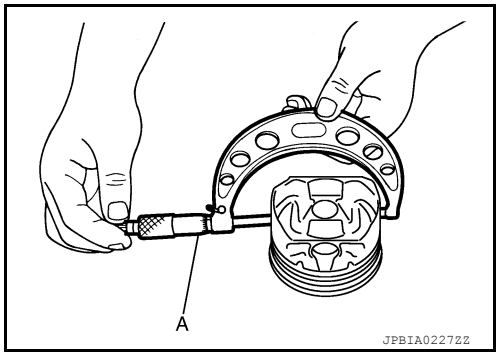
- If the measured value exceeds the limit, or if there are scratches and/or seizure on the cylinder inner wall, hone or re-bore the inner wall.
- Oversize piston is provided. When using oversize piston, re-bore cylinder so that the clearance of the piston-to-cylinder bore satisfies the standard.

CAUTION:
When using oversize piston, use oversize pistons for all cylinders with oversize piston rings.

Oversize (O/S) : 0.2 mm (0.008 in)

Piston Skirt Diameter

Measure the outer diameter of piston skirt with a suitable tool (A).

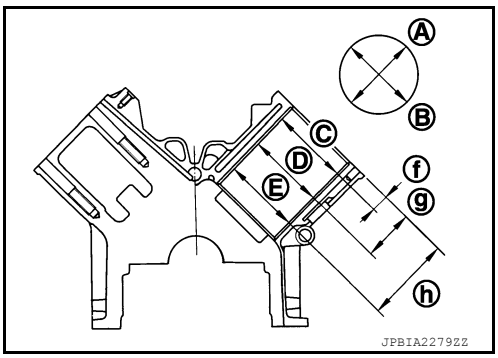


Measure point
Standard : Refer to EM-159, "Cylinder Block".

Piston-to-Cylinder Bore Clearance

Calculate by piston skirt diameter and cylinder bore inner diameter [direction (B), position (D)].

(A) : Longitudinal direction
(C) : Top position
(E) : Bottom position
(F) : 10 mm (0.39 in)
(G) : 60 mm (2.36 in)
(H) : 120 mm (4.72 in)



(Clearance) = (Cylinder bore inner diameter) – (Piston skirt diameter).

Standard and limit : Refer to EM-159, "Cylinder Block".

- If the calculated value exceeds the limit, replace piston and piston pin assembly. Refer to EM-159, "Cylinder Block".

Re-boring Cylinder Bore

1. Cylinder bore size is determined by adding piston to cylinder bore clearance to piston skirt diameter.

Re-bored size calculation: D = A + B – C

where,

D: Bored diameter

A: Piston skirt diameter as measured

B: Piston to cylinder bore clearance (standard value)

C: Honing allowance 0.02 mm (0.0008 in)

2. Install main bearing cap, and tighten to the specified torque. Otherwise, cylinder bores may be distorted in final assembly.
3. Cut cylinder bores.
   NOTE:
   - When any cylinder needs boring, all other cylinders must also be bored.
   - Do not cut too much out of cylinder bore at a time. Cut only 0.05 mm (0.0020 in) or so in diameter at a time.
4. Hone cylinders to obtain the specified piston to cylinder bore clearance.
5. Measure finished cylinder bore for the out-of-round and taper.
   NOTE:
   Perform measurement after cylinder bore cools down.

CRANKSHAFT MAIN JOURNAL DIAMETER

- Measure the outer diameter of crankshaft main journals with a suitable tool.

Standard : Refer to EM-159, "Cylinder Block".

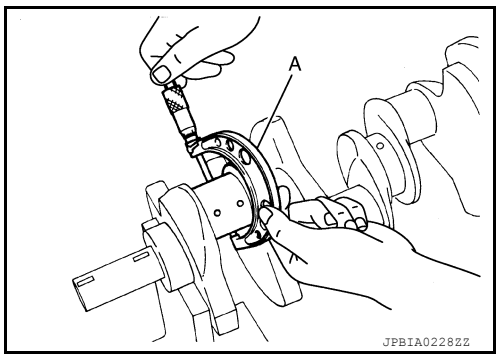
- If out of the standard, measure the main bearing oil clearance. Then use undersize bearing. Refer to EM-150, "Main Bearing".

CRANKSHAFT PIN JOURNAL DIAMETER

- Measure the outer diameter of crankshaft pin journal with a suitable tool (A).

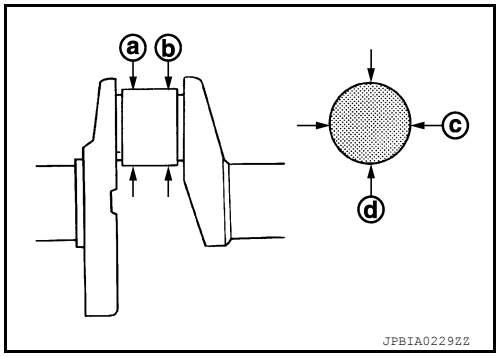
Standard : Refer to EM-159, "Cylinder Block".

- If out of the standard, measure the connecting rod bearing oil clearance. Then use undersize bearing. Refer to EM-148, "Connecting Rod Bearing".



CRANKSHAFT OUT-OF-ROUND AND TAPER

- Measure the dimensions at four different points as shown in the figure on each main journal and pin journal with a micrometer.
- Out-of-round is indicated by the difference in the dimensions between (d) and (c) at (a) and (b).
- Taper is indicated by the difference in the dimensions between.



Out-of-round (Difference between “c” and “d”)
Taper (Difference between “a”and “b”) : Refer to EM-159, "Cylinder Block".

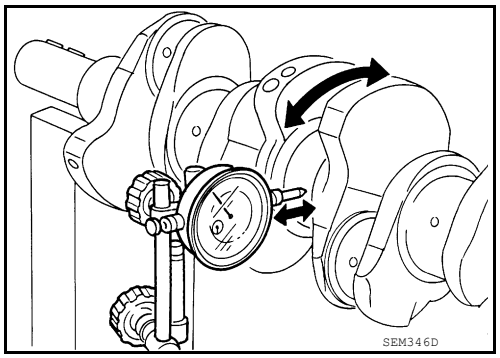
- If the measured value exceeds the limit, correct or replace crankshaft.
- If corrected, measure the bearing oil clearance of the corrected main journal and/or pin journal. Then select the main bearing and/or connecting rod bearing. Refer to EM-150, "Main Bearing" and/or EM-148, "Connecting Rod Bearing".

CRANKSHAFT RUNOUT

- Place V-block on precise flat table, and support the journals on both ends of crankshaft.
- Place a suitable tool straight up on the No. 3 journal.
- While rotating crankshaft, read the movement of the suitable tool. (Total indicator reading)

Standard and limit : Refer to EM-159, "Cylinder Block".

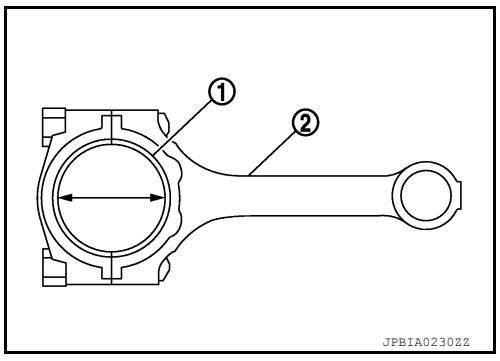
- If it exceeds the limit, replace crankshaft.



CONNECTING ROD BEARING OIL CLEARANCE

Method by Calculation

- Install connecting rod bearings (1) to connecting rod (2) and connecting rod cap, and tighten connecting rod bolts to the specified torque. Refer to EM-129, "Disassembly and Assembly" for the tightening procedure.

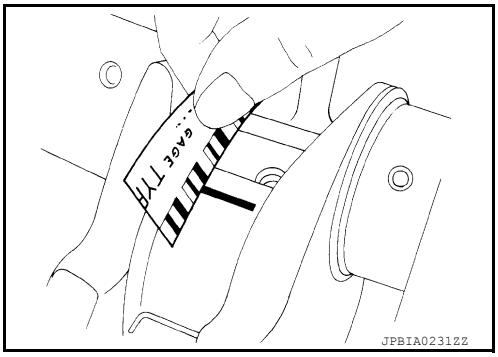


• Measure the inner diameter of connecting rod bearing with a suitable tool.
(Oil clearance) = (Connecting rod bearing inner diameter) – (Crankshaft pin journal diameter)

Standard and limit : Refer to EM-164, "Connecting Rod Bearing".

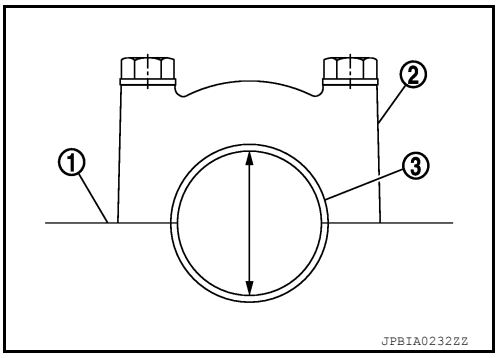
• If the calculated value exceeds the limit, select proper connecting rod bearing according to connecting rod big end diameter and crankshaft pin journal diameter to obtain the specified bearing oil clearance. Refer to EM-147, "Description".

Method of Using Plastigage
• Remove oil and dust on crankshaft pin journal and the surfaces of each bearing completely.
• Cut a plastigage slightly shorter than the bearing width, and place it in crankshaft axial direction, avoiding oil holes.
• Install connecting rod bearings to connecting rod and connecting rod bearing cap, and tighten connecting rod bolts to the specified torque. Refer to EM-129, "Disassembly and Assembly" for the tightening procedure.
CAUTION:
Never rotate crankshaft.
• Remove connecting rod bearing cap and bearings, and using the scale on the plastigage bag, measure the plastigage width.
NOTE:
The procedure when the measured value exceeds the limit is the same as that described in the “Method by Calculation”.



MAIN BEARING OIL CLEARANCE

Method by Calculation
• Install main bearings (3) to cylinder block (1) and main bearing cap (2), and tighten main bearing cap bolts to the specified torque. Refer to EM-129, "Disassembly and Assembly" for the tightening procedure.
• Measure the inner diameter of main bearing with a bore gauge.
(Oil clearance) = (Main bearing inner diameter) – (Crankshaft main journal diameter)

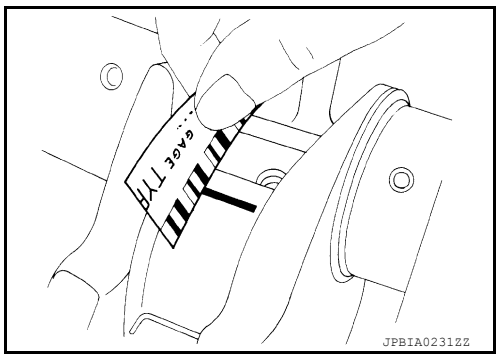


Standard and limit : Refer to EM-163, "Main Bearing".

• If the calculated value exceeds the limit, select proper main bearing according to main bearing inner diameter and crankshaft main journal diameter to obtain the specified bearing oil clearance. Refer to EM-147, "Description".

Method of Using Plastigage
• Remove engine oil and dust on crankshaft journal and the surfaces of each bearing completely.
• Cut a plastigage slightly shorter than the bearing width, and place it in crankshaft axial direction, avoiding oil holes.
• Install main bearing to cylinder block and main bearing cap, and tighten main bearing cap bolts with main bearing cap to the specified torque. Refer to EM-129, "Disassembly and Assembly" for the tightening procedure.
CAUTION:
Never rotate crankshaft.

- Remove main bearing cap and bearings, and using the scale on the plastigage bag, measure the plastigage width.
  NOTE:
  The procedure when the measured value exceeds the limit is the same as that described in the “Method by Calculation”.



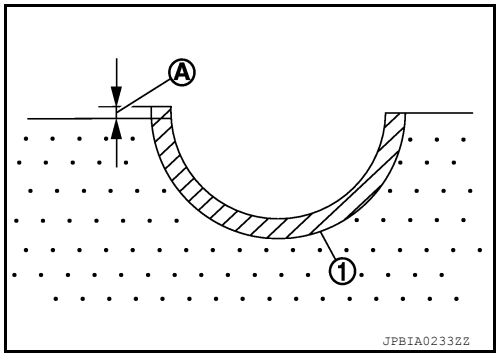
MAIN BEARING CRUSH HEIGHT

- When main bearing cap is removed after being tightened to the specified torque with main bearings (1) installed, the tip end of bearing must protrude. Refer to EM-129, "Disassembly and Assembly" for the tightening procedure.

  (A) : Crush height

  Standard : There must be crush height.

- If the standard is not met, replace main bearings.



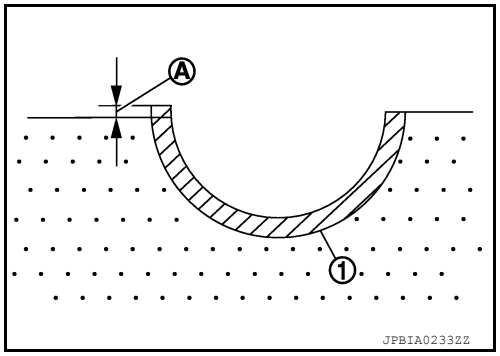
CONNECTING ROD BEARING CRUSH HEIGHT

- When connecting rod bearing cap is removed after being tightened to the specified torque with connecting rod bearings (1) installed, the tip end of bearing must protrude. Refer to EM-129, "Disassembly and Assembly" for the tightening procedure.

  (A) : Crush height

  Standard : There must be crush height.

- If the standard is not met, replace connecting rod bearings.



MAIN BEARING CAP BOLT OUTER DIAMETER

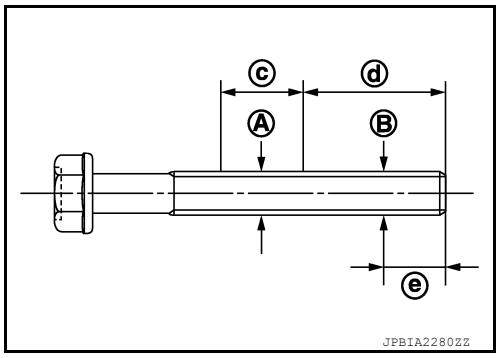
- Measure the outer diameters (A), (B) at two positions as shown in the figure.

  (C) : 20 mm (0.79 in)
  (D) : 55 mm (2.17 in)
  (E) : 12 mm (0.47 in)

- If reduction appears in (A) range, regard it (B).

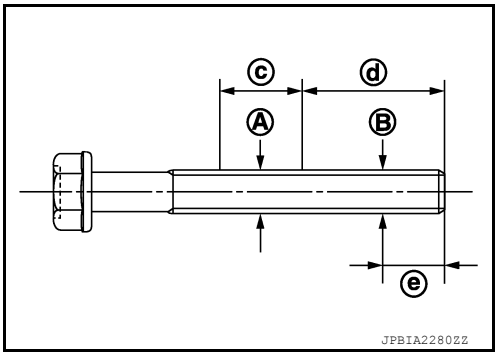
  Limit [(B) – (A)] : 0.15 mm (0.0059 in)

- If it exceeds the limit (large difference in dimensions), replace main bearing cap bolts with new one.



MAIN BEARING CAP SUB BOLT OUTER DIAMETER

- Measure the outer diameters (A), (B) at two positions as shown in the figure.



(C) : 20 mm (0.79 in)
(D) : 15 mm (0.59 in)
(E) : 9 mm (0.35 in)

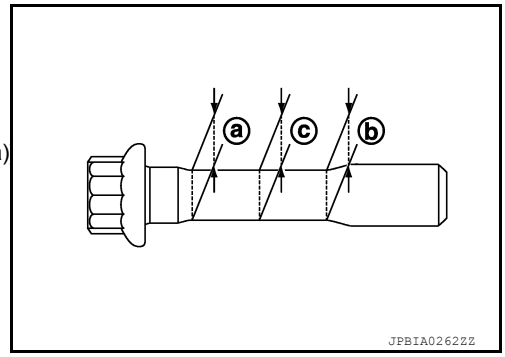
- If reduction appears in (A) range, regard it (B).

Limit [(B) – (A)] : 0.10 mm (0.0039 in)

- If it exceeds the limit (large difference in dimensions), replace main bearing cap sub bolts with new one.

CONNECTING ROD BOLT OUTER DIAMETER

1. Measure the outer diameters [(a), (b) and (c)] at the position shown in the figure.



(A) : Value at the end of the smaller diameter of the bolt
(B) : Value at the end of the smaller diameter of the bolt [opposite side of (a)]
(C) : Value of the smallest diameter of the smaller of the bolt

2. Obtain a mean value (d) of (a) and (b).
3. Subtract (c) from (d).

Limit [(d) – (c)] : 0.09 mm (0.0035 in)

4. If it exceeds the limit (large difference in dimensions), replace the bolt with new one.

HOW TO SELECT PISTON AND BEARING

Description

INFOID:0000000014418541

Selection points	Selection parts	Selection items	Selection methods
Between cylinder block and crankshaft	Main bearing	Main bearing grade (bearing thickness)	Determined by match of cylinder block bearing housing grade (inner diameter of housing) and crankshaft journal grade (outer diameter of journal)
Between crankshaft and connecting rod	Connecting rod bearing	Connecting rod bearing grade (bearing thickness)	Determined by match of connecting rod big end diameter grade (inner diameter of housing) and crankshaft pin outer diameter.
Between cylinder block and piston	Piston and piston pin assembly (Piston is available together with piston pin as assembly.)	Piston grade (piston skirt diameter)	Piston grade = cylinder bore grade (inner diameter of bore)

- The identification grade stamped on each part is the grade for the dimension measured in new condition. This grade cannot apply to reused parts.
- For reused or repaired parts, measure the dimension accurately. Determine the grade by comparing the measurement with the values of each selection table.
- For details of the measurement method of each part, the reuse standards and the selection method of the selective fitting parts, refer to the text.

Piston

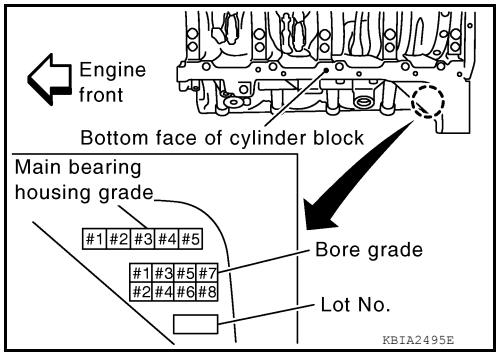
INFOID:0000000014418542

WHEN NEW CYLINDER BLOCK IS USED

Check the cylinder bore grade on the bottom face of the cylinder block, and select the piston of the same grade.

NOTE:

Piston is available with piston pin as a set for the service part.

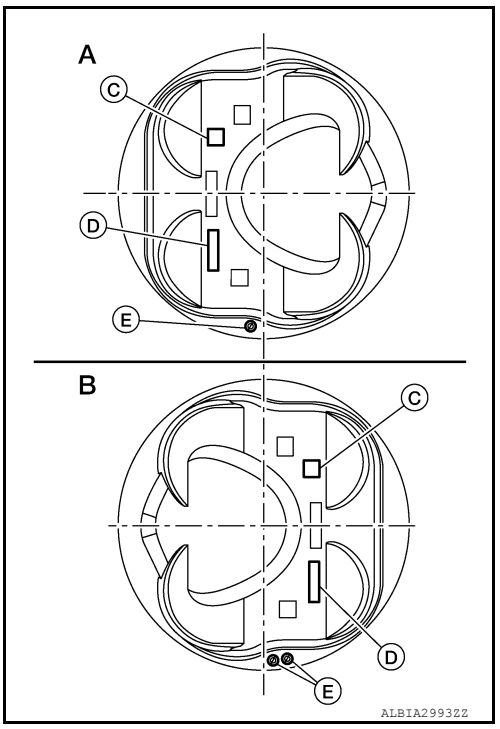


WHEN CYLINDER BLOCK IS REUSED

1. Measure the cylinder bore inner diameter. Refer to EM-159, "Cylinder Block".

2. Determine the bore grade by comparing the measurement with the values under the cylinder bore inner diameter of the “PISTON SELECTION TABLE”.

   (A) : Bank 2
   (B) : Bank 1
   (C) : Piston grade
   (D) : Identification code
   (E) : Front mark



3. Select piston of the same grade.

PISTON SELECTION TABLE

Unit: mm (in)

Grade	1	2	3
Cylinder bore inner diameter	98.000 - 98.010 (3.8583 - 3.8587)	98.010 - 98.020 (3.8587 - 3.8590)	98.020 - 98.030 (3.8590 - 3.8594)
Piston skirt diameter	97.980 - 97.990 (3.8575 - 3.8579)	97.990 - 98.000 (3.8579 - 3.8583)	98.000 - 98.010 (3.8583 - 3.8587)

NOTE:
Piston is available together with piston pin as assembly.

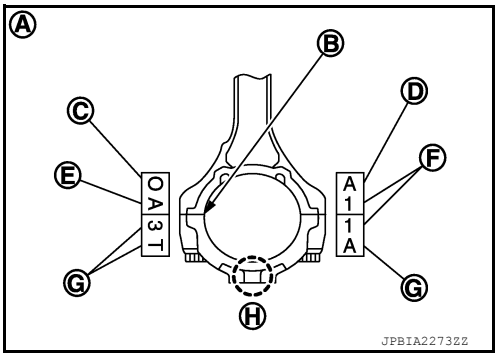
Connecting Rod Bearing

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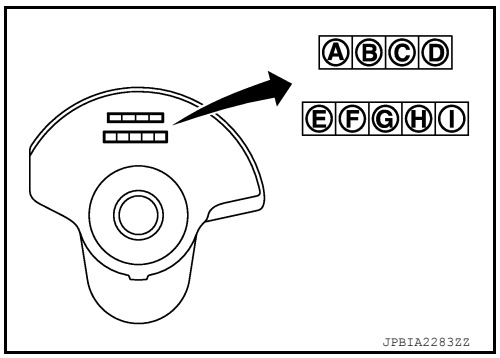
WHEN NEW CONNECTING ROD AND CRANKSHAFT ARE USED

1. Apply connecting rod big end diameter grade stamped (D) on connecting rod side face to the row in the “CONNECTING ROD BEARING SELECTION TABLE”.

   A : Sample codes
   B : Bearing stopper groove
   C : Small-end diameter grade
   E : Weight grade
   F : Cylinder No.
   G : Management code
   H : Front mark



2. Apply crankshaft pin journal diameter grade stamped on crankshaft front side to the column in the “CONNECTING ROD BEARING SELECTION TABLE”.



A : Pin diameter grade No. 1
B : Pin diameter grade No. 2
C : Pin diameter grade No. 3
D : Pin diameter grade No. 4
E : Journal diameter grade No. 1
F : Journal diameter grade No. 2
G : Journal diameter grade No. 3
H : Journal diameter grade No. 4
I : Journal diameter grade No. 5

3. Read the symbol at the cross point of selected row and column in the “CONNECTING ROD BEARING SELECTION TABLE”.
4. Apply the symbol obtained to the “CONNECTING ROD BEARING GRADE TABLE” to select connecting rod bearing.

WHEN CONNECTING ROD AND CRANKSHAFT ARE REUSED

1. Measure connecting rod big end diameter and crankshaft pin journal diameter. Refer to EM-137, "Inspection".
2. Correspond the measured dimension in connecting rod big end diameter row of “CONNECTING ROD BEARING SELECTION TABLE”.
3. Correspond the measured dimension in crankshaft pin journal diameter column of “CONNECTING ROD BEARING SELECTION TABLE”.
4. Follow from step 3 in “WHEN NEW CONNECTING ROD AND CRANKSHAFT ARE USED”.

CONNECTING ROD BEARING SELECTION TABLE

Crankshaft pin outer diameter: Mark	Crankshaft pin outer diameter: Outer diameter Unit: mm (in)	Connecting rod big end. inner diameter: Mark	Inner diameter Unit: mm (in)													
		A	B	C	D	E	F	G	H	J	K	L	M	N
		57.000 – 57.001 (2.2441 – 2.2441)	57.001 – 57.002 (2.2441 – 2.2442)	57.002 – 57.003 (2.2442 – 2.2442)	57.003 – 57.004 (2.2442 – 2.2443)	57.004 – 57.005 (2.2443 – 2.2443)	57.005 – 57.006 (2.2443 – 2.2443)	57.006 – 57.007 (2.2443 – 2.2444)	57.007 – 57.008 (2.2444 – 2.2444)	57.008 – 57.009 (2.2444 – 2.2444)	57.009 – 57.010 (2.2444 – 2.2445)	57.010 – 57.011 (2.2445 – 2.2445)	57.011 – 57.012 (2.2445 – 2.2446)	57.012 – 57.013 (2.2446 – 2.2446)
0	53.968 – 53.974 (2.1247 – 2.1250)	1	1	1	1	1	1	2	2	2	2	2	2	3
1	53.962 – 53.968 (2.1245 – 2.1247)	2	2	2	2	2	2	3	3	3	3	3	3	4
2	53.956 – 53.962 (2.1243 – 2.1245)	3	3	3	3	3	3	4	4	4	4	4	4	4

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CONNECTING ROD BEARING GRADE TABLE

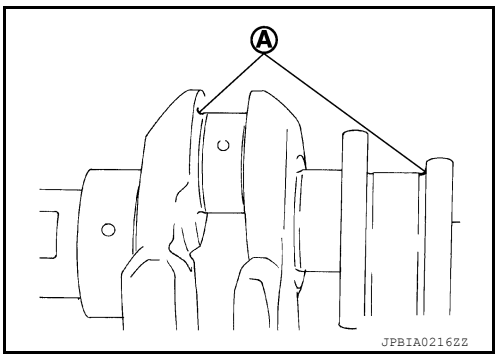
Connecting rod bearing grade table : Refer to EM-164, "Connecting Rod Bearing".

UNDERSIZE BEARING USAGE GUIDE

- When the specified connecting rod bearing oil clearance is not obtained with standard size connecting rod bearings, use undersize (US) bearings.
- When using undersize (US) bearing, measure the connecting rod bearing inner diameter with bearing installed, and grind crankshaft pin so that the connecting rod bearing oil clearance satisfies the standard.

CAUTION:

In grinding crankshaft pin to use undersize bearings, keep the fillet R (A) [1.5 - 1.7 mm (0.059 - 0.067 in)].



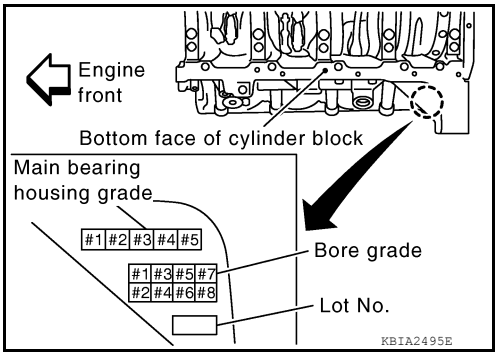
Bearing undersize table : Refer to EM-164, "Connecting Rod Bearing".

Main Bearing

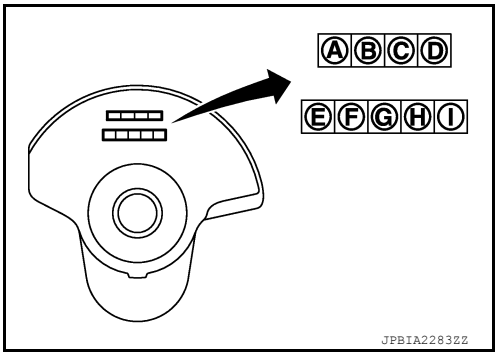
INFOID:0000000014418544

WHEN NEW CYLINDER BLOCK AND CRANKSHAFT ARE USED

1. Apply the main bearing housing grade on the bottom face of the cylinder block to the row in “MAIN BEARING SELECTION TABLE”.



2. “MAIN BEARING SELECTION TABLE” columns correspond to journal diameter grade on front side of crankshaft.



A : Pin diameter grade No. 1
B : Pin diameter grade No. 2
C : Pin diameter grade No. 3
D : Pin diameter grade No. 4
E : Journal diameter grade No. 1
F : Journal diameter grade No. 2
G : Journal diameter grade No. 3
H : Journal diameter grade No. 4
I : Journal diameter grade No. 5

3. Select main bearing grade at the point where selected row and column meet in “MAIN BEARING SELECTION TABLE”.
CAUTION:
- **Initial clearance for No. 1, 5 journal and No. 2, 3, 4 journal is different. Use two different selection table for each part.**
- **No. 1, 5 journal and No. 2, 3, 4 journal have the same signs but different measures. Never confuse.**

4. Apply sign at crossing in above step 3 to “MAIN BEARING GRADE TABLE”.
NOTE:
- “MAIN BEARING GRADE TABLE” applies to all journals.
- Service parts are available as a set of both upper and lower.

WHEN CYLINDER BLOCK AND CRANKSHAFT ARE REUSED

1. Measure cylinder block main bearing housing inner diameter and crankshaft main journal diameter. Refer to EM-137, "Inspection".

2. Correspond the measured dimension in “Cylinder block main bearing housing inner diameter” row of “MAIN BEARING SELECTION TABLE”.
3. Correspond the measured dimension in “Crankshaft main journal diameter” column of “MAIN BEARING SELECTION TABLE”.
4. Follow from step 3 in “When New Cylinder Block and Crankshaft are Used”.

MAIN BEARING SELECTION TABLE (No. 1 and 5 Journal)

Cylinder block main bearing housing inner diameter / Crankshaft main journal diameter		I.D. mark	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	4	7
		Hole diameter Unit: mm (in)	68.944 - 68.945 (2.7143 - 2.7144)	68.945 - 68.946 (2.7144 - 2.7144)	68.946 - 68.947 (2.7144 - 2.7144)	68.947 - 68.948 (2.7144 - 2.7145)	68.948 - 68.949 (2.7145 - 2.7145)	68.949 - 68.950 (2.7145 - 2.7146)	68.950 - 68.951 (2.7146 - 2.7146)	68.951 - 68.952 (2.7146 - 2.7146)	68.952 - 68.953 (2.7146 - 2.7147)	68.953 - 68.954 (2.7147 - 2.7147)	68.954 - 68.955 (2.7147 - 2.7148)	68.955 - 68.956 (2.7148 - 2.7148)	68.956 - 68.957 (2.7148 - 2.7148)	68.957 - 68.958 (2.7148 - 2.7149)	68.958 - 68.959 (2.7149 - 2.7149)	68.959 - 68.960 (2.7149 - 2.7150)	68.960 - 68.961 (2.7150 - 2.7150)	68.961 - 68.962 (2.7150 - 2.7150)	68.962 - 68.963 (2.7150 - 2.7151)	68.963 - 68.964 (2.7151 - 2.7151)	68.964 - 68.965 (2.7151 - 2.7152)	68.965 - 68.966 (2.7152 - 2.7152)	68.966 - 68.967 (2.7152 - 2.7152)	68.967 - 68.968 (2.7152 - 2.7153)
I.D. mark	Axle diameter Unit: mm (in)																									
G	63.964 - 63.963 (2.5183 - 2.5182)		1	1	12	12	12	2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5
H	63.963 - 63.962 (2.5182 - 2.5182)		1	12	12	12	2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5
J	63.962 - 63.961 (2.5182 - 2.5181)		12	12	12	2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5
K	63.961 - 63.960 (2.5181 - 2.5181)		12	12	2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56
L	63.960 - 63.959 (2.5181 - 2.5181)		12	2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56
M	63.959 - 63.958 (2.5181 - 2.5180)		2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56
N	63.958 - 63.957 (2.5180 - 2.5180)		2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6
P	63.957 - 63.956 (2.5180 - 2.5179)		2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6
R	63.956 - 63.955 (2.5179 - 2.5179)		23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6
S	63.955 - 63.954 (2.5179 - 2.5179)		23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67
T	63.954 - 63.953 (2.5179 - 2.5178)		23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67
U	63.953 - 63.952 (2.5178 - 2.5178)		3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67
V	63.952 - 63.951 (2.5178 - 2.5178)		3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7
W	63.951 - 63.950 (2.5178 - 2.5177)		3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7	7
X	63.950 - 63.949 (2.5177 - 2.5177)		34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7	7	7
Y	63.949 - 63.948 (2.5177 - 2.5176)		34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7	7	7	78
1	63.948 - 63.947 (2.5176 - 2.5176)		34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7	7	7	78	78
2	63.947 - 63.946 (2.5176 - 2.5176)		4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7	7	7	78	78	78
3	63.946 - 63.945 (2.5176 - 2.5175)		4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7	7	7	78	78	78	8
4	63.945 - 63.944 (2.5175 - 2.5175)		4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7	7	7	78	78	78	8	8
5	63.944 - 63.943 (2.5175 - 2.5174)		45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7	7	7	78	78	78	8	8	8
6	63.943 - 63.942 (2.5174 - 2.5174)		45	45	5	5	5	56	56	56	6	6	6	67	67	67	7	7	7	78	78	78	8	8	8	X
7	63.942 - 63.941 (2.5174 - 2.5174)		45	5	5	5	56	56	56	6	6	6	67	67	67	7	7	7	78	78	78	8	8	8	X	X
9	63.941 - 63.940 (2.5174 - 2.5173)		5	5	5	56	56	56	6	6	6	67	67	67	7	7	7	78	78	78	8	8	8	X	X	X

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MAIN BEARING SELECTION TABLE (No. 2, 3 and 4 Journal)

Cylinder block main bearing housing inner diameter / Crankshaft main journal diameter		I.D. mark	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	4	7
		Hole diameter Unit: mm (in)	68.944 - 68.945 (2.7143 - 2.7144)	68.945 - 68.946 (2.7144 - 2.7144)	68.946 - 68.947 (2.7144 - 2.7144)	68.947 - 68.948 (2.7144 - 2.7145)	68.948 - 68.949 (2.7145 - 2.7145)	68.949 - 68.950 (2.7145 - 2.7146)	68.950 - 68.951 (2.7146 - 2.7146)	68.951 - 68.952 (2.7146 - 2.7146)	68.952 - 68.953 (2.7146 - 2.7147)	68.953 - 68.954 (2.7147 - 2.7147)	68.954 - 68.955 (2.7147 - 2.7148)	68.955 - 68.956 (2.7148 - 2.7148)	68.956 - 68.957 (2.7148 - 2.7148)	68.957 - 68.958 (2.7148 - 2.7149)	68.958 - 68.959 (2.7149 - 2.7149)	68.959 - 68.960 (2.7149 - 2.7150)	68.960 - 68.961 (2.7150 - 2.7150)	68.961 - 68.962 (2.7150 - 2.7150)	68.962 - 68.963 (2.7150 - 2.7151)	68.963 - 68.964 (2.7151 - 2.7151)	68.964 - 68.965 (2.7151 - 2.7152)	68.965 - 68.966 (2.7152 - 2.7152)	68.966 - 68.967 (2.7152 - 2.7152)	68.967 - 68.968 (2.7152 - 2.7153)
I.D. mark	Axle diameter Unit: mm (in)																									
A	63.964 - 63.963 (2.5183 - 2.5182)		0	0	01	01	01	1	1	1	12	12	12	2	2	2	23	23	23	3	3	3	34	34	34	4
B	63.963 - 63.962 (2.5182 - 2.5182)		0	01	01	01	1	1	1	12	12	12	2	2	2	23	23	23	3	3	3	34	34	34	4	4
C	63.962 - 63.961 (2.5182 - 2.5181)		01	01	01	1	1	1	12	12	12	2	2	2	23	23	23	3	3	3	34	34	34	4	4	4
D	63.961 - 63.960 (2.5181 - 2.5181)		01	01	1	1	1	12	12	12	2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45
E	63.960 - 63.959 (2.5181 - 2.5181)		01	1	1	1	12	12	12	2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45
F	63.959 - 63.958 (2.5181 - 2.5180)		1	1	1	12	12	12	2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45
G	63.958 - 63.957 (2.5180 - 2.5180)		1	1	12	12	12	2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5
H	63.957 - 63.956 (2.5180 - 2.5179)		1	12	12	12	2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5
J	63.956 - 63.955 (2.5179 - 2.5179)		12	12	12	2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5
K	63.955 - 63.954 (2.5179 - 2.5179)		12	12	2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56
L	63.954 - 63.953 (2.5179 - 2.5178)		12	2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56
M	63.953 - 63.952 (2.5178 - 2.5178)		2	2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56
N	63.952 - 63.951 (2.5178 - 2.5178)		2	2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6
P	63.951 - 63.950 (2.5178 - 2.5177)		2	23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6
R	63.950 - 63.949 (2.5177 - 2.5177)		23	23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6
S	63.949 - 63.948 (2.5177 - 2.5176)		23	23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67
T	63.948 - 63.947 (2.5176 - 2.5176)		23	3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67
U	63.947 - 63.946 (2.5176 - 2.5176)		3	3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67
V	63.946 - 63.945 (2.5176 - 2.5175)		3	3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7
W	63.945 - 63.944 (2.5175 - 2.5175)		3	34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7	7
X	63.944 - 63.943 (2.5175 - 2.5174)		34	34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7	7	7
Y	63.943 - 63.942 (2.5174 - 2.5174)		34	34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7	7	7	78
1	63.942 - 63.941 (2.5174 - 2.5174)		34	4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7	7	7	78	78
2	63.941 - 63.940 (2.5174 - 2.5173)		4	4	4	45	45	45	5	5	5	56	56	56	6	6	6	67	67	67	7	7	7	78	78	78

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MAIN BEARING GRADE TABLE (ALL JOURNALS)

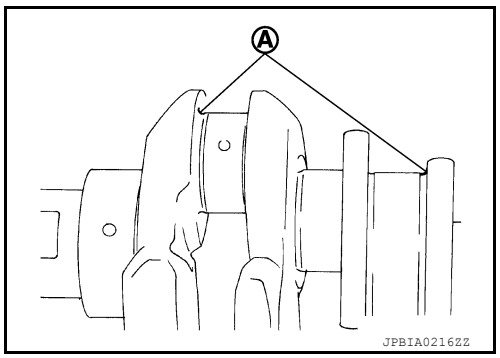
Main bearing grade table (All journals) : Refer to EM-163, "Main Bearing".

UNDERSIZE BEARING USAGE GUIDE

- When the specified main bearing oil clearance is not obtained with standard size main bearings, use undersize (US) bearing.
- When using undersize (US) bearing, measure the main bearing inner diameter with bearing installed, and grind main journal so that the main bearing oil clearance satisfies the standard.

CAUTION:

In grinding crankshaft main journal to use undersize bearings, keep the fillet R (A) [1.5 - 1.7 mm (0.059 - 0.067 in)].



Bearing undersize table : Refer to EM-163, "Main Bearing".

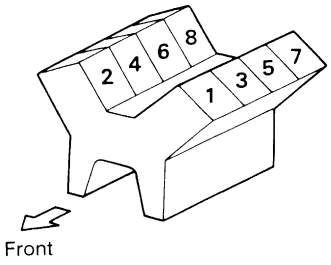
SERVICE DATA AND SPECIFICATIONS (SDS)

SERVICE DATA AND SPECIFICATIONS (SDS)

General Specification

INFOID:0000000014418545

GENERAL SPECIFICATIONS

Cylinder arrangement		V-8
Displacement cm^3 (cu in)		5,552 (338.80)
Bore and stroke mm (in)		98.0 x 92.0 (3.86 x 3.62)
Valve arrangement		DOHC
Firing order		1-8-7-3-6-5-4-2
Number of piston rings	Compression	2
	Oil	1
Number of main bearings		5
Compression ratio		11.2
Compression pressure kPa (kg/cm^2, psi)/200 rpm	Standard	1,820 (18.5, 264)
	Minimum	1,670 (17.0, 242)
	Differential limit between cylinders	100 (1.0, 15)
Cylinder number	 SEM957C	

Unit: degree

Valve timing	Intake valve open (BTDC)	(–74) - (+ 68)
	Intake valve close (ABDC)	(+148) - (+290)
	Exhaust valve open (BBDC)	(+201) - (+236)
	Exhaust valve close (ATDC)	(+8) - (+43)

Drive Belts

INFOID:0000000014418546

DRIVE BELT

Tension of drive belts	Belt tension is not necessary, as it is automatically adjusted by drive belt auto-tensioner.

Spark Plug

INFOID:0000000014418547

SPARK PLUG

Unit: mm (in)

Make	NGK
Standard type	DILKAR7B11

Gap	Standard	1.1 (0.043)
	Limit	1.25 (0.049)

Exhaust Manifold

INFOID:0000000014418548

EXHAUST MANIFOLD

Unit: mm (in)

Items		Limit
Surface distortion	Exhaust manifold	0.3 (0.012)

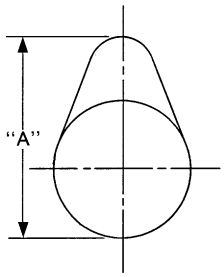
Camshaft

INFOID:0000000014418549

EXHAUST CAMSHAFT

Unit: mm (in)

Items	Standard	Limit
Exhaust camshaft journal oil clearance	0.030 - 0.071 (0.0012 - 0.0028)	0.150 (0.0059)
VVEL ladder assembly bracket inner diameter (EXH side)	26.000 - 26.021 (1.0236 - 1.0244)	—
Exhaust camshaft journal diameter	25.950 - 25.970 (1.0217 - 1.0224)	—
Exhaust camshaft journal No. 1 width	30.500 - 30.548 (1.2008 - 1.2027)	—
Cylinder head journal No. 1 width	30.360 - 30.385 (1.1953 - 1.1963)	—
Exhaust camshaft end play	0.115 - 0.188 (0.0045 - 0.0074)	0.24 (0.0094)
Exhaust camshaft cam height “A”	45.475 - 45.665 (1.7904 - 1.7978)	45.275 (1.7825)
Exhaust camshaft runout [TIR*]	Less than 0.02 (0.0008)	0.05 (0.002)
Exhaust camshaft sprocket runout [TIR*]	—	0.14 (0.0055)



SEM671

*: Total indicator reading

INTAKE CAMSHAFT

Unit: mm (in)

Items	Standard	Limit
Intake camshaft journal No.1 width	30.500 - 30.548 (1.2008 - 1.2027)	—
Cylinder head journal No. 1 width	30.360 - 30.385 (1.1953 - 1.1963)	—
Drive shaft end play	0.115 - 0.188 (0.0045 - 0.0074)	0.24 (0.0094)
Intake camshaft sprocket runout [TIR*1]	—	0.15 (0.0059)

*1: Total indicator reading

VALVE LIFTER

Unit: mm (in)

Items	Standard
Valve lifter outer diameter	33.980 - 33.990 (1.3378 - 1.3382)

Valve lifter hole diameter	34.000 - 34.016 (1.3386 - 1.3392)
Valve lifter clearance	0.010 - 0.036 (0.0004 - 0.0014)

VALVE CLEARANCE

Unit: mm (in)

Items	Cold	Hot* (reference data)
Intake	0.26 - 0.34 (0.010 - 0.013)	0.304 - 0.416 (0.012 - 0.016)
Exhaust	0.29 - 0.37 (0.011 - 0.015)	0.308 - 0.432 (0.012 - 0.017)

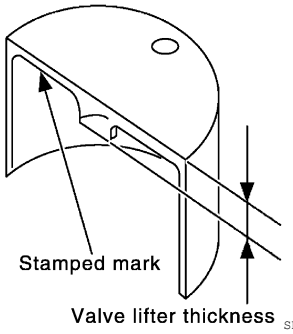
*: Approximately 80°C (176°F)

AVAILABLE VALVE LIFTER

Unit: mm (in)

Identification (stamped) mark	Thickness
300N or 300n	3.00 (0.1181)
302N or 302n	3.02 (0.1189)
304N or 304n	3.04 (0.1197)
306N or 306n	3.06 (0.1205)
308N or 308n	3.08 (0.1213)
310N or 310n	3.10 (0.1220)
312N or 312n	3.12 (0.1228)
314N or 314n	3.14 (0.1236)
316N or 316n	3.16 (0.1244)
318N or 318n	3.18 (0.1252)
320N or 320n	3.20 (0.1260)
322 N or 322n	3.22 (0.1268)
324N or 324n	3.24 (0.1276)
326N or 326n	3.26 (0.1283)
328N or 328n	3.28 (0.1291)
330N or 330n	3.30 (0.1300)
332N or 332n	3.32 (0.1307)
334N or 334n	3.34 (0.1315)
336N or 336n	3.36 (0.1323)
338N or 338n	3.38 (0.1331)
340N or 340n	3.40 (0.1339)
342N or 342n	3.42 (0.1346)
344N or 344n	3.44 (0.1354)
346N or 346n	3.46 (0.1362)
348N or 348n	3.48 (0.1370)

Identification (stamped) mark	Thickness
350N or 350n	3.50 (0.1378)



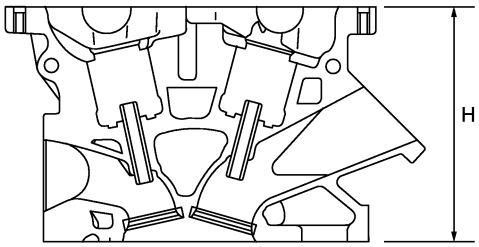
Cylinder Head

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CYLINDER HEAD

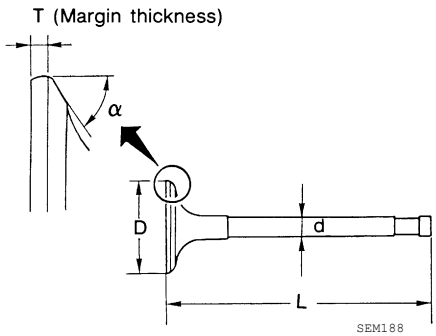
Unit: mm (in)

Items	Standard	Limit
Head surface distortion	Less than 0.03 (0.0012)	0.1 (0.004)
Normal cylinder head height “H”	126.3 (4.97)	—



VALVE DIMENSIONS

Unit: mm (in)

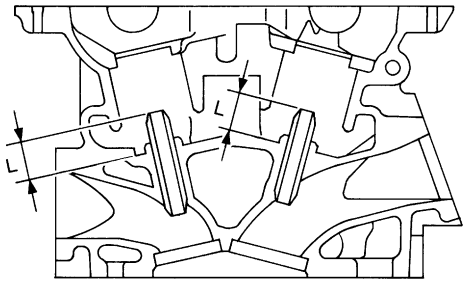


Valve head diameter “D”	Intake	36.6 - 36.9 (1.441 - 1.453)
	Exhaust	31.2 - 31.5 (1.228 - 1.240)
Valve length “L”	Intake	104.08 - 104.58 (4.0976 - 4.1173)
	Exhaust	98.60 - 99.13 (3.8819 - 3.9027)
Valve stem diameter “d”	Intake	5.965 - 5.980 (0.2348 - 0.2354)
	Exhaust	5.955 - 5.970 (0.2344 - 0.2350)

Valve seat angle “α”	Intake	45°15′ - 45°45′
	Exhaust	
Valve margin “T”	Intake	1.1 (0.043)
	Exhaust	1.3 (0.051)
Valve margin “T” limit		0.5 (0.020)
Valve stem end surface grinding limit		0.2 (0.008)

VALVE GUIDE

Unit: mm (in)



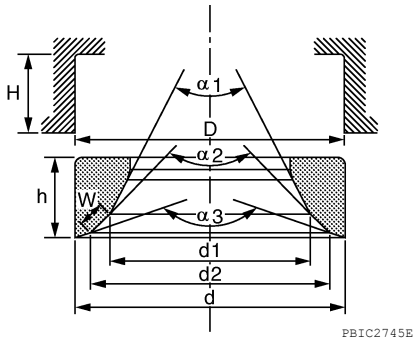
SEM950E

Items		Standard	Oversize (Service) [0.2 (0.008)]*
Valve guide	Outer diameter	10.023 - 10.034 (0.3946 - 0.3950)	10.223 - 10.234 (0.4025 - 0.4029)*
	Inner diameter (Finished size)	6.000 - 6.018 (0.2362 - 0.2369)	
Cylinder head valve guide hole diameter		9.975 - 9.996 (0.3927 - 0.3935)	10.175 - 10.196 (0.4006 - 0.4014)*
Interference fit of valve guide		0.027 - 0.059 (0.0011 - 0.0023)	
Items		Standard	Limit
Valve guide clearance	Intake	0.020 - 0.053 (0.0008 - 0.0021)	0.08 (0.003)
	Exhaust	0.030 - 0.063 (0.0012 - 0.0025)	0.09 (0.004)
Projection length “L”	Intake	12.6 - 12.8 (0.496 - 0.504)	
	Exhaust	12.6 - 12.8 (0.496 - 0.504)	

*: Parts settings are for exhaust side only

VALVE SEAT

Unit: mm (in)



PBIC2745E

Items		Standard	Oversize (Service) [0.5 (0.02)] *4
Cylinder head seat recess diameter “D”	Intake	38.000 - 38.016 (1.4961 - 1.4967)	—
	Exhaust	32.200 - 32.216 (1.2677 - 1.2683)	32.700 - 32.716 (1.2874 - 1.2880)*4

Valve seat outer diameter “d”	Intake	38.097 - 38.113 (1.4999 - 1.5005)	—
	Exhaust	32.280 - 32.296 (1.2709 - 1.2715)	32.780 - 32.796 (1.2906 - 1.2912)*4
Valve seat interference fit	Intake	0.081 - 0.113 (0.0032 - 0.0044)	
	Exhaust	0.064 - 0.096 (0.0025 - 0.0038)	
Diameter “d1”*1	Intake	34.6 (1.362)	
	Exhaust	28.7 (1.130)	
Diameter “d2”*2	Intake	35.9 - 36.4 (1.413 - 1.433)	
	Exhaust	30.3 - 30.8 (1.193 - 1.213)	
Angle “α1”		59 - 61°	
Angle “α2”		89°15′ - 89°95′	
Angle “α3”		119 - 121°	
Contacting width “W”*3	Intake	1.0 - 1.4 (0.039 - 0.055)	
	Exhaust	1.2 - 1.6 (0.047 - 0.063)	
Height “h”	Intake	5.9 - 6.0 (0.232 - 0.236)	—
	Exhaust	5.9 - 6.0 (0.232 - 0.236)	4.95 - 5.05 (0.1949 - 0.1988)*4
Depth “H”		6.0 (0.236)	

*1: Diameter made by intersection point of conic angles “α1” and “α2”

*2: Diameter made by intersection point of conic angles “α2” and “α3”

*3: Machining data

*4: Parts settings are for exhaust side only

VALVE SPRING

Item		Standard	
		Intake	Exhaust
Free height		54.31 mm (2.1382 in)	51.81 mm (2.0398 in)
Pressure	Installation	166 - 188 N (16.9 - 19.2 kg, 37 - 42 lb) at 31.4 mm (1.2362 in)	166 - 188 N (16.9 - 19.2 kg, 37 - 42 lb) at 36.11 mm (1.4217 in)
	Valve open	392 - 442 N (40.0 - 45.1 kg, 88.1 - 99.4 lb) at 31.4 mm (1.2362 in)	315 - 355 N (32.1 - 36.2 kg, 70.8 - 79.8 lb) at 26.31 mm (1.0358 in)
Identification color		Orange	White

Item	Limit	
	Intake	Exhaust
Out-of-square	2.4 mm (0.094 in)	2.3 mm (0.080 in)

Cylinder Block

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CYLINDER BLOCK

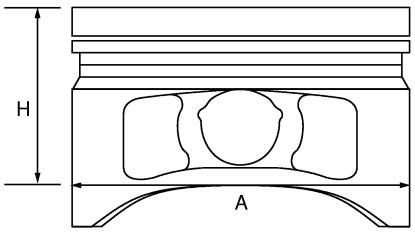
Unit: mm (in)

Surface flatness		Limit		0.1 (0.004)
Main bearing housing inner diameter		Standard		68.944 - 68.968 (2.7143 - 2.7153)
Cylinder bore	Inner diameter	Standard	Grade No. 1	98.000 - 98.010 (3.8583 - 3.8587)
			Grade No. 2	98.010 - 98.020 (3.8587 - 3.8590)
			Grade No. 3	98.020 - 98.030 (3.8590 - 3.8594)
		Wear limit		0.2 (0.008)
Out-of-round		Limit		0.015 (0.0006)
Taper				0.010 (0.0004)

Main bearing housing inner diameter grade (Without bearing)		Grade No. A	68.944 - 68.945 (2.7143 - 2.7144)
		Grade No. B	68.945 - 68.946 (2.7144 - 2.7144)
		Grade No. C	68.946 - 68.947 (2.7144 - 2.7144)
		Grade No. D	68.947 - 68.948 (2.7144 - 2.7145)
		Grade No. E	68.948 - 68.949 (2.7145 - 2.7145)
		Grade No. F	68.949 - 68.950 (2.7145 - 2.7146)
		Grade No. G	68.950 - 68.951 (2.7146 - 2.7146)
		Grade No. H	68.951 - 68.952 (2.7146 - 2.7146)
		Grade No. J	68.952 - 68.953 (2.7146 - 2.7147)
		Grade No. K	68.953 - 68.954 (2.7147 - 2.7147)
		Grade No. L	68.954 - 68.955 (2.7147 - 2.7148)
		Grade No. M	68.955 - 68.956 (2.7148 - 2.7148)
		Grade No. N	68.956 - 68.957 (2.7148 - 2.7148)
		Grade No. P	68.957 - 68.958 (2.7148 - 2.7149)
		Grade No. R	68.958 - 68.959 (2.7149 - 2.7149)
		Grade No. S	68.959 - 68.960 (2.7149 - 2.7150)
		Grade No. T	68.960 - 68.961 (2.7150 - 2.7150)
		Grade No. U	68.961 - 68.962 (2.7150 - 2.7150)
		Grade No. V	68.962 - 68.963 (2.7150 - 2.7151)
		Grade No. W	68.963 - 68.964 (2.7151 - 2.7151)
		Grade No. X	68.964 - 68.965 (2.7151 - 2.7152)
		Grade No. Y	68.965 - 68.966 (2.7152 - 2.7152)
		Grade No. 4	68.966 - 68.967 (2.7152 - 2.7152)
		Grade No. 7	68.967 - 68.968 (2.7152 - 2.7153)
Difference in inner diameter between cylinders	Standard		Less than 0.01 (0.0004)

AVAILABLE PISTON

Unit: mm (in)



PBIC0188E

Items		Standard	Oversize (Service) [0.2 (0.008)]
Piston skirt diameter “A”	Grade No. 1	97.980 - 97.990 (3.8575 - 3.8579)	—
	Grade No. 2	97.990 - 98.000 (3.8579 - 3.8583)	—
	Grade No. 3	98.000 - 98.010 (3.8583 - 3.8587)	—
	Service	—	98.190 - 98.200 (3.8657 - 3.8661)
Items		Standard	Limit
“H” dimension		40.0 (1.5748)	—
Piston pin hole diameter		21.993 - 21.999 (0.8659 - 0.8661)	—
Piston to cylinder bore clearance		0.010 - 0.030 (0.0004 - 0.0012)	0.08 (0.0031)

PISTON RING

Unit: mm (in)

Items		Standard	Limit
Side clearance	Top	0.040 - 0.080 (0.0016 - 0.0031)	0.11 (0.0043)
	2nd	0.030 - 0.070 (0.0012 - 0.0028)	0.10 (0.0039)
	Oil ring	0.015 - 0.185 (0.0006 - 0.00728)	0.22 (0.0087)

End gap	Top	0.23 - 0.28 (0.0091 - 0.0110)	0.50 (0.0197)
	2nd	0.50 - 0.65 (0.0197 - 0.0256)	0.84 (0.0331)
	Oil (rail ring)	0.20 - 0.60 (0.0079 - 0.0236)	0.95 (0.0374)

PISTON PIN

Unit: mm (in)

Items	Standard	Limit
Piston pin outer diameter	21.989 - 21.995 (0.8657 - 0.8659)	—
Piston to piston pin oil clearance	0.002 - 0.006 (0.0001 - 0.0002)	—
Connecting rod bushing oil clearance	0.005 - 0.017 (0.0002 - 0.0007)	0.030 (0.0012)

CONNECTING ROD

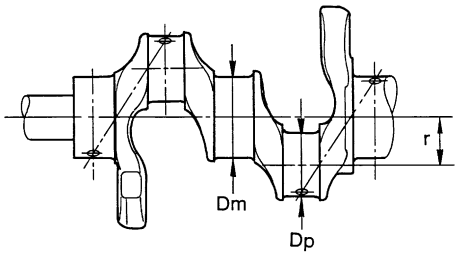
Unit: mm (in)

Items	Standard	Limit
Center distance	154.45 - 154.55 (6.08 - 6.08)	—
Bend [per 100 (3.94)]	—	0.15 (0.0059)
Torsion [per 100 (3.94)]	—	0.30 (0.0118)
Connecting rod bushing inner diameter*	22.000 - 22.006 (0.8661 - 0.8664)	—
Connecting rod big end diameter (Without bearing)	Grade No. A	57.000 - 57.001 (2.2441 - 2.2441)
	Grade No. B	57.001 - 57.002 (2.2441 - 2.2442)
	Grade No. C	57.002 - 57.003 (2.2442 - 2.2442)
	Grade No. D	57.003 - 57.004 (2.2442 - 2.2442)
	Grade No. E	57.004 - 57.005 (2.2442 - 2.2443)
	Grade No. F	57.005 - 57.006 (2.2443 - 2.2443)
	Grade No. G	57.006 - 57.007 (2.2443 - 2.2444)
	Grade No. H	57.007 - 57.008 (2.2444 - 2.2444)
	Grade No. J	57.008 - 57.009 (2.2444 - 2.2444)
	Grade No. K	57.009 - 57.010 (2.2444 - 2.2445)
	Grade No. L	57.010 - 57.011 (2.2445 - 2.2445)
	Grade No. M	57.011 - 57.012 (2.2445 - 2.2446)
	Grade No. N	57.012 - 57.013 (2.2446 - 2.2446)
Side clearance	0.20 - 0.40 (0.0079 - 0.0158)	0.40 (0.0157)

*: After installing in connecting rod

CRANKSHAFT

Unit: mm (in)



SEM645

Main journal diameter. “Dm” grade (No. 1 and 5 journal)	Standard	Grade No. G	63.964 - 63.963 (2.5183 - 2.5182)
		Grade No. H	63.963 - 63.962 (2.5182 - 2.5182)
		Grade No. J	63.962 - 63.961 (2.5182 - 2.5181)
		Grade No. K	63.961 - 63.960 (2.5181 - 2.5181)
		Grade No. L	63.960 - 63.959 (2.5181 - 2.5181)
		Grade No. M	63.959 - 63.958 (2.5181 - 2.5180)
		Grade No. N	63.958 - 63.957 (2.5180 - 2.5180)
		Grade No. P	63.957 - 63.956 (2.5180 - 2.5179)
		Grade No. R	63.956 - 63.955 (2.5179 - 2.5179)
		Grade No. S	63.955 - 63.954 (2.5179 - 2.5179)
		Grade No. T	63.954 - 63.953 (2.5179 - 2.5178)
		Grade No. U	63.953 - 63.952 (2.5178 - 2.5178)
		Grade No. V	63.952 - 63.951 (2.5178 - 2.5178)
		Grade No. W	63.951 - 63.950 (2.5178 - 2.5177)
		Grade No. X	63.950 - 63.949 (2.5177 - 2.5177)
		Grade No. Y	63.949 - 63.948 (2.5177 - 2.5176)
		Grade No. 1	63.948 - 63.947 (2.5176 - 2.5176)
		Grade No. 2	63.947 - 63.946 (2.5176 - 2.5176)
		Grade No. 3	63.946 - 63.945 (2.5176 - 2.5175)
		Grade No. 4	63.945 - 63.944 (2.5175 - 2.5175)
		Grade No. 5	63.944 - 63.943 (2.5175 - 2.5174)
		Grade No. 6	63.943 - 63.942 (2.5174 - 2.5174)
		Grade No. 7	63.942 - 63.941 (2.5174 - 2.5174)
		Grade No. 9	63.941 - 63.940 (2.5174 - 2.5173)
Main journal diameter. “Dm” grade (No. 2, 3 and 4 journal)	Standard	Grade No. A	63.963 - 63.964 (2.5182 - 2.5183)
		Grade No. B	63.962 - 63.963 (2.5182 - 2.5182)
		Grade No. C	63.961 - 63.962 (2.5181 - 2.5182)
		Grade No. D	63.960 - 63.961 (2.5181 - 2.5181)
		Grade No. E	63.959 - 63.960 (2.5181 - 2.5181)
		Grade No. F	63.958 - 63.959 (2.5180 - 2.5181)
		Grade No. G	63.957 - 63.958 (2.5180 - 2.5180)
		Grade No. H	63.956 - 63.957 (2.5179 - 2.5180)
		Grade No. J	63.955 - 63.956 (2.5179 - 2.5179)
		Grade No. K	63.954 - 63.955 (2.5179 - 2.5179)
		Grade No. L	63.953 - 63.954 (2.5178 - 2.5179)
		Grade No. M	63.952 - 63.953 (2.5178 - 2.5178)
		Grade No. N	63.951 - 63.952 (2.5178 - 2.5178)
		Grade No. P	63.950 - 63.951 (2.5177 - 2.5178)
		Grade No. R	63.949 - 63.950 (2.5177 - 2.5177)
		Grade No. S	63.948 - 63.949 (2.5176 - 2.5177)
		Grade No. T	63.947 - 63.948 (2.5176 - 2.5176)
		Grade No. U	63.946 - 63.947 (2.5176 - 2.5176)
		Grade No. V	63.945 - 63.946 (2.5175 - 2.5176)
		Grade No. W	63.944 - 63.945 (2.5175 - 2.5175)
		Grade No. X	63.943 - 63.944 (2.5174 - 2.5175)
		Grade No. Y	63.942 - 63.943 (2.5174 - 2.5174)
		Grade No. 1	63.941 - 63.942 (2.5174 - 2.5174)
		Grade No. 2	63.940 - 63.941 (2.5173 - 2.5174)
Pin journal diameter. “Dp” grade	Standard	Grade No. 0	53.968 - 53.974 (2.1247 - 2.1250)
		Grade No. 1	53.962 - 53.968 (2.1245 - 2.1247)
		Grade No. 2	53.956 - 53.962 (2.1243 - 2.1245)

Center distance “r”		45.96 - 46.04 (1.8095 - 1.8126)
Taper	Limit	0.0025 (0.0001)
Out-of-round		0.0025 (0.0001)
Crankshaft runout [TIR*]	Standard	Less than 0.05 (0.002)
	Limit	0.10 (0.0039)
Crankshaft end play	Standard	0.10 - 0.26 (0.0039 - 0.0102)
	Limit	0.30 (0.012)

*: Total indicator reading

Main Bearing

INFOID:0000000014418552

MAIN BEARING

Grade number		Thickness mm (in)	Width mm (in)	Identification color	Remarks
0		2.483 - 2.486 (0.0978 - 0.0979)	19.9 - 20.1 (0.783 - 0.791)	Black	Grade is the same for upper and lower bearings.
1		2.486 - 2.489 (0.0979 - 0.0980)		Brown	
2		2.489 - 2.492 (0.0980 - 0.0981)		Green	
3		2.492 - 2.495 (0.0981 - 0.0982)		Yellow	
4		2.495 - 2.498 (0.0982 - 0.0983)		Blue	
5		2.498 - 2.501 (0.0983 - 0.0985)		Pink	
6		2.501 - 2.504 (0.0985 - 0.0986)		Purple	
7		2.504 - 2.507 (0.0986 - 0.0987)		White	
8		2.507 - 2.510 (0.0987 - 0.0988)		Red	
01	UPR	2.483 - 2.486 (0.0978 - 0.0979)		Black	Grade and color are different for upper and lower bearings.
	LWR	2.486 - 2.489 (0.0979 - 0.0980)		Brown	
12	UPR	2.486 - 2.489 (0.0979 - 0.0980)		Brown	
	LWR	2.489 - 2.492 (0.0980 - 0.0981)		Green	
23	UPR	2.489 - 2.492 (0.0980 - 0.0981)		Green	
	LWR	2.492 - 2.495 (0.0981 - 0.0982)		Yellow	
34	UPR	2.492 - 2.495 (0.0981 - 0.0982)		Yellow	
	LWR	2.495 - 2.498 (0.0982 - 0.0983)		Blue	
45	UPR	2.495 - 2.498 (0.0982 - 0.0983)		Blue	
	LWR	2.498 - 2.501 (0.0983 - 0.0985)		Pink	
56	UPR	2.498 - 2.501 (0.0983 - 0.0985)		Pink	
	LWR	2.501 - 2.504 (0.0985 - 0.0986)		Purple	
67	UPR	2.501 - 2.504 (0.0985 - 0.0986)		Purple	
	LWR	2.504 - 2.507 (0.0986 - 0.0987)		White	
78	UPR	2.504 - 2.507 (0.0986 - 0.0987)		White	
	LWR	2.507 - 2.510 (0.0987 - 0.0988)		Red	

UNDERSIZE

Unit: mm (in)

Items	Thickness	Main journal diameter
0.25 (0.0098)	2.618 - 2.626 (0.1031 - 0.1034)	Grind so that bearing clearance is the specified value.

MAIN BEARING OIL CLEARANCE

Unit: mm (in)

Items		Standard	Limit
Main bearing oil clearance	No.1 and 5	0.001 - 0.011 (0.00004 - 0.00043)*	0.065 (0.0026)
	No.2, 3 and 4	0.007 - 0.017 (0.0003 - 0.0007)*	

*: Actual clearance

Connecting Rod Bearing

INFOID:0000000014418553

CONNECTING ROD BEARING

Grade number	Thickness mm (in)	Width mm (in)	Identification color (mark)
0	1.497 - 1.500 (0.0589 - 0.0591)	18.1 - 18.3 (0.713 - 0.720)	Purple
1	1.500 - 1.503 (0.0591 - 0.0592)		Black
2	1.503 - 1.506 (0.0592 - 0.0593)		Brown
3	1.506 - 1.509 (0.0593 - 0.0594)		Green
4	1.509 - 1.512 (0.0594 - 0.0595)		Yellow

UNDERSIZE

Unit: mm (in)

Items	Thickness	Pin journal diameter
0.25 (0.0098)	1.627 - 1.635 (0.0641 - 0.0644)	Grind so that bearing clearance is the specified value.

CONNECTING ROD BEARING OIL CLEARANCE

Unit: mm (in)

Items	Standard	Limit
Connecting rod bearing oil clearance	0.020 - 0.039 (0.0008 - 0.0015)*	0.070 (0.0028)

*: Actual clearance

PRECAUTION

PRECAUTIONS

Precaution for Supplemental Restraint System (SRS) "AIR BAG" and "SEAT BELT PRE-TENSIONER"

INFOID:0000000014418554

The Supplemental Restraint System such as “AIR BAG” and “SEAT BELT PRE-TENSIONER”, used along with a front seat belt, helps to reduce the risk or severity of injury to the driver and front passenger for certain types of collision. Information necessary to service the system safely is included in the SR and SB section of this Service Manual.

WARNING:

- **To avoid rendering the SRS inoperative, which could increase the risk of personal injury or death in the event of a collision which would result in air bag inflation, it is recommended that all maintenance and repair be performed by an authorized NISSAN/INFINITI dealer.**
- **Improper repair, including incorrect removal and installation of the SRS, can lead to personal injury caused by unintentional activation of the system. For removal of Spiral Cable and Air Bag Module, see the SR section.**
- **Do not use electrical test equipment on any circuit related to the SRS unless instructed to in this Service Manual. SRS wiring harnesses can be identified by yellow and/or orange harnesses or harness connectors.**

PRECAUTIONS WHEN USING POWER TOOLS (AIR OR ELECTRIC) AND HAMMERS

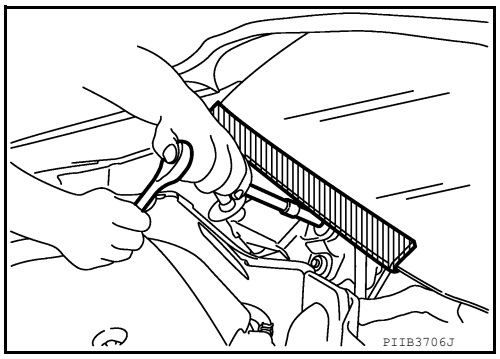
WARNING:

- **When working near the Air Bag Diagnosis Sensor Unit or other Air Bag System sensors with the Ignition ON or engine running, DO NOT use air or electric power tools or strike near the sensor(s) with a hammer. Heavy vibration could activate the sensor(s) and deploy the air bag(s), possibly causing serious injury.**
- **When using air or electric power tools or hammers, always switch the Ignition OFF, disconnect the battery or batteries, and wait at least three minutes before performing any service.**

Precaution for Procedure without Cowl Top Cover

INFOID:0000000014418555

When performing the procedure after removing cowl top cover, cover the lower end of windshield with urethane, etc.



Precaution for Drain Engine Coolant

INFOID:0000000014418556

Drain engine coolant when engine is cooled.

Precaution for Disconnecting Fuel Piping

INFOID:0000000014418557

- Before starting work, make sure no fire or spark producing items are in the work area.
- Release fuel pressure before disconnecting and disassembly.
- After disconnecting pipes, plug openings to stop fuel leakage.

Precaution for Removal and Disassembly

INFOID:0000000014418558

- When instructed to use special service tools, use the specified tools. Always be careful to work safely, avoid forceful or uninstructed operations.
- Exercise maximum care to avoid damage to mating or sliding surfaces.

- Cover openings of engine system with Tool. When Tool is not available, use a residue free tape or the equivalent, if necessary, to seal out foreign materials.

Tool : — (J-54423)
: — (J-54427)

- Mark and arrange disassembly parts in an organized way for easy troubleshooting and assembly.
- When loosening nuts and bolts, as a basic rule, start with the one furthest outside, then the one diagonally opposite, and so on. If the order of loosening is specified, do exactly as specified. Power tools may be used where noted in the step.

Precaution for Inspection, Repair and Replacement

INFOID:0000000014418559

Before repairing or replacing, thoroughly inspect parts. Inspect new replacement parts in the same way, and replace if necessary.

Precaution for Assembly and Installation

INFOID:0000000014418560

- Use torque wrench to tighten bolts or nuts to specification.
- When tightening nuts and bolts, as a basic rule, equally tighten in several different steps starting with the ones in center, then ones on inside and outside diagonally in this order. If the order of tightening is specified, do exactly as specified.
- Replace with new gasket, packing, oil seal or O-ring.
- Thoroughly wash, clean, and air-blow each part. Carefully check engine oil or engine coolant passages for any restriction and blockage.
- Avoid damaging sliding or mating surfaces. Completely remove foreign materials such as cloth lint or dust. Before assembly, oil sliding surfaces well.
- Release air within route when refilling after draining engine coolant.
- Before starting engine, apply fuel pressure to fuel lines with turning ignition switch ON (with engine stopped). Then make sure that there are no leaks at fuel line connections.
- After repairing, start engine and increase engine speed to check engine coolant, fuel, oil, and exhaust systems for leakage.

Parts Requiring Angular Tightening

INFOID:0000000014418561

- For final tightening of the following engine parts use Tool:

Tool number : KV10112100 (BT-8653-A)

- Cylinder head bolts
- Injector hold down clamp
- Main bearing cap bolts
- Connecting rod cap bolts
- Crankshaft pulley bolt (No angle wrench is required as the bolt flange is provided with notches for angle tightening)

- Do not use a torque value for final tightening.
- The torque value for these parts are for a preliminary step.

Precaution for Liquid Gasket

INFOID:0000000014418562

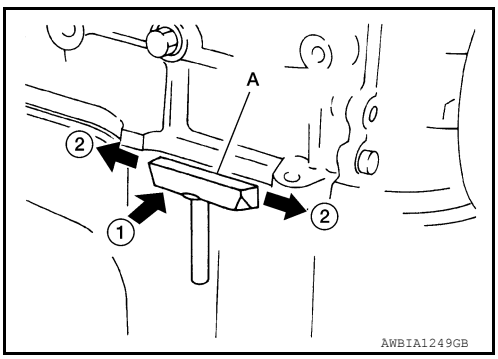
REMOVAL OF LIQUID GASKET

- After removing the bolts and nuts, separate the mating surface and remove the old liquid gasket using Tool (A).

Tool number : KV10111100 (J-37228)

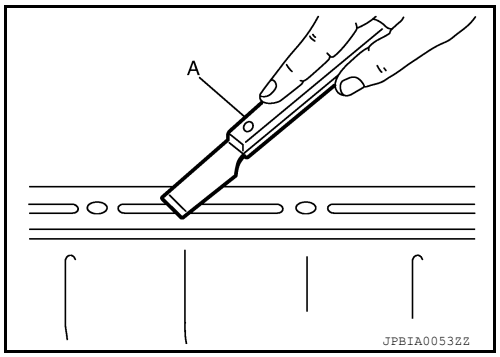
CAUTION:
Do not damage the mating surfaces.

- Tap the seal cutter to insert it (1).
- In areas where the Tool is difficult to use, lightly tap to slide it (2).

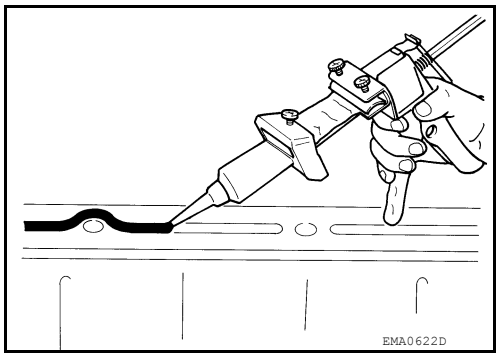


LIQUID GASKET APPLICATION PROCEDURE

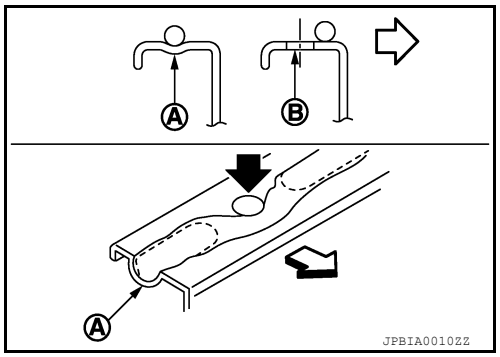
1. Remove the old liquid gasket adhering to the gasket application surface and the mating surface using suitable tool (A).
   - Remove the liquid gasket completely from the groove of the liquid gasket application surface, bolts, and bolt holes.
2. Thoroughly clean the mating surfaces and remove adhering moisture, grease and foreign material.



3. Attach the liquid gasket tube to the suitable tool.
   Use Genuine RTV Silicone Sealant or equivalent. Refer to GI-22, "Recommended Chemical Products and Sealants".
4. Apply the liquid gasket without breaks to the specified location with the specified dimensions.



- If there is a groove (A) for the liquid gasket application, apply the liquid gasket to the groove.
- Normally apply the liquid gasket on the inside edge of the bolt holes. Also apply to the outside edge of the bolt holes (B) when specified in the procedure.
- Within five minutes of liquid gasket application, install the mating component.
- If the liquid gasket protrudes, wipe it off immediately.
- Do not retighten after the installation.
- Wait 30 minutes or more after installation before refilling the engine with oil or coolant. Refer to LU-35, "Changing Engine Oil" and CO-47, "Changing Engine Coolant".



CAUTION:
If there are more specific instructions in the procedures contained in this manual concerning liquid gasket application, observe them.

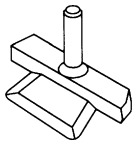
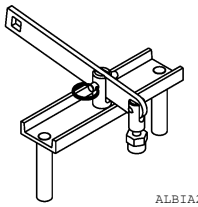
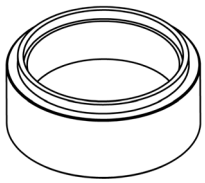
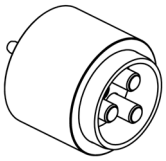
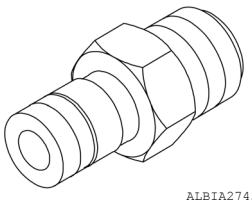
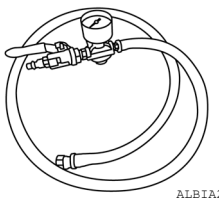
PREPARATION

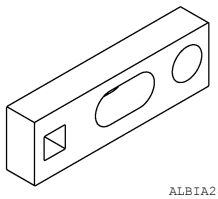
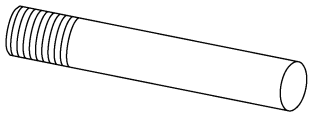
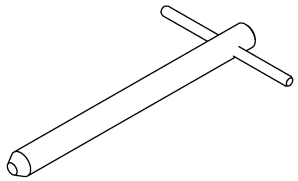
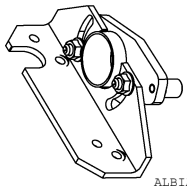
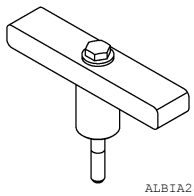
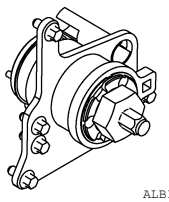
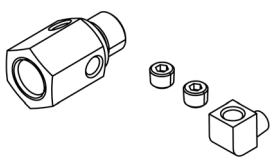
PREPARATION

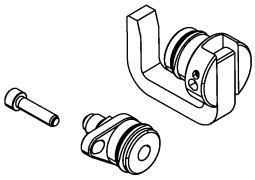
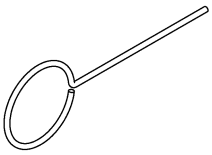
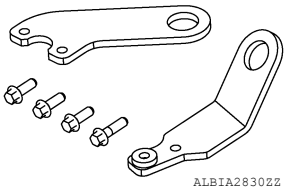
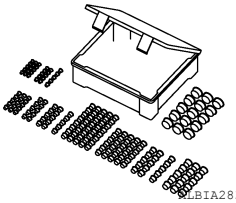
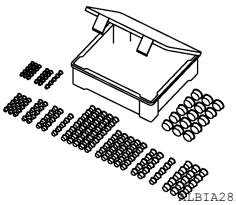
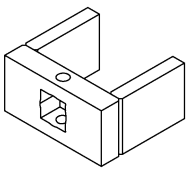
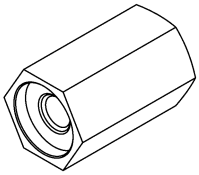
Special Service Tool

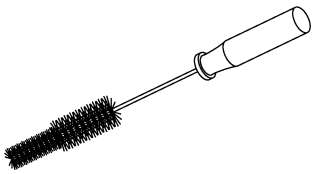
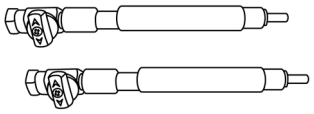
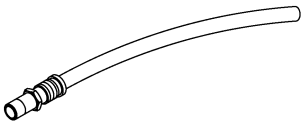
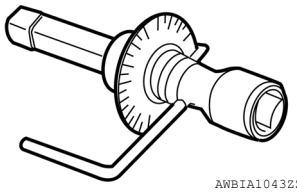
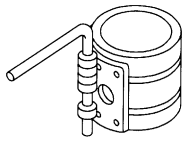
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The actual shape of the tools may differ from those illustrated here.

Tool number (TechMate No.) Tool name		Description
KV10111100 (J-37228) Seal cutter	 S-NT046	Removing steel oil pan and block stiffening plate
— (J-54402) Injector puller	 ALBIA2815ZZ	Removing injectors
— (J-54405) Rear oil seal installer	 ALBIA2738ZZ	Installing rear oil seal
— (J-54406) Front oil seal installer	 ALBIA2746ZZ	Installing front oil seal
— (J-54417) Quick connect fitting (male)	 ALBIA2743ZZ	Adapt to quick connect fittings
— (J-54429) Air pressure regulator	 ALBIA2745ZZ	Regulate shop air pressure for pressure testing EGR cooler

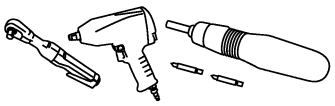
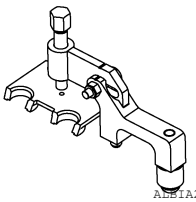
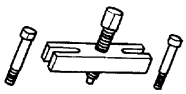
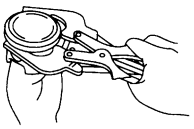
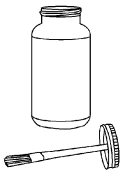
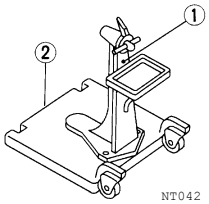
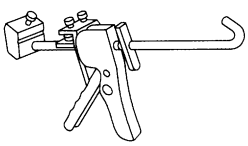
Tool number (TechMate No.) Tool name		Description
— (J-54401) Barring tool	 ALBIA2816ZZ	Installed on vibration damper bolts to turn engine over. Can also be used on rear of crankshaft with flexplate removed.
— (J-54403) Front cover assembly guide pins	 ALBIA2817ZZ	Aligning and installing front cover
— (J-54404) Nylon timing pin	 ALBIA2819ZZ	Timing fixture for vibration damper to front cover
— (J-54408) Camshaft sprocket retaining tool	 ALBIA2820ZZ	Retain camshaft sprocket when removing camshaft
— (J-54409) Camshaft timing fixture	 ALBIA2822ZZ	Lock intake and exhaust camshafts in specific orientation
— (J-54411) Fuel pump removal tool	 ALBIA2823ZZ	Remove fuel pump sprocket and hold fuel pump sprocket and drive chain in position when fuel pump is removed
— (J-54412) Oil switch T adapter	 ALBIA2740ZZ	Thread into cylinder block to test engine oil pressure

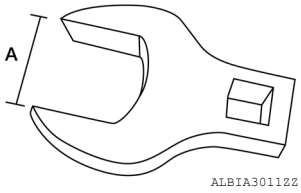
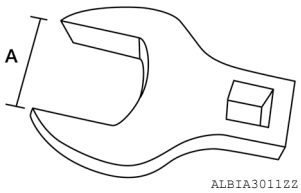
Tool number (TechMate No.) Tool name		Description
— (J-54414) EGR cooler pressure test kit	 ALBIA2825ZZ	Test EGR cooler coolant passages for leaks
— (J-54418) Chain tensioner retaining tool	 ALBIA2827ZZ	Keep chain tensioner plunger from expanding
— (J-54419) Engine slingers	 ALBIA2830ZZ	Lifting engine
— (J-54423) Cap plug kit - air handling	 ALBIA2834ZZ	To protect air handling components from contaminants.
— (J-54427) Cap plug kit - fuel system	 ALBIA2834ZZ	To protect fuel system from contaminants.
— (J-54424) U-shape barring tool	 ALBIA2835ZZ	Used on vibration damper to turn engine over.
— (J-54425) Exhaust lock plate kit	 ALBIA2836ZZ	Used to install exhaust manifold lockplates onto exhaust manifold nuts.

Tool number (TechMate No.) Tool name		Description
— (J-54428) Injector bore brush	 ALBIA2837ZZ	Used to clean injector seal seat of carbon build up.
— (J-54415) Compression test adapter	 ALBIA2943ZZ	A kit containing two adapters used to replace injectors to measure cylinder pressure.
— (J-54431) Fuel system leak tester	 ALBIA2838ZZ	Used to measure the fuel pressure relief valve drain flow.
KV10112100 (BT-8653-A) Angle wrench	 AWBIA1043ZZ	Tightening bolts for cylinder head, main bearing cap, connecting rod cap, vibration damper and injector hold down clamp
EM03470000 (J-8037) Piston ring compressor	 S-NT044	Installing piston assembly into cylinder bore

Commercial Service Tool

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(TechMate No.) Tool name	Description
(—) Power tool  PIIB1407E	Loosening nuts, screws and bolts
(—) Valve spring compressor  AEBIA2843ZZ	Used to compress intake and exhaust valve springs
(—) Pulley puller  ZZA0010D	Removing crankshaft pulley
(—) Piston ring expander  S-NT030	Removing and installing piston ring
(—) Anti-seize lubricant (Permatex 133AR or equivalent meeting MIL specification MIL-A-907)  AEM489	Lubricating A/F sensors and heated oxygen sensor thread cleaning tool when reconditioning exhaust system threads
(—) Engine stand assembly 1. Engine stand 2. Base  NT042	Disassembling and assembling engine
(—) Tube presser  S-NT052	Pressing the tube of liquid gasket

(TechMate No.) Tool name		Description
(—) Crowfoot	 ALBIA3011ZZ	Removing and installing fuel pressure relief valve **(A) : 30 mm**
(—) Crowfoot	 ALBIA3011ZZ	Removing and installing injector supply lines [(high pressure (bank 1)] **(A) : 17 mm**

SYSTEM DESCRIPTION

ENGINE ASSEMBLY

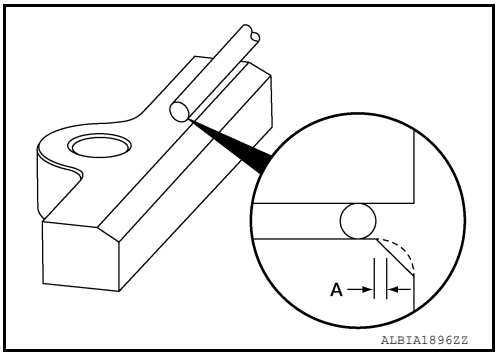
GENERAL SPECIFICATION

GENERAL SPECIFICATION : System Description

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COMPLETE ENGINE - OVERVIEW

- It is important that oil passages are plugged and cavities are masked prior to scraping gasket material and/or cleaning the joint surfaces. Washed parts that will not immediately be assembled into the engine must be covered up to protect against contamination. Regularly clean sockets, wrenches, gauges and containers used for engine repairs. Clean the work surfaces of carts, tool boxes and tables regularly to prevent contaminations of parts.
- Before beginning repairs on a fuel system, be sure to understand the fuel flow of the engine. Pay particular attention to the last point of filtration in the fuel system. After the last point of filtration, contaminants introduced into the fuel system have no possibility of being removed before entering contaminant-sensitive fuel system components.
- Engines that have experienced engine damage because of intake air system component damage that resulted in cylinder liner and piston ring wear must be treated as if the lubricating oil system has been contaminated with debris. The engine must be disassembled and cleaned appropriately to remove debris from the oil galleries, block cavities, cylinder head, and air intake system. Camshafts, rocker arm pins and rollers must also be thoroughly cleaned and examined for wear.
- A number of joints on this engine seal with a formed-in-place gasket (FIPG). Thoroughly clean old sealant, dirt, and oil from parts before applying the sealant. Do not allow oil to contaminate the flanges before or immediately after applying the sealant. Clean all surfaces with isopropyl alcohol prior to applying sealant. Isopropyl alcohol improves the adhesion of the sealant better than brake cleaner and contact cleaner.
- Alodine is then applied to the sealing surfaces and allowed to dry before sealant is applied. Alodine promotes strong adhesion and prevents leaks.
- Always use the sealant specified, and follow the guidelines for bead width and path location. Apply the bead 1 - 2 mm (0.04 - 0.08 in) (A) from the chamfered edge of the flange, and always draw the bead on the inside edge of the bolt holes. For details on the location and quantity of sealant to apply to a component, refer to the sealant path drawing of that individual component. Do not apply more sealant than specified. Excessive amounts of sealant could clog oil passages in the engine.

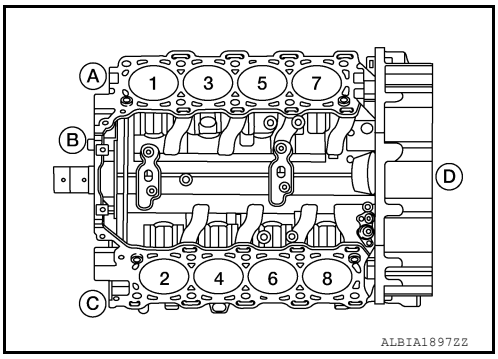


- Parts must be installed and bolts hand tightened within 10 minutes of the sealant being applied. Exceeding this time will reduce the effectiveness of the sealant. Complete the torquing procedure within 30 minutes of applying the sealant.

DEFINITIONS

The following nomenclature is used in all procedures:

- The front of the engine is the engine front (B), the rear of the engine is the engine rear (D).
- Bank 1 (A) and bank 2 (C) of the engine are stated as viewed from the engine rear.
- The cylinders are numbered starting on bank 1 and alternating sides. For example, cylinder number 1 is at the front of the bank 1, and cylinder number 2 is at the front of the bank 2.



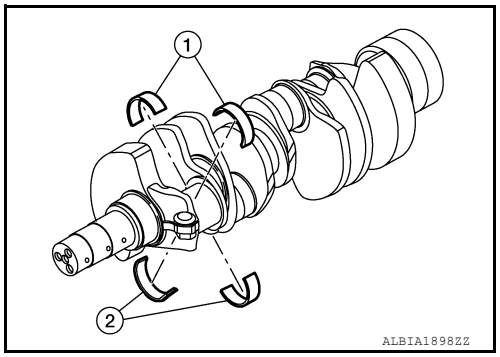
CYLINDER BLOCK

CYLINDER BLOCK : System Description

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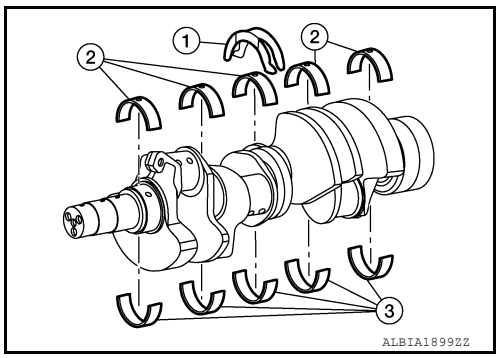
Connecting Rod Bearing

- The upper connecting rod bearing (1) and lower connecting rod bearing (2) are both tri-metal overlays with different linings.
- The upper connecting rod bearings are identified by the mark "UPR" stamped on the back of the connecting rod bearing. The lower connecting rod bearings are identified by the mark "LWR" stamped on the back of the connecting rod bearing.



Main Bearing

- The crankshaft and cylinder block utilize five main bearing journals. Thrust bearings (1) are located on the third main bearing journal to control the end thrust of the crankshaft when axial loads are applied to the end of the crankshaft.
- The upper main bearings (2) are identified by the mark "UPR" stamped on the back of the main bearing. The lower main bearings (3) are identified by the mark "LWR" stamped on the back of the main bearing.
- The upper main bearings have one hole that receives lubricating oil from the main rifle.
- A common cause for increased crankshaft end play and thrust bearing damage is increased end-loading of the engine. The increased end-loading can be the result of driven units at the front or rear of the engine being one of the following:

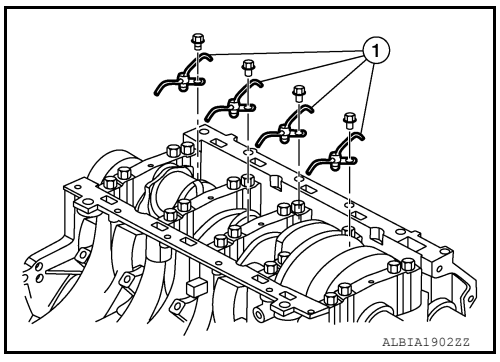


- Incorrectly installed.
- Incorrectly adjusted.
- Incorrectly matched to the engine and exceeding the thrust load limits.

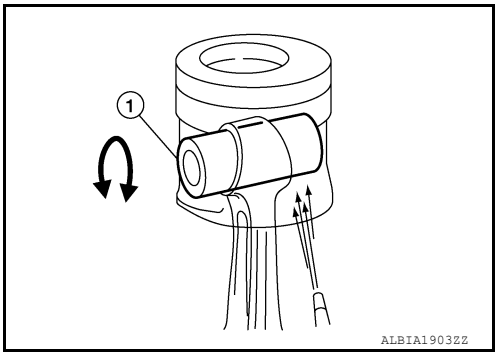
- Improper maintenance of the lubricating system is the primary cause of reduced bearing life.

Piston and Connecting Rod Assembly

- The piston coolant nozzles (1) supply engine oil to the underside of the pistons. The pistons have an oil passage cast into the piston for cooling purposes.

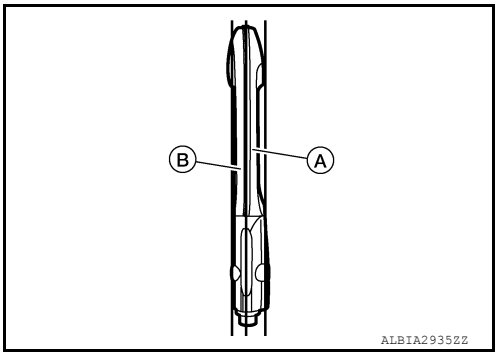


- A free-floating, hollow piston pin (1) is used to attach the piston to the connecting rod. Lubrication for the piston pin and journal is supplied by residual spray from the piston coolant nozzles.

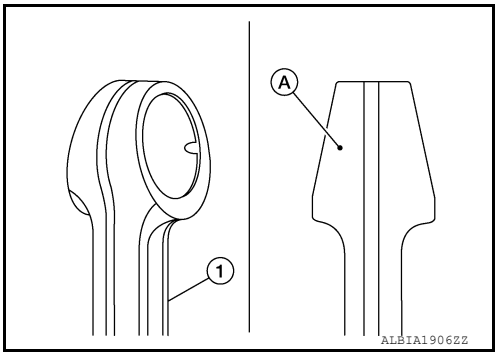


Connecting Rod

- The large end of the connecting rod is wider on one side (A) than the other side (B). When installing, the orientation of the connecting rod relative to the piston is important.



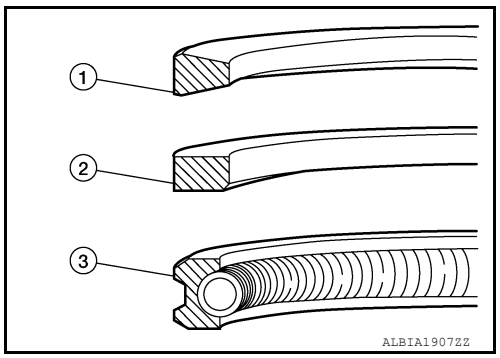
- The connecting rod I-beam is drilled to provide oil to the piston pin.
- The long side of the connecting rod shank is positioned on the left side of the engine, or with the rotation of the crankshaft.
- When assembling and installing the piston and connecting rod assembly, it is critical that the orientation of the components is correct.
- The connecting rod crankshaft bore is an angle and fracture-split design with two bolts.
- The contact surface between the connecting rod and the connecting rod cap is not a machined surface. The surface is the result of the connecting rod being fractured during the manufacturing process to separate the connecting rod cap from the connecting rod.
- This surface can not be considered damaged unless there are deep nicks or cracks across the surface.
- The piston pin end (A) of the connecting rod (1) is angle-cut to provide additional bearing surface and is fitted with a bushing.
- The connecting rod small end bore does not have an oil drilling.



Piston Rings

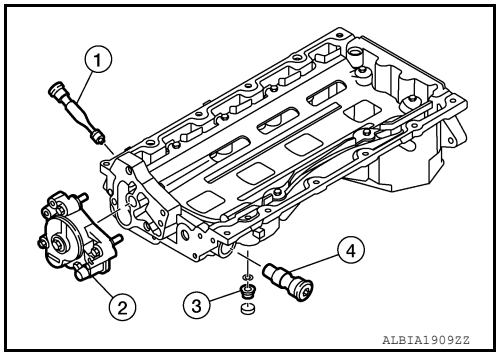
- The piston ring type and location can be identified by the piston ring profile below:

(1) : Top piston ring
(2) : Intermediate piston ring
(3) : Oil control ring

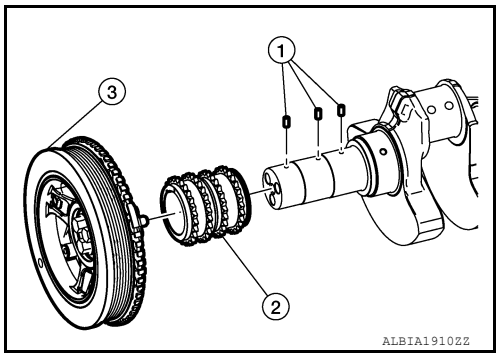


Cylinder Block
- The cylinder block is made of compacted graphite iron.
- The block is a parent bore design and the cylinder bores are not salvageable.

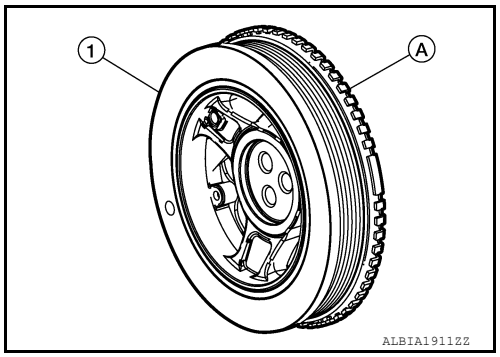
Block Stiffening Plate
- The block stiffening plate is used to help strengthen the cylinder block and contains the oil pump (2), oil pressure regulator (1), crankcase ventilation check valve (3) and the oil check valve (4).



Crankshaft
- The crankshaft nose has three alignment pins (1) for the crankshaft sprockets (2) and vibration damper (3). These pins are not designed to take a load. Align the crankshaft sprocket keyways with the pins before installing onto the crankshaft. Always hold the crankshaft sprockets with a suitable tool when tightening or loosening the camshaft, fuel pump, or oil pump sprockets. Align the vibration damper keyway over the pins before installing the damper.

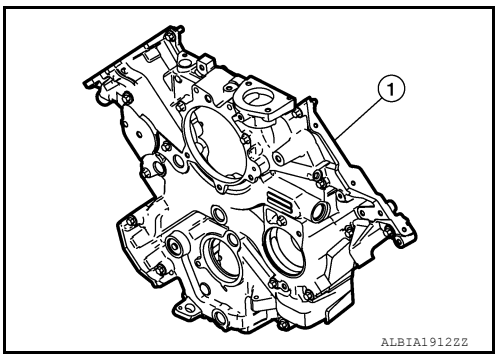


Vibration Damper and Crankshaft Speed Indicator Ring
- The vibration damper (1) and crankshaft speed indicator ring (A) are an assembly. If either the vibration damper or crankshaft speed indicator ring is damaged, the entire assembly must be replaced.



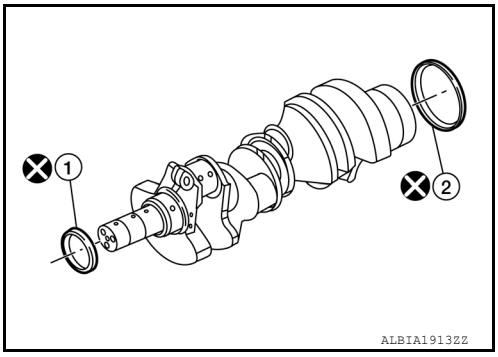
Front Cover

- The front cover (1) houses the chain drive system, lubricating oil pump and fuel pump. The front crankshaft seal, water pump, vacuum pump or fan hub, belt tensioner, lubricating oil filter, water inlet connection, thermostat, lubricating oil cooler, and idler pulleys are installed on the front cover. The front cover has internal oil and coolant passages to feed the block, ladder frame, and cylinder heads.



- The engine uses a lip style front oil seal (1) and rear oil seal (2) in which the rotating portion of sealing occurs at the contact surface between the lip of the seal and crankshaft.
- The front oil seal is installed in the front cover.
- The rear oil seal is installed in the rear seal carrier.

CAUTION:
Do not reuse oil seals.



CYLINDER HEAD

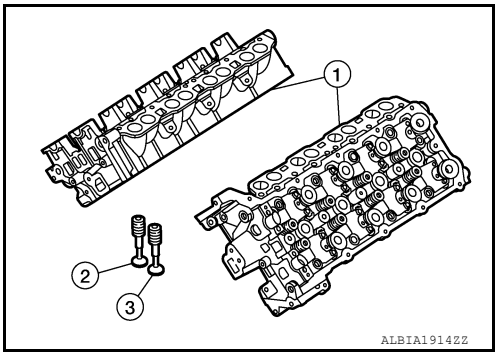
CYLINDER HEAD : System Description

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CYLINDER HEAD - OVERVIEW

Cylinder Head Assembly

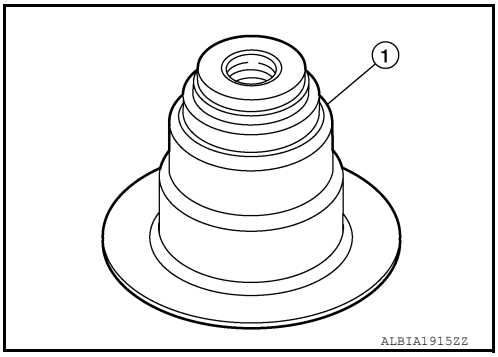
- The cylinder heads (1) are a one-piece, cross flow design with four valves per cylinder made of aluminum. The four valve per cylinder design allows for a centered injector in the cylinder heads.
- The intake valves (2) and exhaust valves (3) are made of heat resistant steel, and have chrome plated stems to prevent scuffing. The intake and exhaust valves are both similar in head diameter and overall length, but have unique face angles, which makes them non-interchangeable.
- The valve springs are made from high-strength, chrome silicon steel.



Valve Guide Seal

- The valve guide seals (1) are of a 'top-hat' design which utilizes the valve spring to secure the valve guide seal in place.

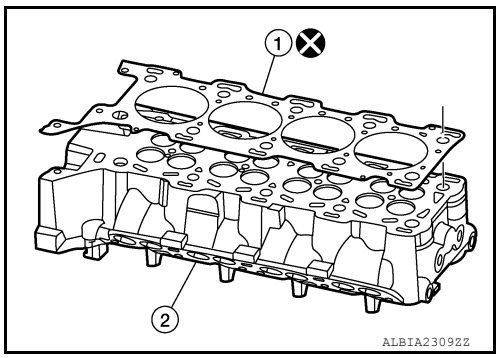
CAUTION:
Do not reuse valve guid seal.



Cylinder Head Gasket

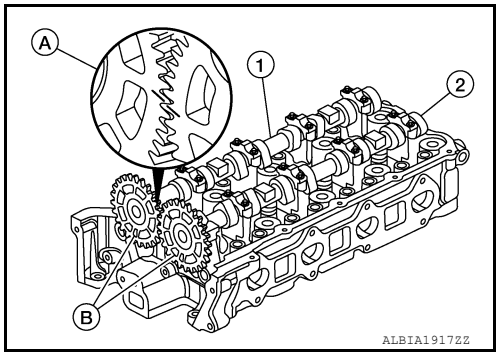
- The cylinder head gasket (1) is a specialized metal design with a printed O-ring seal on both sides around the water holes. The gasket also provides orifices to control coolant flow from the cylinder block to the cylinder heads (2).

CAUTION:
Do not reuse cylinder head gasket.



Camshaft and Camshaft Gear

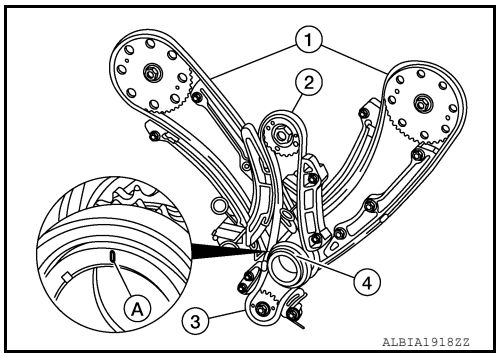
- The intake camshaft (1) and exhaust camshaft (2) are located in the cylinder heads. There are two camshafts per cylinder head; one for intake valves and one for exhaust valves. The camshafts are labeled with position and bank on the rear flat.
- The camshaft gear (B) is press fit onto the camshaft. The camshaft gears are not serviceable.
- The intake and exhaust camshafts have alignment marks (A) to help when installing the intake and exhaust camshafts.



Camshaft Timing Chains, Fuel Pump and Oil Pump Drive Chain

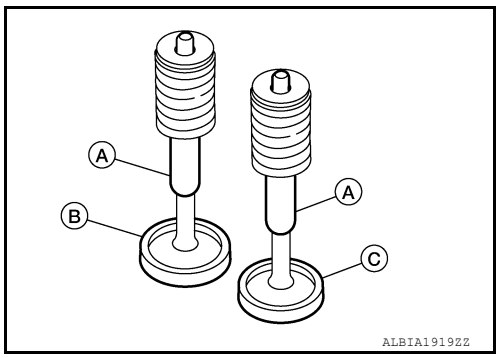
- The camshafts, fuel pump and oil pump are driven by chains.
- The camshaft timing chains (1) are interchangeable. The fuel pump chain (2) has blue links that must be lined up with the marks to the sprockets to time the fuel pump.
- The crankshaft sprocket (oil/fuel pump) (4) has a scribed dot (A) that points up when the piston for cylinder 1 is at top dead center.

(3) : Oil pump drive chain



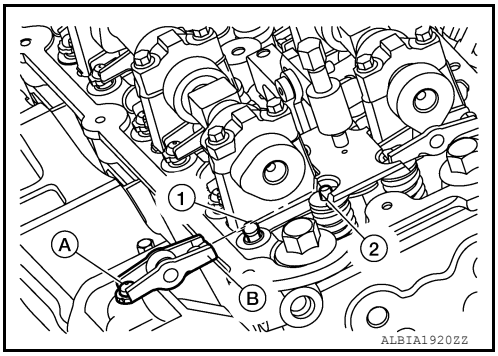
Valve Guide and Valve Insert

- The cylinder head has pressed-in valve guides (A) which can not be replaced.
- The intake valve seat insert (B) and exhaust valve seat insert (C) are not serviceable on this engine.



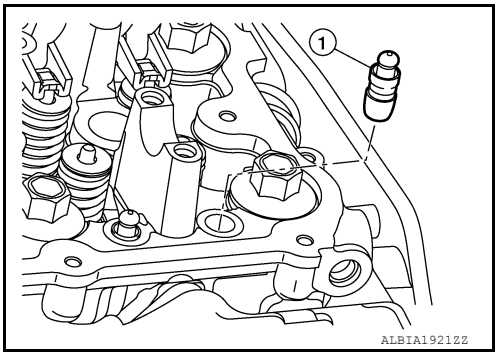
Rocker Arm

- Rocker arm must be installed in the correct orientation on the engine. The spherical cup end (A) should be over the lash adjuster (1), while the flat end (B) is over the valve stem (2).



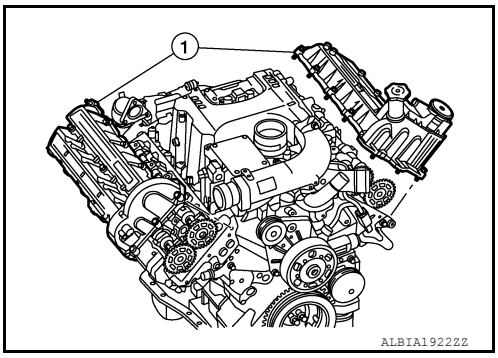
Hydraulic Lash Adjuster

- Hydraulic lash adjusters (1) flow oil from the cylinder head to automatically adjust the clearance between the rocker arms and valve stems. The hydraulic lash adjusters must be installed with the rounded end pointing up.



Rocker Cover

- The bolts in the rocker cover are captured and should not be removed from the bolt holes. In order to remove the rocker covers (1), the fuel injectors and fuel lines must to be removed.

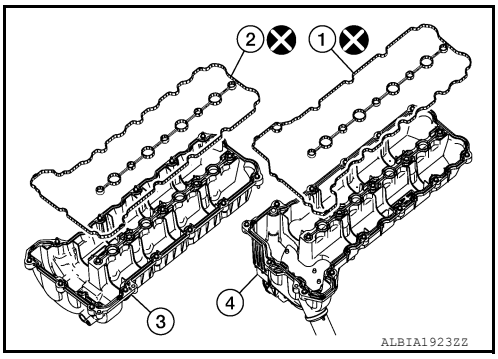


Rocker Cover Gasket

- The rocker cover [bank 1 (3)] and rocker cover [bank 2 (4)] use a molded rubber gasket (1) and (2). The molded gasket is inserted into a groove along the perimeter of the rocker cover.

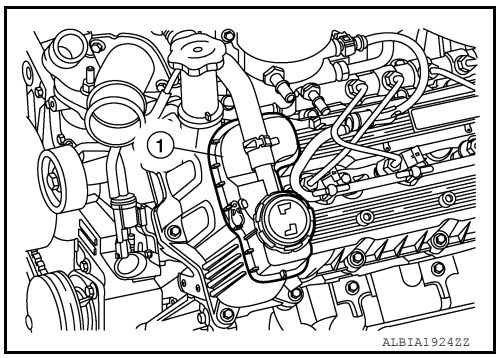
CAUTION:

Do not reuse rocker cover gasket.



Closed Crankcase Breather

- The closed crankcase breather is integrated into the rocker cover [bank 2 (1)]. Oil vapor is separated and condensed in the closed crankcase breather and returned to the oil pan by internal plumbing through the cylinder block. The closed crankcase breather is not serviceable. If the closed crankcase breather is damaged, the rocker cover (bank 2) must be replaced.



INTAKE AIR SYSTEM

INTAKE AIR SYSTEM : System Description

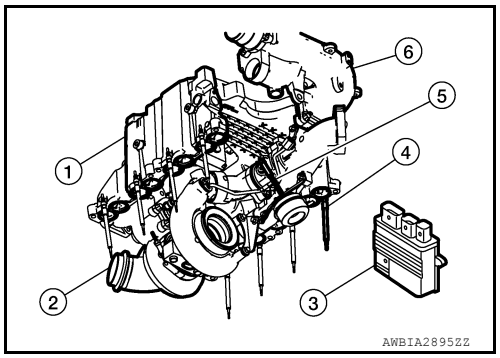
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GENERAL INFORMATION

General Information

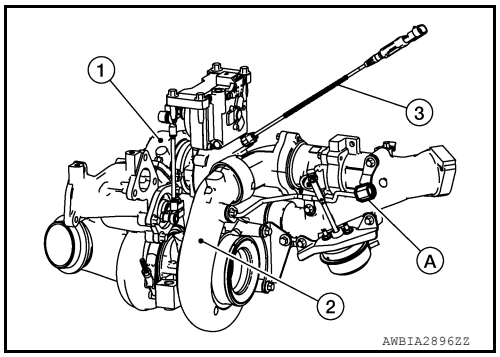
- The air intake system and exhaust system components work together to provide the correct amount of intake charge flow into the engine. The overview will go over the major components of the intake system.

(1) : Intake manifold
(2) : Turbocharger assembly
(3) : Glow plug controller
(4) : Glow plug
(5) : Turbocharger compressor bypass valve
(6) : Air intake connection

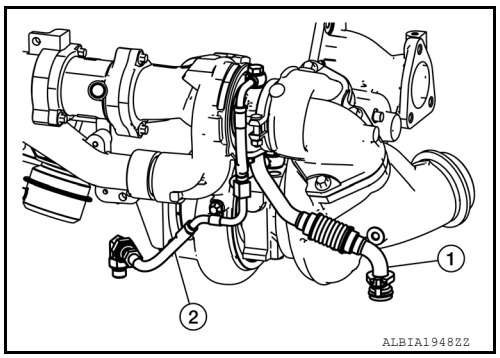


Turbocharger Assembly

- This turbocharger assembly consists of a low-pressure and high-pressure turbocharger.
- The high-pressure turbocharger (1) and low-pressure turbocharger (2) are serviceable as an assembly or can be replaced separately. The high-pressure turbocharger has a speed sensor (3) mounted on its compressor housing.
- The low-pressure turbocharger boost sensor and tube (4) are mounted to the low-pressure turbocharger compressor housing.

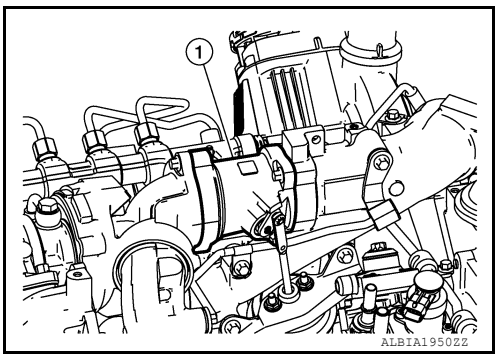


- Engine oil is used to lubricate the bearings and provide cooling for the turbochargers. The engine oil is supplied to the turbocharger through the turbocharger oil supply line (2) at engine operating pressure. The turbocharger oil supply line feeds both turbochargers.
- A turbocharger oil drain line (1) for the high-pressure turbocharger drains into the back of the engine block. The low-pressure turbocharger drains through it's mount on the engine block.

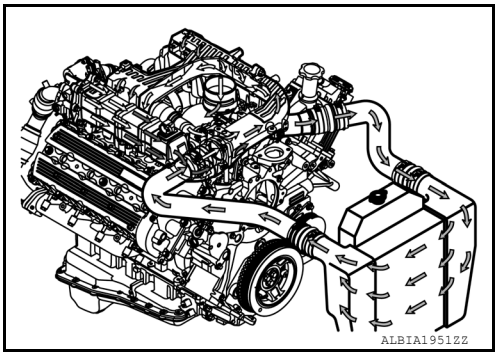


Turbocharger Compressor Bypass Valve

- The turbocharger compressor bypass valve (1) controls the amount of air that goes into the high-pressure turbocharger. The turbocharger compressor bypass valve actuator is mounted on the turbocharger compressor outlet connection, vacuum driven, and controlled by the ECM via the turbocharger compressor bypass valve solenoid.



- This engine uses a charge-air cooler to improve engine performance. This system also uses large diameter piping to transfer the air from the turbocharger to the charge-air cooler, then returns the air from the charge-air cooler to the intake manifold.
- As the intake air is compressed by the turbocharger, the air temperature increases. This heated air is then passed through the charge-air cooler, which cools the air. Cool air is more dense, which allows more air to be compressed into the cylinder, yielding higher combustion efficiency.



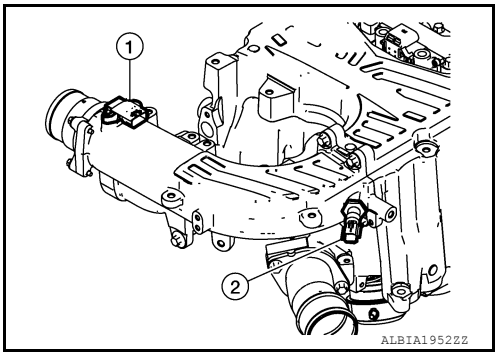
INTAKE AIR SYSTEM : Overview

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AIR INTAKE SYSTEM - OVERVIEW

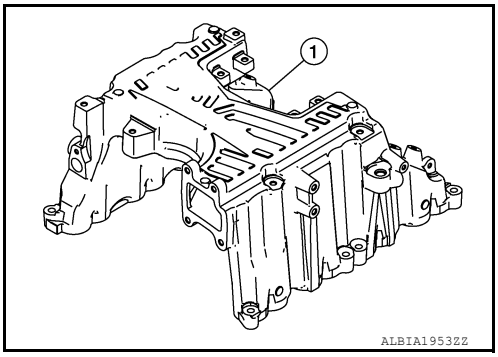
Air Intake Connection

- Once the intake air is cooled and exits the charge-air cooler, it then feeds through the air intake connection.
- The charge-air cooler outlet pressure/temperature sensor (1) is located on the air intake connection. Then, the EGR mixes in from the EGR bypass valve and EGR cooler.
- Further upstream the intake manifold air temperature sensor (2) measures the intake charge temperature before entering the intake manifold.



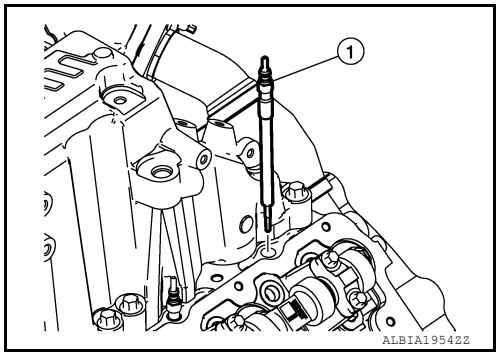
Intake Manifold

- The intake manifold (1) separates the intake flow to feed the bank 1 and bank 2 cylinders.



Glow Plug and Glow Control Unit

- The glow plugs (1) are threaded into the cylinder head and heat the intake charge to facilitate engine starting in cold weather.
- The glow plugs are commanded by a remote mounted glow control unit.



Intake Air Flow Description

Air Cleaner
- Air first flows through the air cleaner, where foreign material and debris are removed.

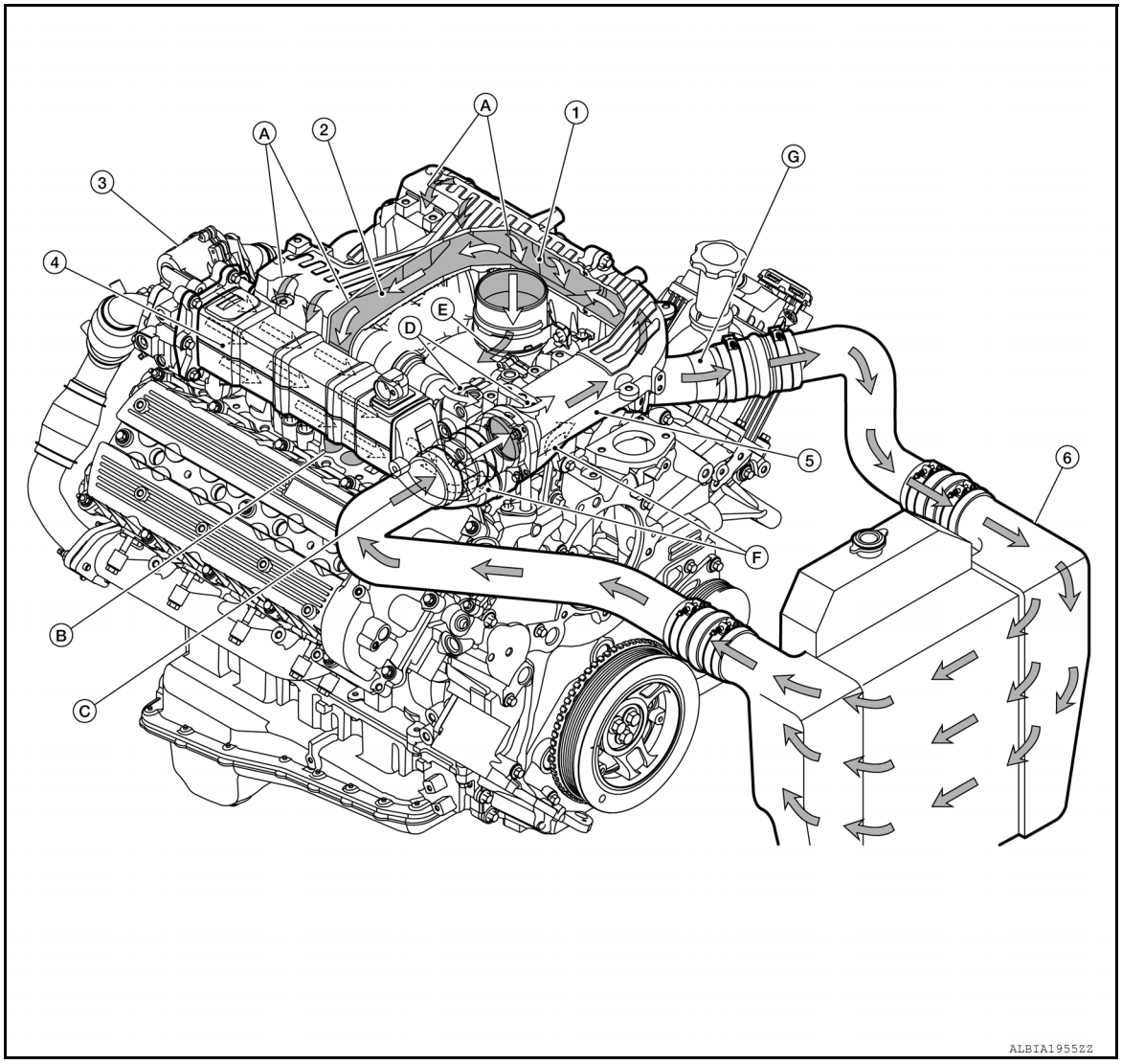
Air Inlet Connection and Low-Pressure Turbocharger
- Air then flows through the air inlet connection to the low-pressure turbocharger compressor inlet. Air is compressed and goes to the high-pressure turbocharger for more pressure or bypasses the high-pressure turbocharger via the turbocharger compressor bypass valve. The intake charge is compressed to a level of pressure determined by the ECM. The ECM regulates the level of pressure in the intake system via the rotary turbine control valve and the turbocharger compressor bypass valve.

Charge-Air Cooler
- After the air flows out of the turbocharger compressor outlet connection, it gets passed through a charge-air cooler to remove some of the heat generated by compressing the air. By lowering the temperature of the air, it's density is increased. The increased density of the air allows the engine to meet emissions levels while maintaining a higher level of performance.

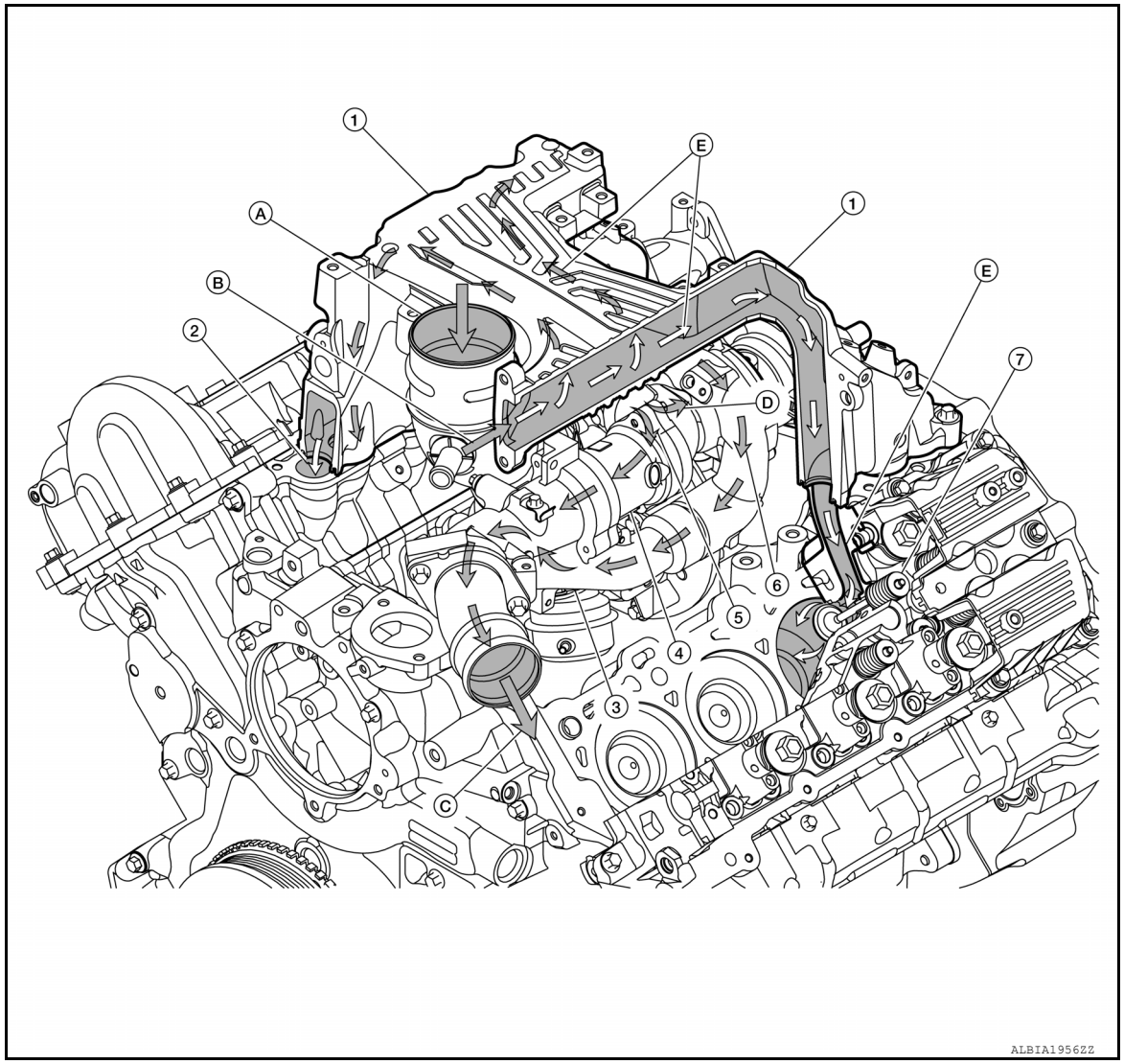
Air Intake Connection Adapter, Air Intake Connection and Intake Manifold
- From the outlet of the charge-air cooler, air flows into the air intake connection. From here, the intake air mixes with the EGR before flowing into the intake manifold, where the EGR and fresh air mixture is distributed to the cylinders.

INTAKE AIR SYSTEM : Air Flow Diagram

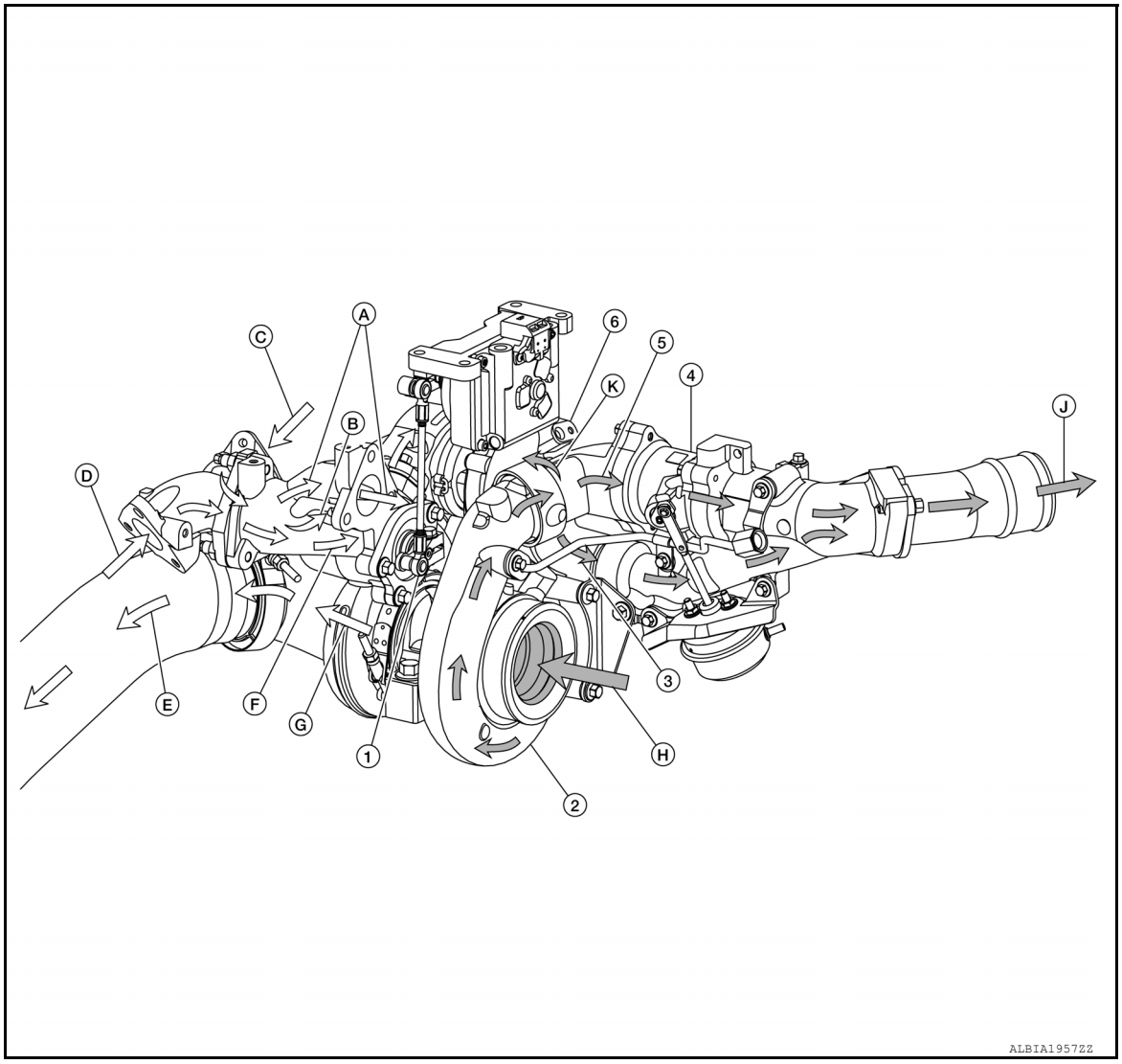
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1. Air inlet connection
2. Intake manifold
3. EGR valve
4. EGR cooler
5. Intake air connection
6. Charge-air cooler
A. Intake air flow to cylinder heads
B. Air intake port to cylinder
C. Air flow to intake air connection
D. Air flow to intake air connection (EGR bypass valve open)
E. Air flow to low pressure turbo-charger compressor inlet
F. EGR cooled exhaust flow to in-take air connection
G. Air flow to charge-air cooler



1. Intake manifold
2. Cylinder head air intake port
3. Turbocharger compressor outlet connection
4. Turbocharger compressor bypass valve
5. Low pressure turbocharger compressor outlet
6. High pressure turbocharger compressor outlet
7. Intake valve
A. Air inlet connection to low pressure turbocharger compressor inlet
B. Air flow from charge-air cooler and intake air connection
C. Air flow to charge-air cooler
D. Low pressure turbocharger compressor outlet to high pressure turbocharger compressor inlet
E. Air flow to bank 1 and bank 2 cylinder heads



1. Rotary turbine control valve
2. Low pressure turbocharger compressor
3. High pressure turbocharger compressor outlet
4. Turbocharger compressor bypass valve
5. Low pressure turbocharger compressor outlet
6. High pressure turbocharger compressor
- A. Exhaust flow to EGR bypass valve
- B. Exhaust flow to high pressure turbocharger turbine
- C. Exhaust flow from bank 2
- D. Exhaust flow from bank 1
- E. Exhaust outlet to aftertreatment system
- F. Exhaust flow to low pressure turbocharger turbine
- G. Exhaust flow from low pressure turbocharger
- H. Intake air flow from air inlet connection
- J. Intake air flow to charge-air cooler
- K. Intake air flow from low pressure turbocharger compressor to high pressure turbocharger compressor

FUEL SYSTEM

FUEL SYSTEM : System Description

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FUEL INJECTORS AND FUEL LINES - OVERVIEW

WARNING:

The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:

- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.**
- **Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

CAUTION:

Cleanliness of the fuel system is extremely important. Small amounts of dirt and debris can cause damage to the fuel system components.

- Due to the fuel system components having small precision tolerances, make certain that the following items are completed for fuel system operation:

- Clean all fuel system fittings, fuel lines, and components before disassembly.
- Make certain that dirt and/or debris does not enter the fuel system components to prevent the passing of contaminants to the fuel rail and fuel injectors.
- Do not pre-fill the stage 1 or stage 2 fuel filter.

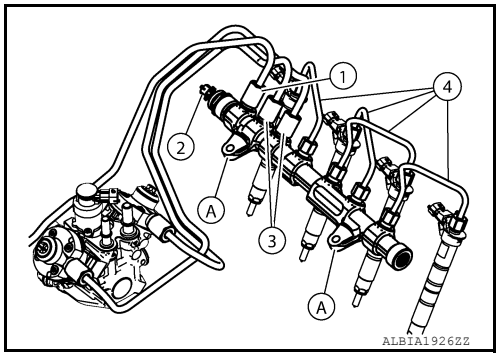
Proper Use of Fuel System Gauges

- **CAUTION:**
  - **Never exceed the maximum capacity of the gauge or flow meter. Exceeding the maximum capacity will cause the gauge to read incorrectly. If the maximum is exceeded, check the gauge against a reference gauge.**
  - **Do not loosen the vacuum gauge connections when the engine is operating. Doing so can introduce air into the fuel system, causing the engine to run rough or stall.**
- **NOTE:**
  - To be sure the pressure gauge reading is correct, always remove the air from the pressure gauge line before taking a reading.
  - Read the gauge in direct alignment with the gauge hand.
  - Portable fuel pressure gauges must be checked regularly against a reference gauge or against the gauge on the fuel pump test stand. Adjust the valve on the gauge until the gauge needle stops vibrating.
  - Always use the same size and material of line or hoses that were originally supplied with the gauge.
  - The distance from the gauge to the connection point must be as short as possible.

Fuel Rail (bank 1)

- The fuel rail contains high-pressure fuel from the fuel pump. The components of the fuel rail (bank 1) include the following items:

(1) : Fuel rail to fuel rail supply line
(2) : Fuel rail pressure sensor
(3) : Fuel supply lines
(4) : Injector supply lines
(A) : Bracket

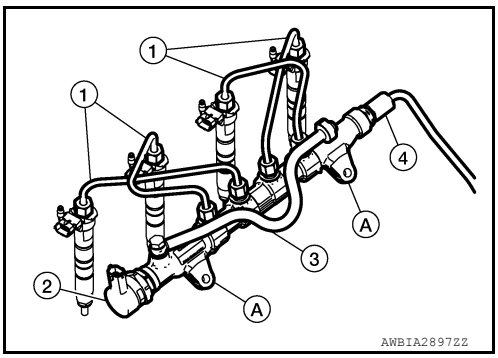


- The fuel supply lines connect the high-pressure fuel pump to the fuel rail.
- The fuel rail to fuel rail fuel supply line connects the fuel rail (bank1) to the fuel rail (bank 2).

Fuel Rail (bank 2)

- The fuel rail contains high-pressure fuel from the fuel pump. The components on the fuel rail (bank 2) include the following items:

(1) : Injector supply lines
(2) : Fuel pressure relief valve
(3) : Fuel rail pressure relief valve drain line
(4) : Fuel rail to fuel rail supply line
(A) : Bracket

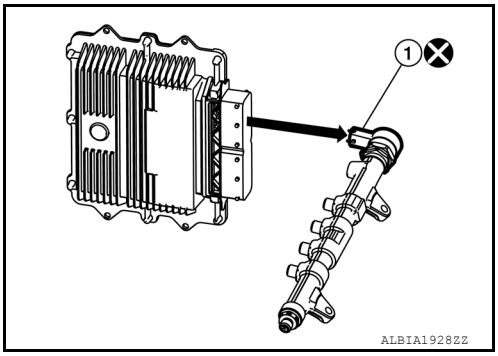


- The fuel rail to fuel rail supply line connects the fuel rail (bank 1) to the fuel rail (bank 2).

Fuel Pressure Relief Valve

- The fuel pressure relief valve (1) is mounted on the rear side of the fuel rail (bank 2). It is electronically controlled by a signal from the ECM. When no current is applied to the fuel pressure relief valve the valve is open. The fuel pressure relief valve and fuel pump actuator work together to maintain the pressure in the fuel rail that is desired. When the fuel pressure relief valve is open fuel flows through the fuel pressure relief valve drain line and joins the return flow from the fuel pump at the stage 2 fuel filter and returns back to the stage 1 fuel filter/ fuel tank.

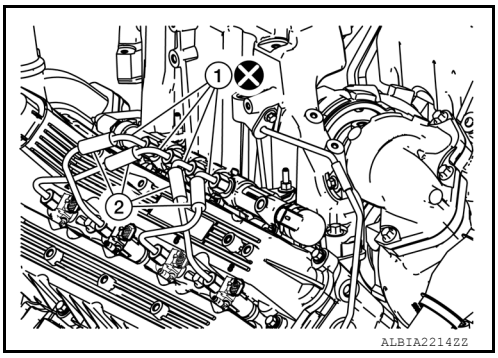
CAUTION:
Do not reuse fuel pressure relief valve.



Injector Supply Line

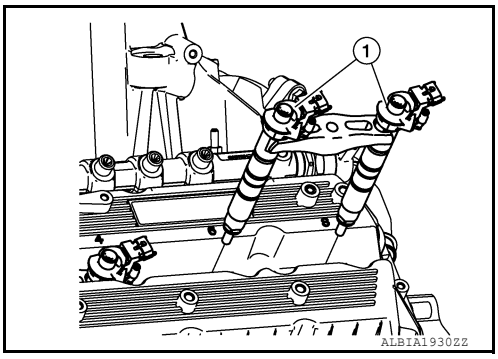
- The injector supply lines (1) are connected to the fuel rail(s) and to the fuel injector(s). The injector supply lines require the use of isolators (2) to dampen vibrations. The injector supply lines do not require external support.

CAUTION:
Do not reuse injector supply lines.



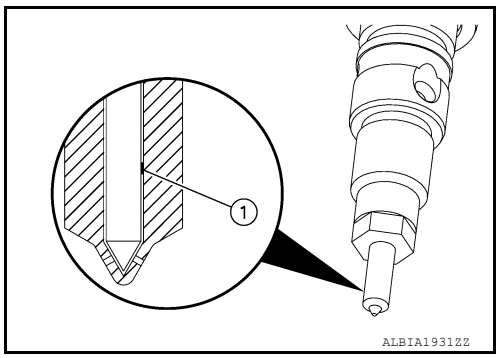
Fuel Injector

- This high-pressure common rail fuel system has piezo actuated fuel injectors (1). High-pressure fuel flows into the top of the fuel injector. When the piezo stack is activated, it expands causing an internal valve to open which lowers the pressure in the control room. The lower pressure in the control room causes the needle to open and fuel is injected.



- The ECM controls the fueling and timing of the engine by actuating the piezo stack in the fuel injector. An electronic pulse is sent to the piezo stack to expand the stack and start the injection event. By electronically controlling the fuel injectors, there is more precise and accurate control of fueling quantity and timing. Also, multiple injection events can be achieved by electronically controlling the injectors.

- The clearances in the nozzle bore (1) are extremely small and any dirt or contaminants will cause the fuel injector to stick.



- This is why it is important to clean around all fuel connections before servicing the fuel system. Also, cap or cover any open fuel connections before a fuel system repair is performed.
- All fuel injectors connect to a fuel injector drain line. Fuel from fuel injectors and both banks combines at a constant pressure valve where pressure is regulated to no less than 1100 kPa (11.22 kg/cm^2, 159.5 psi). Fuel from the fuel injector drain line feeds into the supply of the stage 2 fuel filter. For an engine that has run out of fuel, fuel can run in reverse in the fuel injector drain line to fill the line quicker, this will aid in quicker starting of the engine.

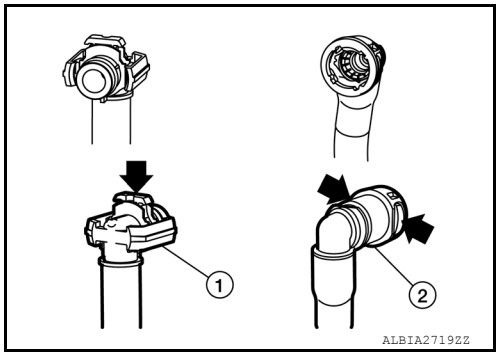
Fuel Supply and Drain Line

CAUTION:

Do not use a screwdriver or pliers on the locking tabs. This may result in damage to the quick disconnect fitting.

Some fuel supply and drain line connections will utilize quick disconnect fittings.

- Direction for service of a one-button quick-disconnect connector (1):
  - Remove the one-button connector by pressing in the raised section of the clip on the connector.
  - With the clip fully depressed, the fuel line can be removed from the mating female port.
  - Install the one-button quick-disconnect style fuel lines by pushing the male connector into the female mating port until it clicks.
- Direction for service of a two-button quick-disconnect connector (2):
  - Remove the two-button style fuel lines by pressing in the locking tangs on both sides of the quick-disconnect connector.
  - After pressing the opposing locking tangs, the fuel line should be free to be pulled off the male fuel fitting.
  - Install the two-button quick-disconnect style fuel lines by pushing the quick-disconnect connector onto the male fuel fitting until it clicks.

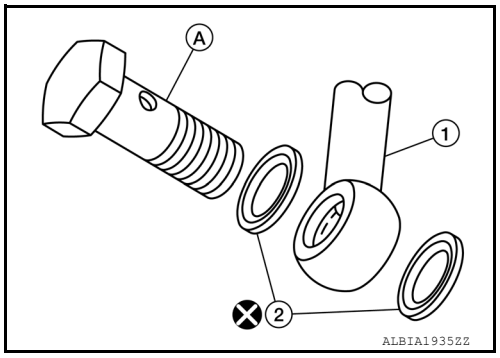


- Some fuel supply and drain line connections will use traditional banjo style fittings.

(A) : Banjo bolt
(1) : Banjo fitting
(2) : Copper sealing washer

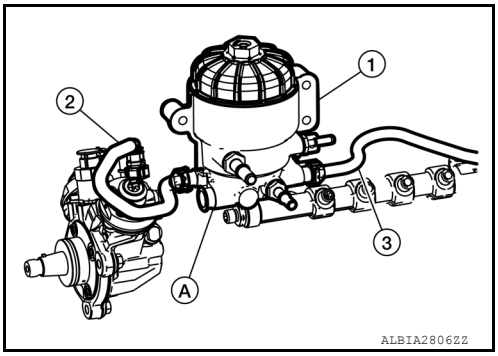
CAUTION:

Do not reuse washer.



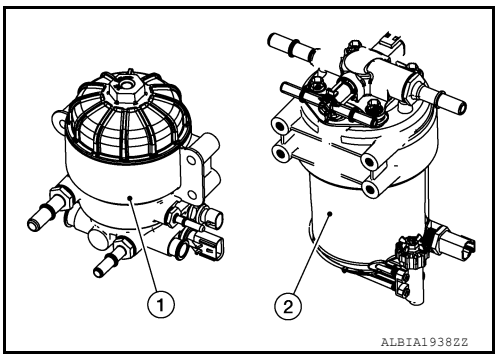
Fuel Pressure Relief Drain Line

- The fuel rail pressure relief valve drain line (3) and fuel pump drain line (2) combine together at a manifold (A) in the bottom of the Stage 2 fuel filter (1). The manifold is where the fuel drain line connects to return the fuel to the Stage 1 fuel filter/fuel supply tank.

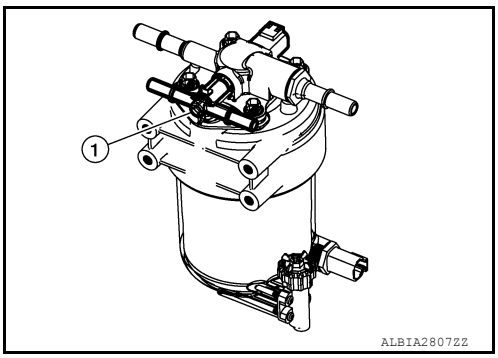


Fuel Filter (Stage 1 and Stage 2)

- The engine uses a dual fuel filter system.
- The Stage 2 fuel filter (1) is used for filtration only.
- The Stage 1 fuel filter (2) is a lift pump; filter and water separator all-in-one. It is located between the fuel tank and Stage 2 fuel filter. Since the fuel filter houses an electric lift pump, it is not possible to measure the Stage 1 fuel filter restriction.



- The drain portion of the stage I fuel filter contains a thermal recirculating valve (1). Based on the fuel temperature, the fuel is either returned to the fuel tank or directed back into the supply flow of the stage I fuel filter.



Proper Use of Fuel System Gauges

- **CAUTION:**
  - **Never exceed the maximum capacity of the gauge or flow meter. Exceeding the maximum capacity will cause the gauge to read incorrectly. If the maximum is exceeded, check the gauge against a reference gauge.**
  - **Do not loosen the vacuum gauge connections when the engine is operating. Doing so can introduce air into the fuel system, causing the engine to run rough or stall.**
- **NOTE:**
  - To be sure the pressure gauge reading is correct, always remove the air from the pressure gauge line before taking a reading.
  - Read the gauge in direct alignment with the gauge hand.
  - Portable fuel pressure gauges must be checked regularly against a reference gauge or against the gauge on the fuel pump test stand. Adjust the valve on the gauge until the gauge needle stops vibrating.
  - Always use the same size and material of line or hoses that were originally supplied with the gauge.
  - The distance from the gauge to the connection point must be as short as possible.

FUEL SYSTEM : Description

INFOID:0000000014418572

SYSTEM OVERVIEW

WARNING:

The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:

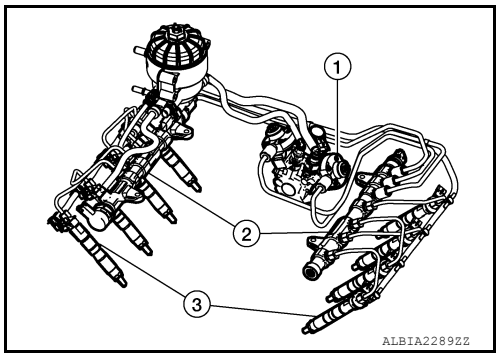
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.**
- **Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

CAUTION:

Cleanliness of the fuel system is extremely important. Small amounts of dirt and debris can cause damage to the fuel system components.

- The fuel system is a high-pressure common rail electronically controlled fuel system. The high-pressure common rail system consists of three main components:

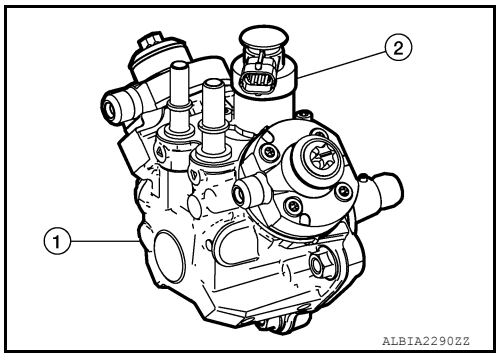
(1) : Fuel pump
(2) : Fuel rail
(3) : Fuel injector



- The fuel pump supplies high-pressure fuel to the fuel rail (bank 1) then to the fuel rail (bank 2). The volumetric fuel flow from the pump is electronically controlled by the fuel pump actuator. The fuel rails pressure is controlled by an interaction between the fuel rail pressure relief valve and the fuel pump actuator. From the fuel rail, a constant supply of high-pressure fuel is supplied to the fuel injectors. The ECM controls the fueling and timing of the engine by actuating the piezo injectors.
- Cleanliness is extremely important in regard to the fuel system components, due to the precision tolerances of these components.
- Make sure to complete the following:
- Clean all fuel system fittings, lines, and components before disassembly.
- Make sure no dirt or debris enters the fuel system components to prevent the passing of contaminants to the high-pressure fuel rail and fuel injectors.
- Do not pre-fill the Stage 1 or Stage 2 fuel filters.
- Even small amounts of dirt and debris can cause a malfunction of the fuel system components.

Fuel Pump

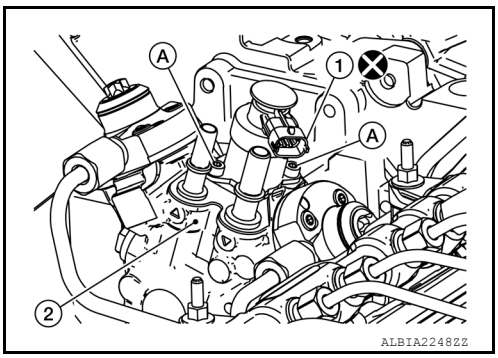
- The fuel pump (1) is chain driven by the crankshaft.
- The fuel pump consists of two main components:
- Pumping chambers - uses two pistons to build high fuel pressure (200,000 kPa [2,040 kg/cm^2, 29,000 psi]).
- Fuel pump actuator (2) - used to control the volumetric flow into the pumping chamber.



Fuel Pump Actuator

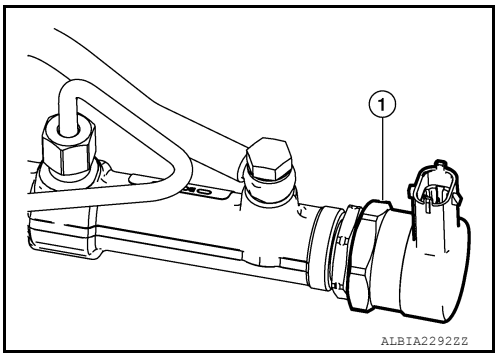
- The fuel pump actuator (1) is mounted on the fuel pump (2) at the inlet to the pumping chambers. It regulates the volume of fuel that is allowed to enter the pumping chambers. The fuel pump actuator is controlled by the signal from the ECM to maintain the pressure in the fuel rails at a desired level (works in conjunction with the fuel pressure relief valve).

(A) : Bolts

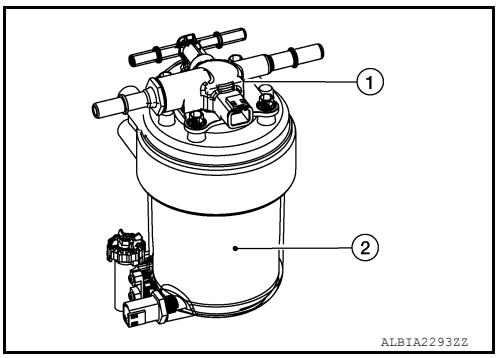


Fuel Pressure Relief Valve

- The fuel rail pressure relief valve (1) is mounted on the rear side of the fuel rail (bank 2). It is electronically controlled by a signal from the ECM. When no current is applied to the fuel rail pressure relief valve, the valve is open. The fuel rail pressure relief valve and fuel pump actuator work together to maintain the pressure in the fuel rail that is desired. When the fuel rail pressure relief valve is open, fuel flows through the fuel rail pressure relief valve drain line and joins the return flow from the fuel pump back to the Stage 1 fuel filter/ fuel tank.



- The engine uses an electric motor-driven lift pump (1). It is located inside the stage 1 fuel filter housing (2). The lift pump draws fuel from the fuel tank and increases fuel pressure before delivering the fuel to the pump. The electric lift pump operates at a constant speed while the engine is operating. If power is lost to the electric lift pump, the engine will not be able to operate.



Fuel Flow Description

Fuel Supply, Fuel Filter and Fuel Pump

- Fuel is drawn from the fuel supply tank through a suction-side fuel/water separating filter (Stage 1), which is remotely mounted on the vehicle chassis, by the electric lift pump (the suction-side fuel filter, fuel water separator, and electric lift pump are all one assembly). The electric lift pump pressurizes the fuel to approximately 450 - 700 kPa (4.5 - 7 kg/cm^2, 65.3 - 101.5 psi) absolute. Fuel exiting the electric lift pump is routed to the pressure-side fuel filter (Stage 2), which is mounted on-engine. From the pressure-side fuel filter, fuel flows to the high-pressure fuel pump. The fuel that enters the high-pressure fuel pump is pressurized to between 25,000 - 200,000 kPa (255 - 2,040 kg/cm^2, 3,625 - 29,000 psi) by two pumping chambers.

Fuel Pump Actuator

- A fuel pump actuator mounted on the fuel pump at the inlet to the two pumping chambers regulates the volume of fuel that is allowed to enter the pumping chambers. The fuel pump actuator is controlled by a pulse-width modulation (PWM) signal from the ECM to maintain the pressure in the fuel rail at a desired level. By regulating the volume of fuel that enters the pumping chambers, the pressure delivered by the fuel pump can be controlled.

Cascade Overflow Valve

- Fuel that is not allowed to enter the two pumping chambers is directed through the cascade overflow valve. The cascade overflow valve directs a certain amount of pressurized fuel to the lube channels of the high-pressure fuel pump. The fuel is then routed to the fuel pump drain line, which returns the fuel to the drain

manifold at the bottom of the Stage 2 fuel filter, which then combines with the fuel rail pressure relief valve flow and returns to the Stage 1 fuel filter/ fuel supply tank.

Fuel Rail (bank 1) and (bank 2), Fuel Rail Pressure Sensor and Fuel Rail Pressure Relief Valve

- High-pressure fuel leaves the fuel pump through a fuel rail supply line to the fuel rail (bank 1). The fuel rail (bank 1) acts as a fuel manifold, accumulating and distributing fuel to each of the injector supply lines. A fuel rail to fuel rail supply line directs fuel from the fuel rail (bank 1) to the fuel rail (bank 2). The fuel rail (bank 1) contains a fuel rail pressure sensor that monitors the pressure provided to the fuel rails from the fuel pump. Pressure measured by the fuel rail pressure sensor is used by the ECM to adjust the valve positions of the fuel pump actuator and the fuel rail pressure relief valve to maintain desired rail pressure. The fuel rail (bank 2) contains a fuel rail pressure relief valve. The fuel rail pressure relief valve is controlled by a PWM signal from the ECM to maintain the pressure in the fuel rail at a desired level. Fuel from the fuel rail pressure relief valve is routed to the return manifold in the bottom of the Stage 2 fuel filter, and is then routed to the Stage 1 fuel filter/ fuel supply tank.

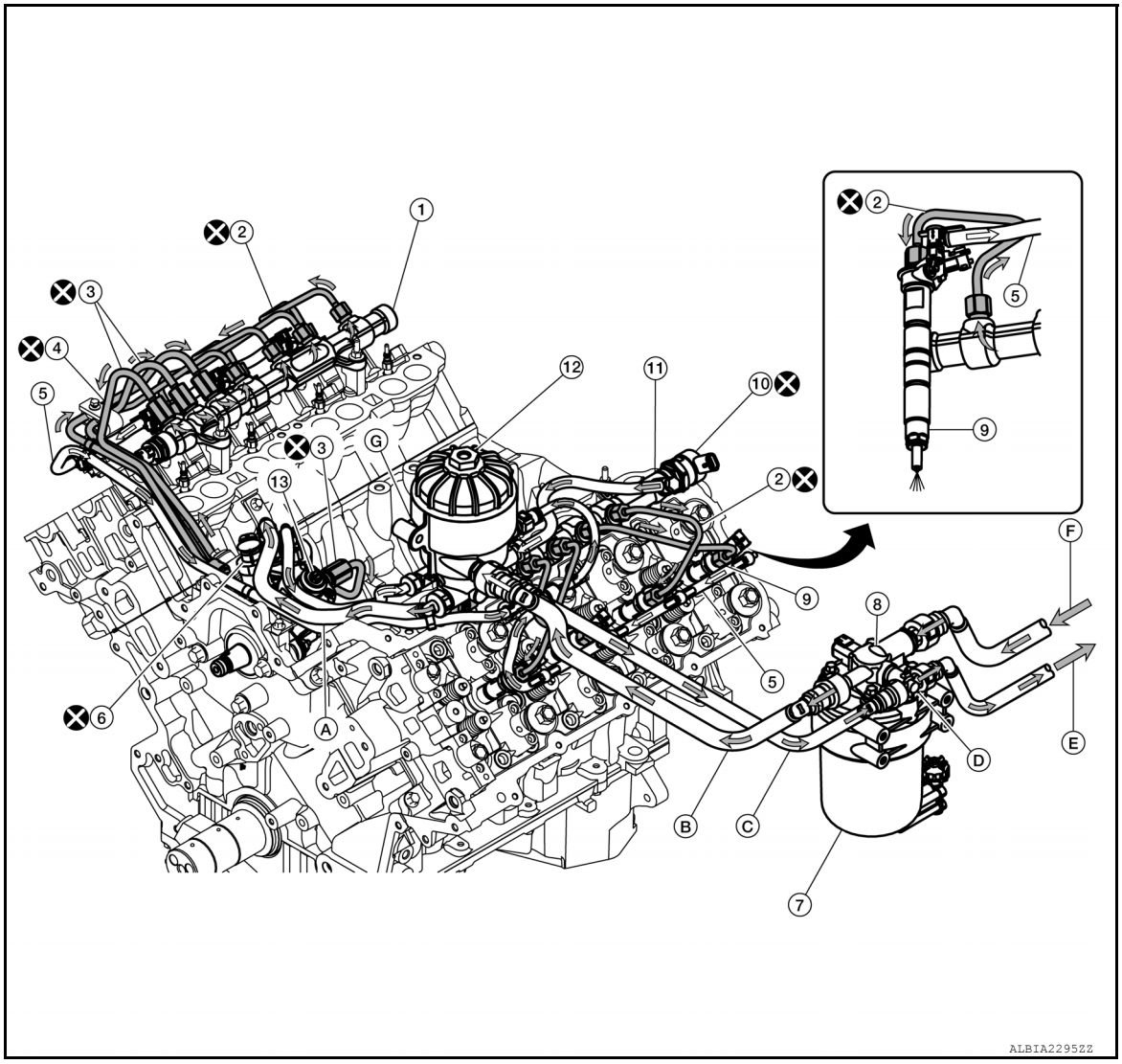
Injector Supply Lines, Fuel Injectors and Injector Drain Line

- From the injector supply lines, high-pressure fuel is directed to the fuel injectors. Each fuel injector is equipped with a piezo stack that, when commanded by the ECM, controls when the fuel injector provides fuel. Excess fuel not used by the fuel injectors is drained into the injector drain line. The injector drain line returns fuel from both banks of fuel injectors. The return fuel flows through a constant pressure valve and back into the supply fuel in the Stage 2 fuel filter housing. The constant pressure valve keeps constant back-pressure on the injectors at 1100 - 1400 kPa (11.22 - 14.28 kg/cm^2, 159.5 - 203.1 psi).

FUEL SYSTEM : Fuel Flow Diagram

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FLOW DIAGRAM



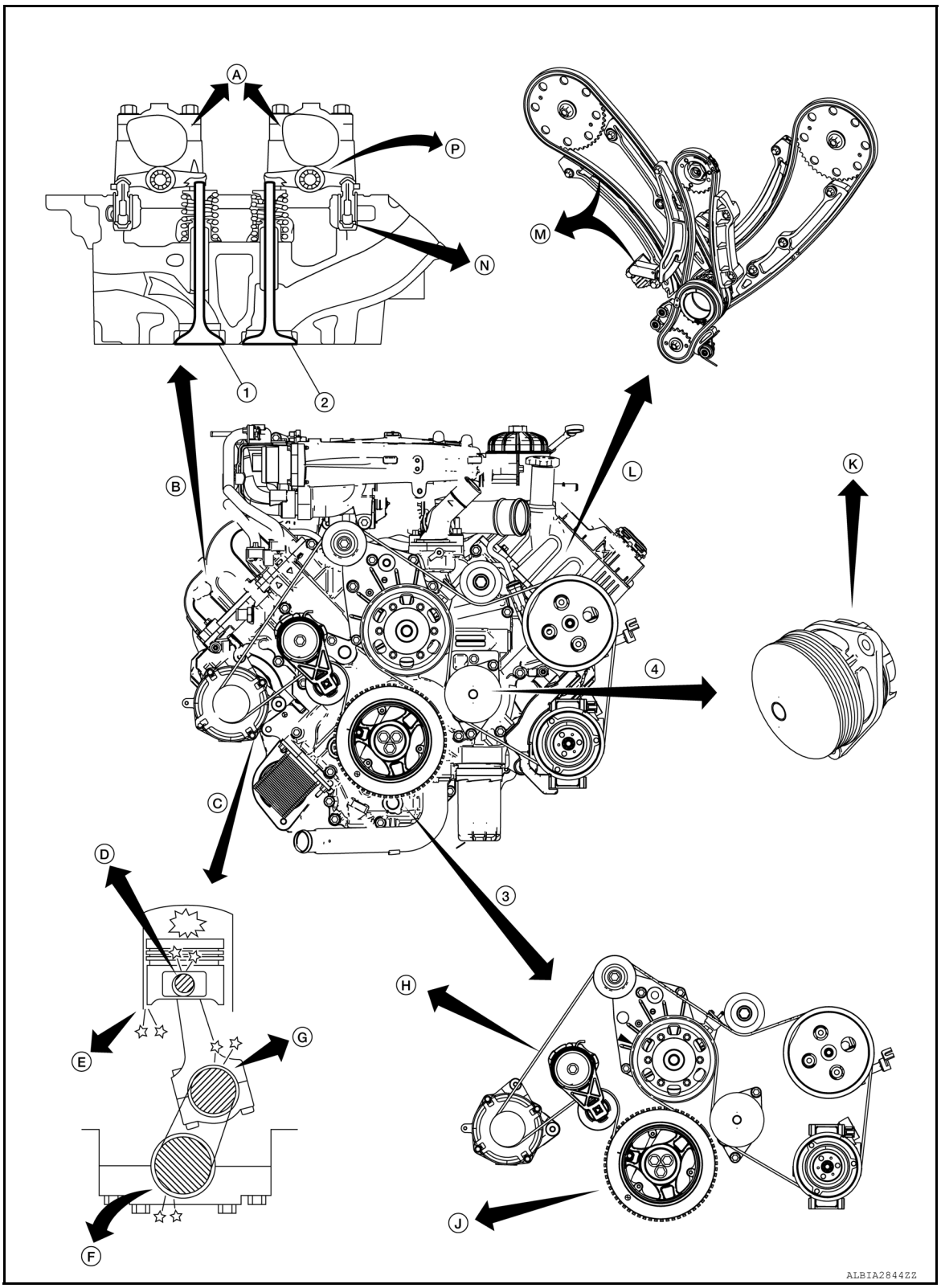
1. Fuel rail (bank 1)
2. Injector supply line
3. Fuel rail supply lines
4. Fuel rail to fuel rail supply line
5. Injector drain line (returns to supply of Stage II fuel filter)
6. Fuel pump actuator
7. Stage I fuel filter housing
8. Electric lift pump
9. Fuel injector
10. Fuel rail pressure relief valve
11. Fuel rail (bank 2)
12. Stage II fuel filter housing
13. Fuel pump
A. Fuel flow to fuel pump
B. Fuel supply to Stage II fuel filter
C. Fuel return to thermal recirculation valve (Stage I fuel filter)
D. Thermal recirculation valve
E. Fuel return to fuel tank
F. Fuel flow from fuel tank
G. Combined fuel return (manifold located in bottom of Stage II fuel filter)

SYMPTOM DIAGNOSIS

NOISE, VIBRATION, AND HARSHNESS (NVH) TROUBLESHOOTING

NVH Troubleshooting - Engine Noise

INFOID:0000000014418574



1. Exhaust valve
2. Intake valve
3. Drive belt
4. Water pump
A. Camshaft noise
B. Valve train
C. Rotating assembly
D. Piston pin noise
E. Piston slap noise
F. Main bearing noise
G. Connecting rod noise
H. Drive belt noise (slipping)
J. Drive belt noise (slipping/sticking)
K. Water pump noise
L. Timing and drive chains
M. Timing chain and chain tensioner noise
N. Hydraulic lash adjuster noise
P. Rocker arm noise

Use the Chart Below to Help You Find the Cause of the Symptom

INFOID:0000000014418575

1. Locate the area where noise occurs.
2. Confirm the type of noise.
3. Specify the operating condition of engine.
4. Check specified noise source.

If necessary, repair or replace these parts.

Location of noise	Type of noise	Operating condition of engine						Source of noise	Check item	Reference page
		Before warm-up	After warm-up	When starting	When idling	When racing	While driving			
Top of engine Rocker cover Cylinder head	Ticking or clicking	A	C	—	B	C	—	Hydraulic lash adjuster noise	Hydraulic lash adjuster	EM-330
	Rattle	C	A	—	A	B	C	Camshaft bearing noise	Camshaft journal clearance	EM-350
Vibration damper Cylinder block (Side of engine) Oil pan	Slap or knock	—	A	—	B	B	—	Piston pin noise	Piston and piston pin clearance	EM-515
	Slap or rap	A	—	—	B	B	A	Piston slap noise	Piston-to-bore clearance Piston ring side clearance Piston ring end gap	EM-515 EM-515 EM-515
	Knock	A	B	C	B	B	B	Connecting rod bearing noise	Connecting rod bushing oil clearance (Small end) Connecting rod bearing clearance (Big end)	EM-515 EM-515
	Knock	A	B	—	A	B	C	Main bearing noise	Main bearing oil clearance	EM-515
Front of engine Front cover	Tapping or ticking	A	A	—	B	B	B	Timing chain and chain tensioner noise	Timing chain cracks and wear	EM-374
Front of engine	Squeaking or fizzing	A	B	—	B	—	C	Drive belts (Sticking or slipping)	Drive belts deflection	EM-198
	Creaking	A	B	A	B	A	B	Drive belts (Slipping)	Idler pulley bearing operation	
	Squall Creaking	A	B	—	B	A	B	Water pump noise	Water pump operation	CO-57

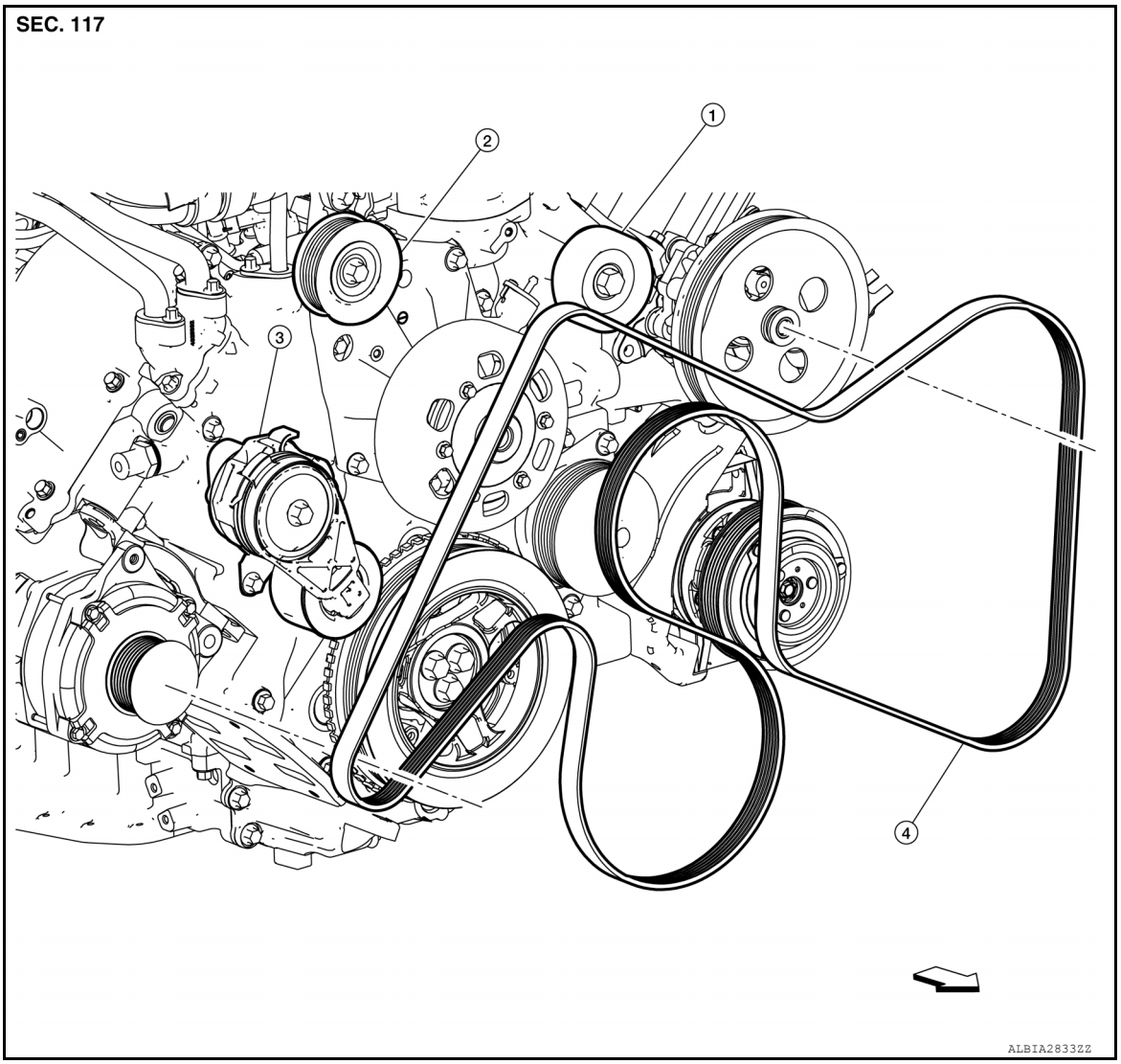
A: Closely related B: Related C: Sometimes related —: Not related

PERIODIC MAINTENANCE

DRIVE BELT

Exploded View

INFOID:0000000014418576



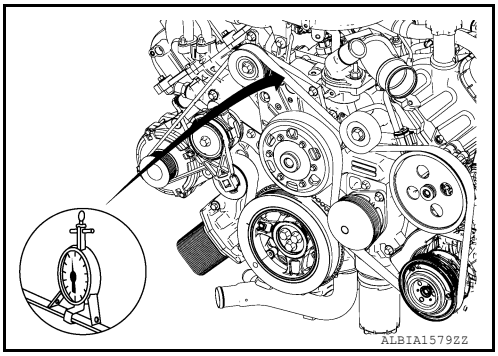
1. Idler pulley
2. Idler pulley
3. Drive belt auto-tensioner
4. Drive belt
⇦ Front

Inspection

INFOID:0000000014418577

INSPECTION BEFORE REMOVAL

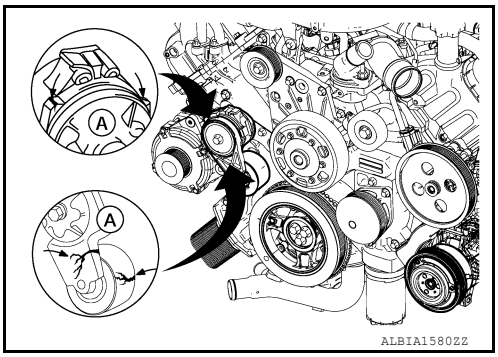
1. With the engine stopped and the drive belt installed, record the drive belt tension generated by the existing drive belt auto-tensioner. Use a suitable tool to measure the tension in the drive belt.



Belt tension minimum : 178 N (18.2 kg-f, 40.0 lb-f)
Belt tension maximum : 365 N (37.2 kg-f, 82.1 lb-f)

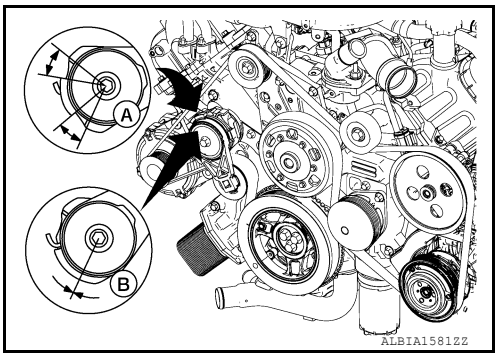
NOTE:
If the measurement is out of the specified range, replace only the drive belt and perform the tension test again. If a new drive belt has been installed and the measurement is still outside of the specified range, replace the drive belt auto-tensioner.

2. With the engine stopped, check the drive belt auto-tensioner arm, pulley, and stops for cracks (A). If any cracks are found, the drive belt auto-tensioner must be replaced.



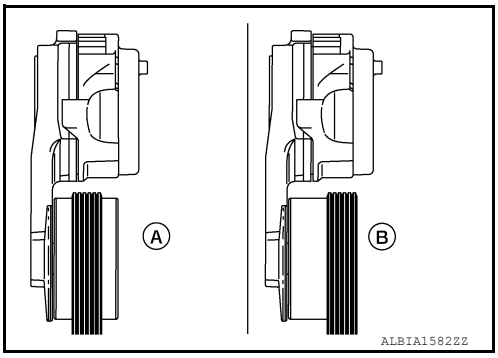
3. With the drive belt installed, verify that the drive belt auto-tensioner arm stop is not in contact with the spring case stop (A). If either of the stops are touching:
   - Verify the correct drive belt part number is installed.
   - If the correct drive belt is installed, replace the drive belt.

   After replacing the drive belt, if the drive belt auto-tensioner arm stops are still in contact with the spring case stop (B), the drive belt auto-tensioner must be replaced.



4. Check the location of the drive belt on the drive belt auto-tensioner pulley. The drive belt should be centered (A) on, or close to the middle of, the pulley. Misaligned drive belts (B), either too far forward or backward, can cause drive belt wear, drive belt roll-off, or increase uneven drive belt auto-tensioner bushing wear.

   NOTE:
   Drive belt misalignment is not always a result of a malfunctioning or faulty drive belt auto-tensioner. Make sure the adjacent pulleys and brackets are aligned and installed correctly.



Removal and Installation - Drive Belt

INFOID:0000000014418578

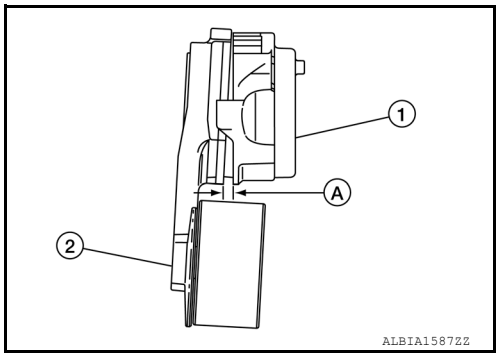
REMOVAL

CAUTION:
The drive belt auto-tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the cooling fan belt tensioner.

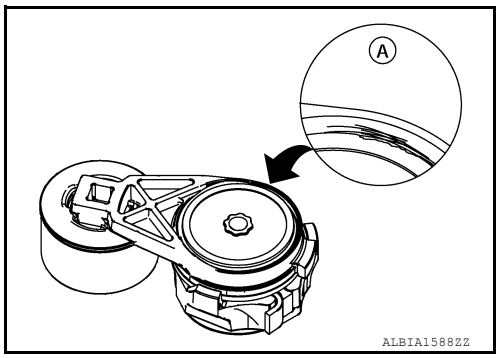
1. Rotate the drive belt auto-tensioner counterclockwise to release the tension.
2. Remove the drive belt.

INSPECTION AFTER REMOVAL

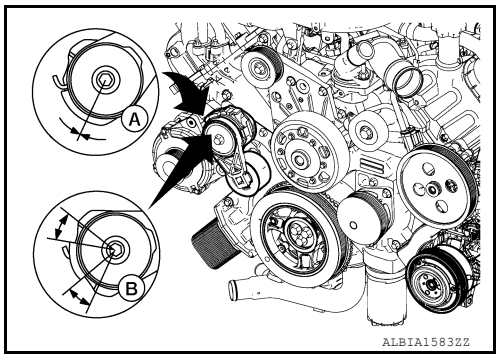
1. Inspect the drive belt for reuse.
2. Measure the clearance between the drive belt auto-tensioner spring case (1) and the drive belt auto-tensioner arm (2) to verify drive belt auto-tensioner wear-out and uneven bearing wear. If the clearance at the measurement point (A) exceeds 3 mm (0.12 in) at any point, the drive belt auto-tensioner is damaged and must be replaced as a complete assembly.
   NOTE:
   - Drive belt auto-tensioner generally show a larger clearance gap (A) near the lower portion of the spring case, resulting in the upper portion rubbing against the tensioner arm.
   - Always replace the drive belt when a drive belt auto-tensioner is replaced. However, it is not always necessary to replace a drive belt auto-tensioner when a drive belt is replaced.



3. Inspect the drive belt auto-tensioner for evidence of the tensioner arm contacting the tensioner cap. If there is evidence of the two areas making contact (A), the pivot tube bushing has malfunctioned and the drive belt auto-tensioner must be replaced.



4. With the belt removed, verify that the drive belt auto-tensioner arm stop is in contact (A) with the spring case stop. If they are not touching (B), the drive belt auto-tensioner must be replaced.



INSTALLATION

Installation is in the reverse order of removal.

NOTE:
- When installing drive belt, install drive belt on water pulley last.
- Check the alignment of the drive belt on the drive belt auto-tensioner.

INSPECTION AFTER INSTALLATION

Operate the engine and check for belt squeal. Excessive belt squeal indicates belt slippage.
If belt squeal is present, check the routing of the belt to make sure that the belt is installed correctly on each pulley.

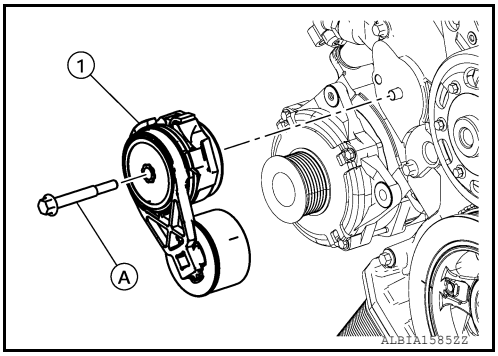
Removal and Installation - Drive Belt Auto-tensioner

INFOID:0000000014418579

REMOVAL

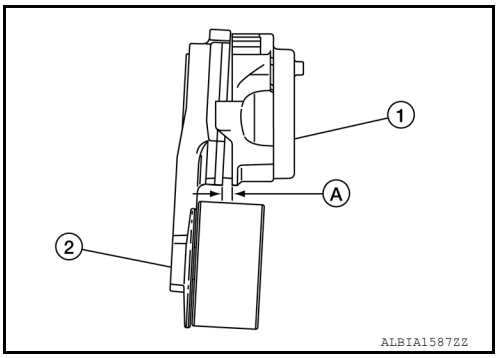
1. Remove the front fender protector. Refer to EXT-41, "Removal and Installation - Front Fender Protector".
2. Remove the drive belt. Refer to EM-198, "Removal and Installation - Drive Belt".

3. Remove bolt (A) and then remove the cooling fan belt tensioner (1) from the front cover.

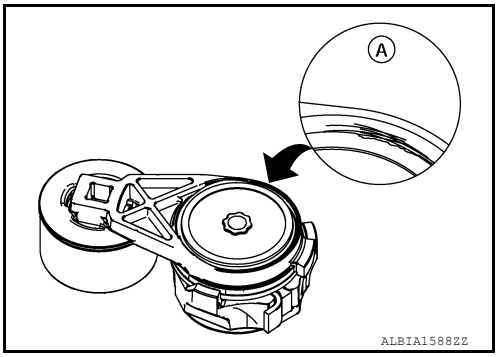


INSPECTION AFTER REMOVAL

1. Inspect the drive belt for reuse.
2. Measure the clearance between the drive belt auto-tensioner spring case (1) and the drive belt auto-tensioner arm (2) to verify drive belt auto-tensioner wear-out and uneven bearing wear. If the clearance at the measurement point (A) exceeds 3 mm (0.12 in) at any point, the drive belt auto-tensioner is damaged and must be replaced as a complete assembly.
   NOTE:
   - Drive belt auto-tensioner generally show a larger clearance gap (A) near the lower portion of the spring case, resulting in the upper portion rubbing against the tensioner arm.
   - Always replace the drive belt when a drive belt auto-tensioner is replaced. However, it is not always necessary to replace a drive belt auto-tensioner when a drive belt is replaced.



3. Inspect the drive belt auto-tensioner for evidence of the tensioner arm contacting the tensioner cap. If there is evidence of the two areas making contact (A), the pivot tube bushing has malfunctioned and the drive belt auto-tensioner must be replaced.



INSTALLATION

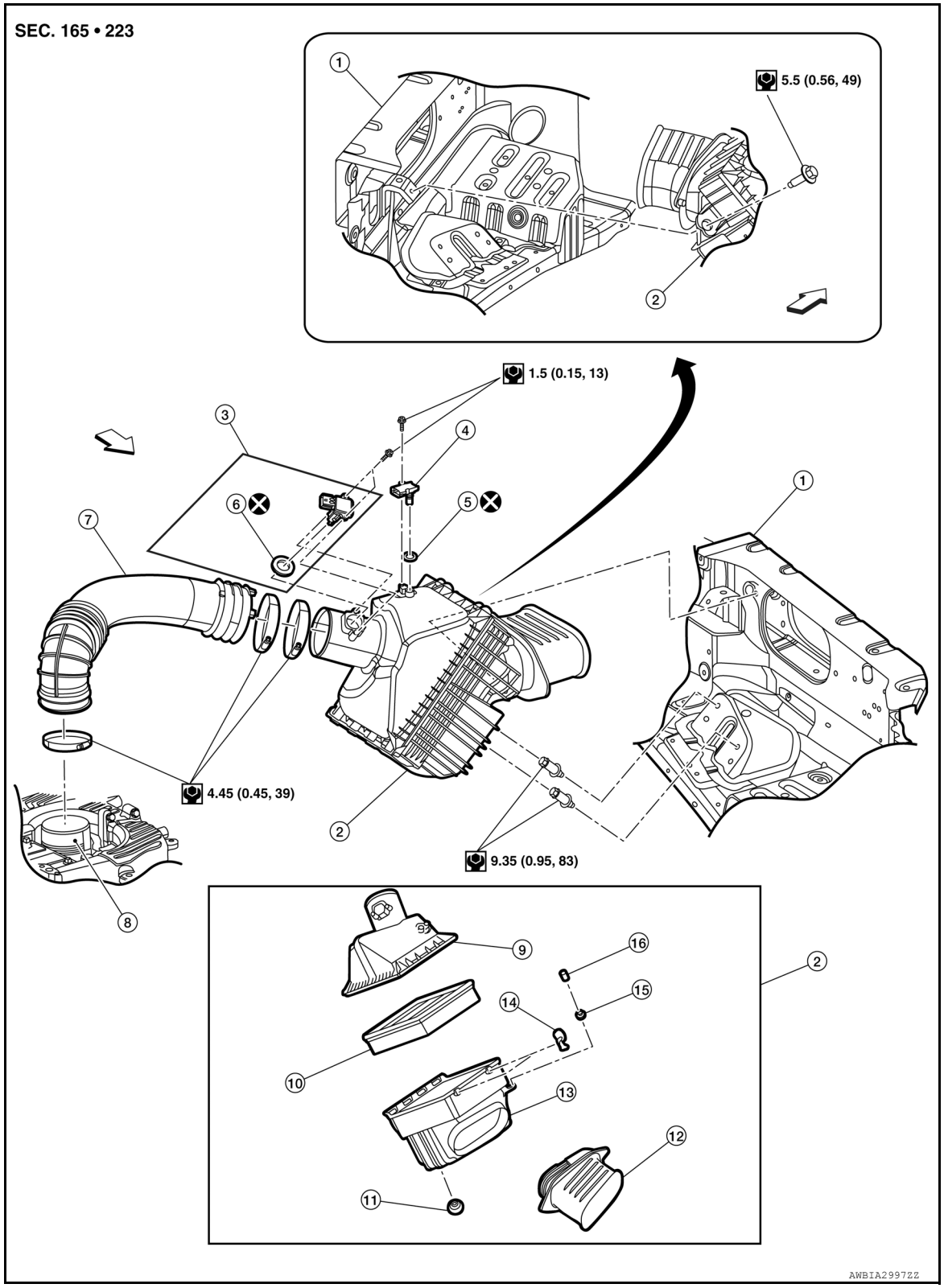
Installation is in the reverse order of removal.

Cooling fan belt tensioner bolt : 46 N·m (4.7 kg-m, 34 ft-lb)

AIR CLEANER FILTER

Exploded View

INFOID:0000000014418580



1. Hoodledge
2. Air cleaner case
3. Mass air flow sensor
4. Turbocharger compressor intake pressure/temperature sensor
5. O-ring
6. O-ring

7. Air duct
8. Air inlet connection
9. Air cleaner case (upper)
10. Air filter
11. Mounting rubber
12. Air duct (inlet)
13. Air cleaner case (lower)
14. Clip
15 Mounting rubber
16. Retainer
⇦ Front

Removal and Installation

INFOID:0000000014418581

REMOVAL

NOTE:
It is not necessary to remove the front air duct to replace the air cleaner filter.

1. Unhook the air cleaner case side clips.
2. Remove the air cleaner filter.

INSTALLATION

Installation is in the reverse order of removal.

COMPRESSION CHECK

Compression Check

INFOID:0000000014418582

GENERAL INFORMATION

- The compression test is designed to show general power cylinder performance and overall condition.

SETUP

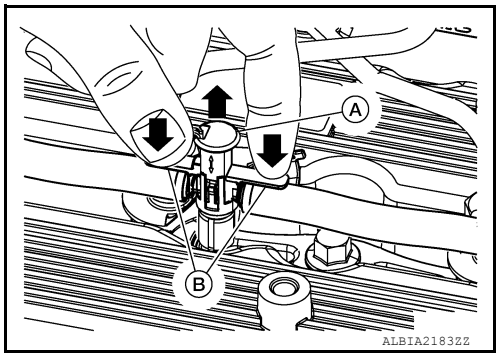
NOTE:

- Before starting the test, be sure the batteries are fully charged and in good working condition. Connect a battery charger to the system during the test.
- Before starting the compression test, be sure to have the proper number of sealing washers and O-rings to reassemble the fuel system during and after testing.

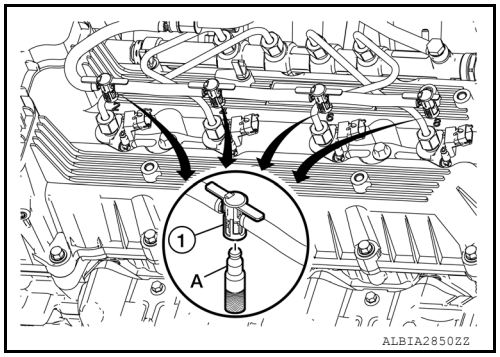
1. Disconnect the harness connector from the fuel filter housing (Stage 1).
   NOTE:
   This will keep the fuel system from building pressure when running the compression test.
2. Disconnect the harness connector from the fuel pressure relief valve. Refer to EM-481, "Exploded View".
   NOTE:
   This will keep the fuel system from building pressure when running the compression test.
3. Clean around all fuel connections being removed with compressed air to prevent debris from entering the fuel system during removal.
4. Disconnect the injector drain line from the injectors using the following procedure:

a. Press down and hold the connector tabs (B), then pull up on the center button (A) as shown in the illustration.

b. Be sure the connector is fully disengaged before removing the connector from the injector drain port.



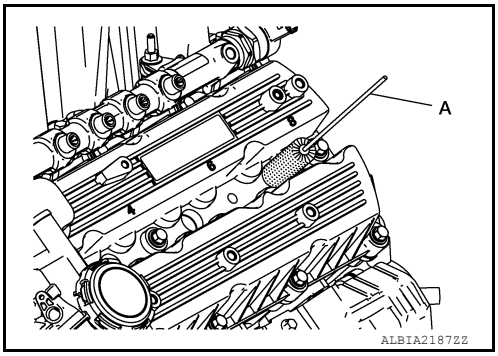
5. Plug the injector drain line (1) with a suitable tool (A).



6. Remove the injector supply lines (high pressure). Refer to EM-463, "Removal and Installation".
7. Remove the fuel injectors. Refer to EM-436, "Removal and Installation (CYLINDER 1 and CYLINDER 3)", EM-439, "Removal and Installation (CYLINDER 2 and CYLINDER 4)", EM-442, "Removal and Installation (CYLINDER 5 and CYLINDER 7)" and EM-446, "Removal and Installation (CYLINDER 6 and CYLINDER 8)".
   NOTE:
   Keep track of which cylinder the fuel injector was removed from so it can be installed in the same location. This is important for the injector trim codes.

8. Clean the injector bore with Tool (A).

Tool : — (J-54428)



9. Install Tool in cylinders number 1 and 3 in the injector locations using the original injector hold-down clamp.

Tool : — (J-54415)

10. Tighten the injector clamp bolt.

Step 1 : 24 N·
Step 2 : Tighten 90°

11. Connect a suitable tool to the Tool on cylinder number 1 to measure compression pressure when cranking the engine and open both ball valves on the Tool.

Tool : — (J-54415)

12. Before starting the test, make sure the engine is capable of reaching a minimum cranking speed of 175 RPM.
NOTE:
If the engine speed is out of the specified range, inspect the condition and charge of the batteries. If the batteries are found to be within specifications, it may help to remove the drive belt. Refer to EM-198, "Removal and Installation - Drive Belt".

TEST

1. While watching the suitable tool, crank the engine for 15 seconds.
NOTE:
Make note of cylinder pressure, engine RPM and which cylinders are being tested.
2. Move the suitable tool to cylinder number 3 and repeat step 1 while recording the cylinder pressure and engine RPM.
3. Repeat for all other cylinder pairs.
NOTE:
- Inspect Tool before each compression test for damage.
- The difference limit between cylinders is ± 25%.
- When calculating variation, average all 8 pressure readings and calculate difference from that average.

Tool : — (J-54415)

4. If the compression variation of a cylinder exceeds the comparative limit, pour a small amount [10 mL (0.3 US fl oz, 0.4 Imp fl oz) MAX] of clean engine oil into the injector hole of the cylinder and measure the compression again.
- If the addition of engine oil to the cylinder improves the cylinder pressure reading, the piston rings must be inspected. Refer to EM-515, "Inspection After Disassembly".
- If the addition of engine oil to the cylinder does not improve the cylinder pressure reading, the valve train could be malfunctioning. Inspect the valves, cylinder head and camshaft timing chain.
- If the addition of engine oil to the cylinder does not improve the cylinder pressure reading for two adjoining cylinders, the cylinder head gasket could be leaking. Inspect the cylinder head and cylinder head gasket.

FINISHING STEPS

1. Remove the Tool and suitable tool.

Tool : — (J-54415)

2. Installation is in the reverse order of removal.
NOTE:
- Prime the fuel system. Refer to EM-219, "Priming".
- Operate the engine and check for leaks.

BASIC INSPECTION

AIR LEAKS, AIR INTAKE AND EXHAUST SYSTEMS

Inspection

INFOID:0000000014418583

GENERAL INFORMATION

- It is important that the intake and exhaust system(s) on this engine remain sealed. This ensures proper performance, intake system pressure, heat retention, emissions compliance, and contamination avoidance.
- This procedure uses air pressure to help identify leak paths in the intake system. Exhaust leaks will be identified by noise or discoloration caused by escaping hot gases.

INSPECTION BEFORE REMOVAL

Intake System

- Leaks in the intake system are most commonly identified by:

  CAUTION:

  Intake air must be filtered to keep dirt and debris from entering the engine. If intake air piping is damaged or loose, unfiltered intake air will enter the engine and cause premature wear.

- Inspection of piping for cracked or loose clamps
- Application of a solution of soapy water in the suspected area and inspecting for bubbles.
- Audible hissing in the suspected leak area.
- Inspect the inlet air hoses for cracked hoses and damaged or loose clamps.
- Replace damaged hoses and tighten loose clamps, if necessary, to make sure the charge-air piping and hoses do not leak.
- Check for corrosion of the inlet system piping under the clamps and hoses. Corrosion can allow corrosive products and dirt to enter the intake system.
- Disassemble and clean as required.

Exhaust System

- Inspect the exhaust piping and components for cracks and damaged or loose clamps.

  NOTE:

  Leaks occurring in exhaust pipes and joints before the diesel particulate filter (DPF) are likely to be appear as soot streaks. Because soot is trapped in a properly functioning DPF it is unlikely that soot streaks will be visible for leaks occurring after the DPF.

- Disassemble and clean as required.

TEST PROCEDURE

Intake System

1. Disconnect the air outlet hose from the outlet of the charge air cooler. Refer to EM-256, "Exploded View".

   NOTE:

   When removing the air outlet hose, cap the air intake connection with Tool.

   Tool : — (J-54423)

2. Remove the air duct. Refer to EM-220, "Exploded View".
3. The following portion of this procedure will help diagnose an intake air system leak.
   1. Test the cold side of the turbocharger and charge-air cooler system for audible leaks.
   2. Install a suitable tool that fits onto the outlet of the charge air cooler.
   3. Install a suitable tool and air supply fitting that fits into the air inlet connection. Tighten the clamps.
4. Pinch off the crankcase breather tube with a suitable tool.

   CAUTION:

   Use only suitable tools designed to pinch off rubber hoses to prevent damage to the tube.

5. Loosen the oil fill cap. Leave it resting on the oil fill opening.

   CAUTION:

   - **If the oil fill cap is not loosened the crankcase pressure will exceed the designed limits of some of the oil seals for the crankcase and will damage the seals.**
   - **The oil cap resting in the oil fill opening prevents any unwanted debris or tools from entering the engine.**

6. Connect a compressed air source with Tool to the pressure fitting on the air inlet connection.

Tool : — (J-54429)

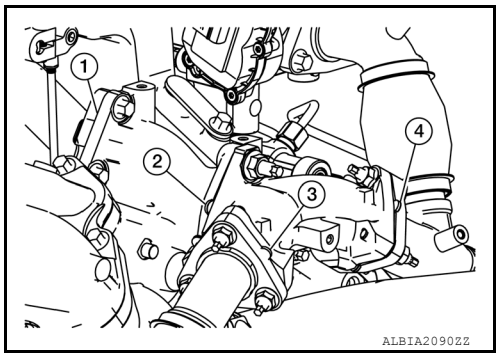
7. Use the Tool to regulate air pressure to no more than 69 kpa (0.7 kg/cm^2, 10 psi) of pressure into the system.
CAUTION:
Exceeding air pressure specified in this procedure could result in engine damage.
8. Listen for an air leaks throughout the cold side turbocharger and charge-air cooler system. Be sure to check coupler connections, sealing surfaces and gaskets. A solution of soap and water can be used to find small leaks.
NOTE:
It may be necessary to allow a few minutes until pressure fills the system.
9. If leaks are identified under the intake manifold it will be necessary to remove the intake manifold. Refer to EM-239, "Removal and Installation".
CAUTION:
Exceeding air pressure specified in this procedure could result in engine damage.
NOTE:
- The system will not hold pressure. Some air leaks to the crankcase will occur through the cold side turbocharger oil seals. Some leaks are acceptable and will be audible.
- Once the intake manifold is removed the pressure can be applied again to allow for further inspection.

10. After testing is complete, installation is in the reverse order of removal.
NOTE:
Operate the engine and check for leaks.

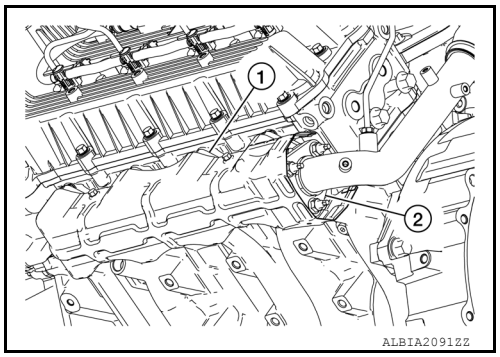
Exhaust System

1. The following portion of this procedure will help diagnose an exhaust system leak. Leaks in the exhaust system will cause the turbocharger to operate at a lower speed, reducing the amount of air going to the cylinders during engine operation.
NOTE:
Leaks can be identified by noise or discoloration caused by escaping hot gases.

2. Inspect the following locations for exhaust system leaks:
- Exhaust manifold collector pipe gasket (2), exhaust transfer tube gasket [bank 1 (4)], exhaust transfer tube gasket [bank 2 (3)] and EGR bypass tube gasket (1).

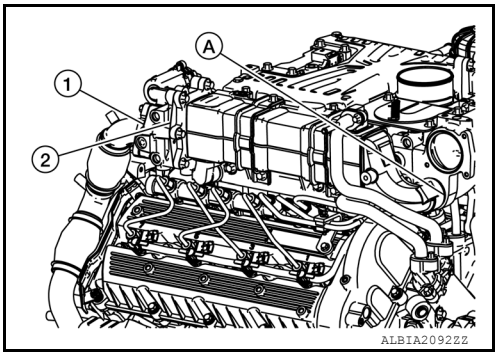


- Exhaust manifold gasket (1) and exhaust transfer tube gasket [bank 2 (2)].

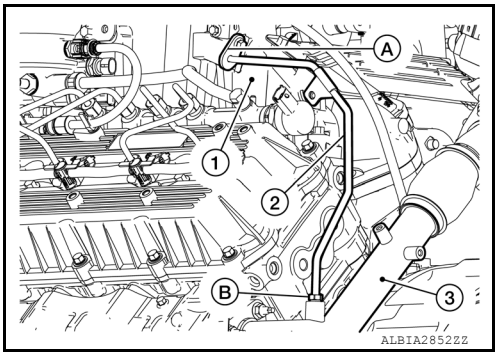


- Exhaust gas recirculation (EGR) components:

- Exhaust transfer tube (bank 1) gasket (1).
- EGR valve gasket (2).
- EGR cooler outlet O-ring connection (A).



- Exhaust pressure sensor tube (2) to intake manifold (1) connection (A) and exhaust pressure sensor tube (2) to exhaust transfer tube [bank 2 (3)] connection (B).



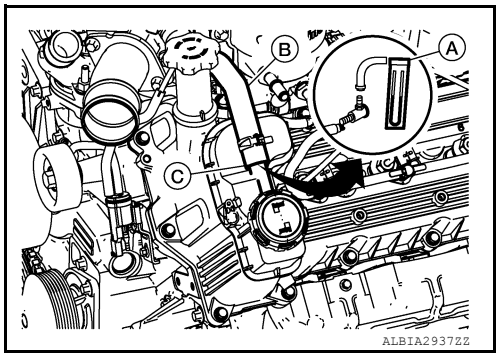
AIR FILTER

Inspection

INFOID:0000000014418584

MEASURE

1. Disconnect the crankcase breather tube (1) and install suitable tool (A) at location (C).



2. Operate the engine at 3200 revolutions per minute (rpm) under load. Record the value.

Maximum air inlet restriction : 5.48 kPa (558.8 mm H_2O, 22 in H_2O)

3. If restriction exceeds specifications, replace or clean the air filter element.
4. Inspect the air duct for damage.
5. Remove the suitable tool and reconnect the crankcase breather tube.

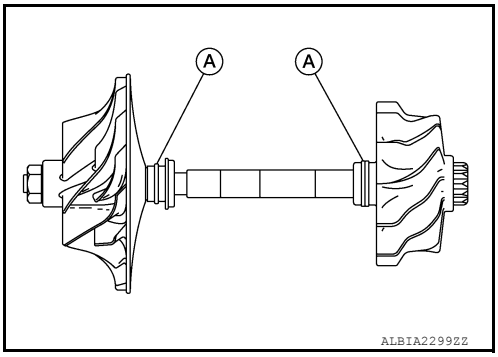
TURBOCHARGER

Inspection

INFOID:0000000014418585

MALFUCTIONING TURBOCHARGER

1. A malfunction of the internal components of the turbocharger can reduce its effectiveness. A bearing malfunction can produce friction, which will slow the speed of the rotor assembly. Worn bearings can also allow the blades of the rotor assembly to rub the housing, reducing the rotor assembly speed.
   NOTE:
   Lower pitched sounds or rattles, at slower engine speeds, can indicate that debris is in the system or that the rotor assembly is touching the housings. If there is a complaint for noise, low power, engine response, or oil consumption, verify the conditions under which the complaint occurred.
2. O-rings (A) are used on each end of the rotor assembly. The primary function of the O-rings (A) is to prevent exhaust gases and compressed air from entering the turbocharger housing. Oil leaks from the O-rings are rare, but it can occur.



3. Because this engine is equipped with a closed crankcase ventilation system, a light coating of oil in the turbocharger compressors is normal. If oil is pooled further investigation is required.
   NOTE:
   - Excessive crankcase pressure will not allow the oil to drain from the turbocharger. This will load the bearing housing and allow oil to leak past the O-rings and into the intake system and exhaust system of the engine.
   - If O-ring leaks into the exhaust occur, the aftertreatment system must be inspected for reuse.
4. A restricted or damaged oil return connection will cause the turbocharger housing to be pressurized, causing oil to migrate past the O-rings on both the intake and exhaust side of the turbocharger.
5. Additionally, high intake or exhaust restrictions can cause a vacuum between the compressor and the turbocharger housing, resulting in oil leaking past the O-rings at the intake side.
   NOTE:
   If this occurs, it is necessary to flush the charge-air cooler to clean the oil from the intake system, clean the intake manifold, and clean the charge-air cooler.
6. Make sure the rotary turbine control valve is functioning properly.
7. The rotary turbine control valve can be tested using the RTCV Hysteresis Test, which can be started through CONSULT. The test confirms the rotary control valve can achieve all positions in its operating range. The test results determine if further inspection is required of the following components:
   - Rotary turbine control valve linkage
   - Rotary turbine control valve actuator
   - Turbocharger. Refer to EM-398, "Exploded View".

TURBOCHARGER NOISE

- It is normal for the turbocharger to emit a whining sound that varies in intensity, depending on turbine wheel speed. The sound is caused by the very high rotational speed of the rotor assembly and the method used to balance the rotor assembly during manufacturing. Because the engine uses a two stage turbocharger, the sound may not be the loudest at rated engine speed and load. Depending on engine and aftertreatment requirements for exhaust temperatures and exhaust pressure, the sound may be most noticeable around idle speed conditions or slightly above.

GLOW PLUG

Inspection

INFOID:0000000014418586

GLOW PLUG

1. The on/off operation of the glow plugs is controlled by the glow control unit.
2. A symptom of a malfunctioning glow plug or glow control unit is a hard start in cold ambient temperatures and/or white smoke on engine startup.
3. Use the following procedures for verifying the glow plug function. Refer to EM-260, "Removal and Installation".

CHARGE AIR COOLER

Inspection

INFOID:0000000014418587

CHARGE-AIR COOLER

1. The charge-air cooler makes sure that the proper intake air density is achieved. External damage to the fins or excessive restriction or pressure losses can affect its performance and reduce engine performance.
2. Inspect the charge-air cooler for damage, leaks, or obstructions. Replace components as necessary.

FUEL SYSTEM

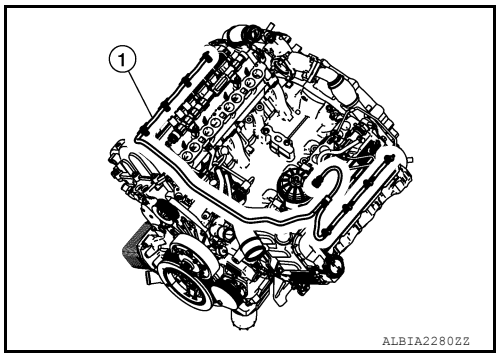
High-Pressure Fuel Injector Drain Line Restriction

INFOID:0000000014418588

GENERAL INFORMATION

1. The following procedure contains measurement steps and specifications regarding the engines fuel system components.
   CAUTION:
   Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.
   NOTE:
   This procedure is not intended to take the place of troubleshooting tree repair direction. Refer to EC-1986, "Symptom Table".

2. The purpose of this test is to check for a restricted injector drain line (1).



INITIAL SETUP

WARNING:

- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
  - **Do not exceed 30psi (207 kPa).**
  - **Wear appropriate eye protection and protective clothing including gloves.**
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
  - **Wear appropriate eye protection and protective clothing including gloves and a face shield.**
- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
  - **Do not loosen any fittings while the engine is running.**
  - **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
  - **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
  - **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

1. Before diagnosing any fuel system component, (such as fuel lines, fuel pump, injectors, fuel rail, etc.) which would expose the fuel system or internal engine component to potential contaminants, prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed.
   NOTE:
   Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are not cleaned, resulting in damage to the fuel system and engine.
2. Disconnect the injector drain line from injectors 1, 3, 5, and 7 on the bank 1 side of the engine. Refer to EM-429, "Removal and Installation".
3. Plug injector drain opening with Tool.

Tool : — (J-54427)

4. Plug injector drain line connections 1, 3, and 5 with a suitable tool.
5. Route the injector 7 drain line connection so it will flow into a suitable measuring device.

Measurement

1. Use CONSULT to run the Electric Lift Pump Test. Refer to EC-806, "CONSULT Function".
2. An unrestricted fuel injector drain line will have a steady stream of fuel from injector 7 drain connection when the Electric Lift Pump Test is run.
3. Repeat for bank 2 of engine as necessary.
4. For further diagnosis. Refer to EC-1986, "Symptom Table"

FINISHING STEPS

1. Remove all test equipment.
2. Install the fuel system components with new O-rings.
   CAUTION:
   Do not reuse the O-rings.
3. Prime the fuel system. Refer to EM-219, "Priming".
4. Operate the engine and check for leaks.

High-Pressure Fuel System Actuator Override Test

INFOID:0000000014418589

GENERAL INFORMATION

- The following procedure contains measurement steps and specifications regarding the engines fuel system components.
- The purpose of this test is to check for a stuck fuel pump actuator or a fuel pressure relief valve.

CAUTION:
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

INITIAL SETUP

WARNING:

- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
- **Wear appropriate eye protection and protective clothing including gloves and a face shield.**
- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

1. Before diagnosing any fuel system component, (such as fuel lines, fuel pump, injectors, fuel rail, etc.) which would expose the fuel system or internal engine component to potential contaminants, prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed.
2. Remove banjo bolt from fuel pressure relief valve drain connection. Refer to FL-32, "Exploded View".
3. Install the Tool into the fuel pressure relief valve drain connection.

Tool : — (J-54431)

4. Route the diagnostic line, into a graduated beaker.

5. Make certain the test lines are not kinked or leaking after installation.

MEASUREMENT

- The HPCR Fuel Act Override Test in CONSULT must be used to run the electric lift pump and open and close the fuel pump actuator and fuel pressure relief valve. Refer to EC-806, "CONSULT Function".

1. Select "NO Command" in the drop menu.
2. Select Start.
   NOTE:
   At this point in the test, the fuel pump actuator and fuel pressure relief valve are in the open position
3. Wait for system to run for 30 seconds.
4. Observe and record flow from the diagnostic line (steady stream of fuel or no fuel).
5. Select Stop.
6. Choose HPFS Pressure Reflief Valve cdm close in the drop menu.
7. Selsct Start.
8. Wait for system to prime (30 seconds)
9. Observe and record flow from diagnostic line (steady stream of fuel or no fuel flow).
10. Select Stop.
11. Choose HPFS Pressure Reflief Valve cdm open in the drop menu.
12. Repeat steps 7-10.
13. Choose HPFS actuator pump cdm close in the drop menu.
14. Repeat steps 7-10.
15. Choose HPFS actuator pump cdm open in the drop menu.
16. Repeat steps 7-10.
17. Select End.
18. Key off vehicle for at least 70 seconds. This ensures the lift pump stops pumping.

CAUTION:
The HPCR Fuel Act Override Test cannot be run with the engine running.
NOTE:
Make sure the diagnostic line is routed in a downward slope toward the breaker. Kinks or uneven hose can skew the test results.

- Expected response of good fuel pump actuator and fuel pressure relief valve:

Trial	Component	State	Expected Response
1	Fuel Pump Actuator	Open	Steady Stream of Fuel
	Fuel Pressure Relief Valve	Open	
2	Fuel Pump Actuator	Open	No Fuel Flow
	Fuel Pressure Relief Valve	Closed	
3	Fuel Pump Actuator	Closed	No Fuel Flow
	Fuel Pressure Relief Valve	Open	

FINISHING STEPS

1. Remove all test equipment.
2. Install the fuel system components with new o-rings and seals.
3. Prime the fuel system. Refer to EM-219, "Priming".
4. Operate the engine and check for leaks.

High-Pressure Fuel Injector Return Flow Test

INFOID:0000000014418590

GENERAL INFORMATION

1. The following procedure contains measurement steps and specifications regarding the engines fuel system components.
   CAUTION:
   Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

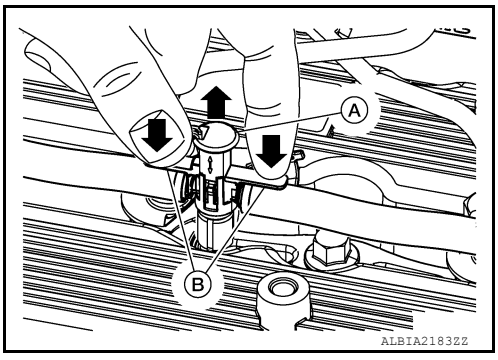
2. The purpose of this test is to check for excessive fuel drain (leakage) from the fuel injectors.
CAUTION:
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.
NOTE:
The steps below will describe the set up to connect the injectors to fuel injector drain flow tool, and run the test.

INITIAL SETUP

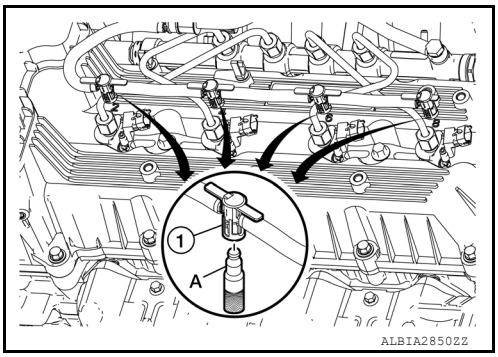
WARNING:
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
- **Wear appropriate eye protection and protective clothing including gloves and a face shield.**
- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

1. Before diagnosing any fuel system component, (such as fuel lines, fuel pump, injectors, fuel rail, etc.) which would expose the fuel system or internal engine component to potential contaminants, prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed.
NOTE:
Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are not cleaned, resulting in damage to the fuel system and engine.

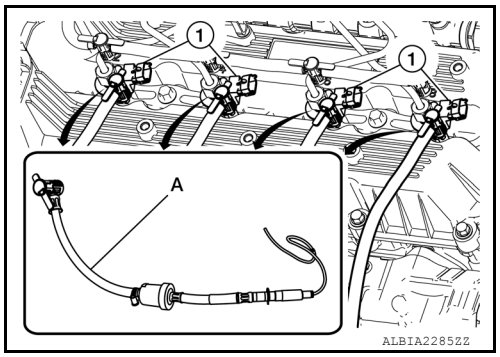
2. Disconnect the fuel injector drain line from the fuel injector using the following procedure:
   - Disconnect the fuel injector quick disconnect connector by pressing down and holding the connector tabs (B), then pulling up on the center button (A) as shown in the illustration.
   - Be sure the connector is fully disengaged before removing the connector from the injector drain port.
   - To connect the injector quick disconnect connector, be sure the quick disconnect connector is in the release position (the button is up).
   - Press **only** on the connector tabs to seat the drain line onto the injector drain port. An audible snap sound will be heard when the connector is seated. When the connector snaps into place, press the button to secure the connector.



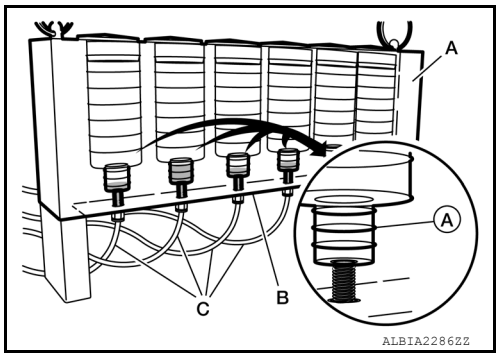
3. Plug the fuel injector drain line (1) with suitable tool (A).



4. Install suitable tool (A) where the fuel injector drain line was removed from on the fuel injectors (1).
NOTE:
Only one bank of fuel injectors will be tested at one time.

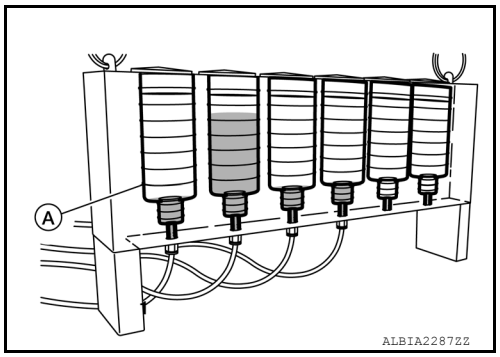


5. Connect suitable tool (C) to suitable tool (B) (Repeat for all fuel injectors on the bank being tested).
6. Position suitable tool (B) on a horizontal surface or hang from hood with straps provided to make sure of accurate measurements.
7. Prime the suitable tool. Start the engine and allow it to run until fuel reaches the marking (A) on the smaller cylinders.
8. Disconnect the suitable tool from the fuel injectors and dump the fuel from the cylinders into an approved container.
9. Reconnect the suitable tool to the fuel injectors and secure the suitable tool on a horizontal surface, as above.



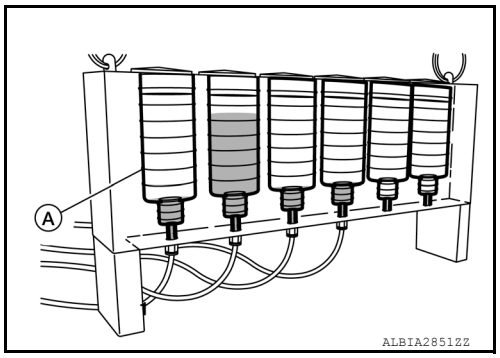
MEASUREMENT - ENGINE WILL NOT START

1. Make certain the test lines are not kinked or leaking after installation.
2. If the engine will not start, crank the engine and measure the amount of fuel returned by the injectors.
3. Crank the engine for 15 seconds.
4. Repeat the test twice to make sure of accurate results.
5. A failed fuel injector will exhibit higher than normal injector drain flow.
6. If fuel in any of the cylinders is above the marking (A) on the larger cylinders, this indicates a failed fuel injector.
7. Repeat the test for the opposite bank.



MEASUREMENT - ENGINE WILL START

1. Start the engine and allow it to run for 30 seconds.
2. A failed fuel injector will exhibit higher than normal injector drain flow.
3. If fuel in any of the cylinders is above the marking (A) on the larger cylinders, this indicates a failed fuel injector.
4. Repeat the test twice to make sure of accurate results.
5. Repeat the test for the opposite bank.



FINISHING STEPS

1. Remove all test equipment.
2. Install the fuel system components with new o-rings.
CAUTION:
Do not reuse O-rings.
3. Prime the fuel system. Refer to EM-219, "Priming".
4. Operate the engine and check for leaks.

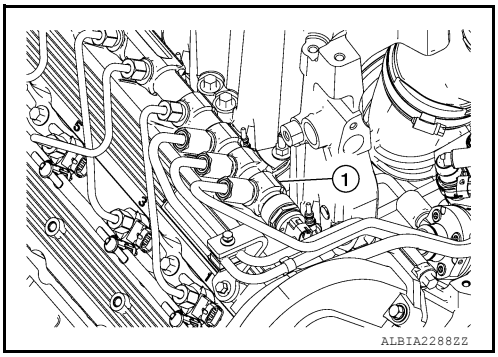
High-Pressure Fuel System Leak Test

INFOID:0000000014418591

GENERAL INFORMATION

1. The following procedure contains measurement steps and specifications regarding the engines fuel system components.
   CAUTION:
   Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

2. The purpose of this test is to check for leakage from the high-pressure fuel system joints. The High-Pressure Fuel System Leakage Test raises rail pressure to 200,000 kPa (2,040 kg/cm^2, 29,000 psi).



(1) : Fuel rail (bank 1)

WARNING:
The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **Do not inspect for leaks while the test is running.**

INITIAL SETUP

WARNING:
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
- **Wear appropriate eye protection and protective clothing including gloves and a face shield.**
- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

CAUTION:
Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are not cleaned, resulting in damage to the fuel system and engine.

1. Before diagnosing any fuel system component, (such as fuel lines, fuel pump, injectors, fuel rail, etc.) which would expose the fuel system or internal engine component to potential contaminants, prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed.
2. Using CONSULT, run the Fuel System Leak Test. Refer to EC-806, "CONSULT Function".
   - Allow the test to run until complete, unless the test needs to be stopped earlier.

- Once the test is completed, inspect for moisture around all high-pressure joints. If moisture is present, replace components as necessary.

WARNING:
Do not inspect for leaks while test is running.

Priming

INFOID:0000000014418592

WARNING:
The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:

- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- After a filter change or running the fuel tank dry, complete the following:

- Key ON vehicle for 90 seconds to prime the fuel system. After 90 seconds, crank the engine for a maximum of 30 seconds or until the engine fires. If it does not fire, repeat this step.
- When the engine does start, it may operate erratically and with increased noise levels for a few minutes. This is a normal condition as air is being removed from the system.

NOTE:

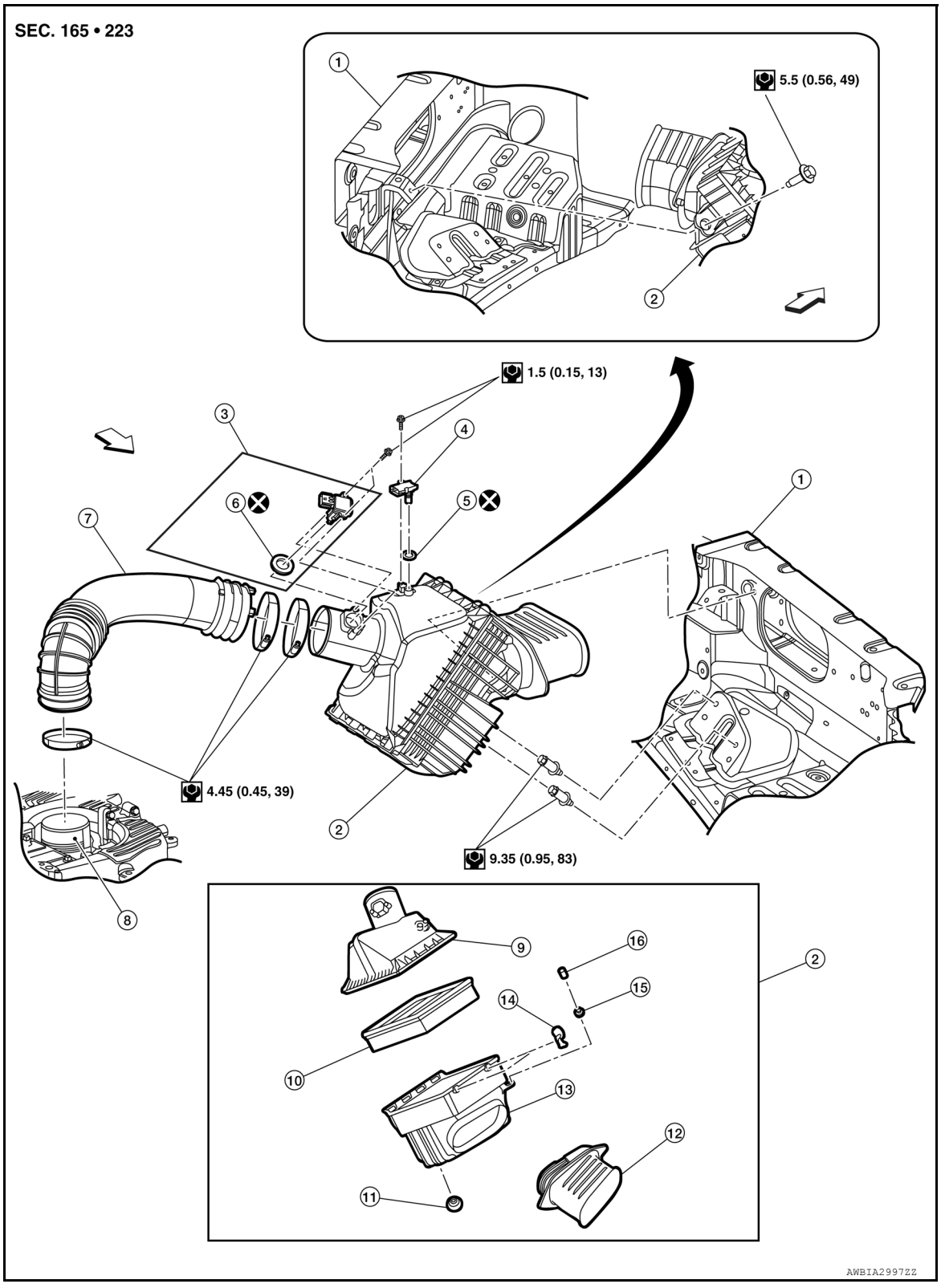
- It is not necessary to vent air from the high-pressure fuel system before starting the engine.
- It is possible P-codes may become active after fuel filter replacement due to air introduced in the system. Make sure to run the engine until air is purged and use CONSULT to clear any active codes.
- Operate the engine and check for leaks.

REMOVAL AND INSTALLATION

AIR CLEANER AND AIR DUCT

Exploded View

INFOID:0000000014418593



1. Hoodledge
2. Air cleaner case
3. Mass air flow sensor
4. Turbocharger compressor intake pressure/temperature sensor
5. O-ring
6. O-ring
7. Air duct
8. Air inlet connection
9. Air cleaner case (upper)
10. Air filter
11. Mounting rubber
12. Air duct (inlet)
13. Air cleaner case (lower)
14. Clip
15 Mounting rubber
16. Retainer
⇦ Front

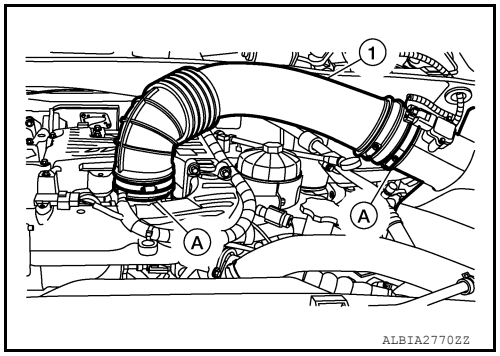
Removal and Installation

INFOID:0000000014418594

NOTE:
Mark location of air duct tabs at mass air flow sensor and air duct for reassembly.

REMOVAL

1. Loosen clamps (A) and remove the air duct (1).



2. Disconnect harness connector from mass air flow sensor.
3. Disconnect harness connector from turbocharger compressor intake pressure/temperature sensor.
4. Remove the air cleaner case (upper) and filter.
5. Remove the bolts and clips and remove the air cleaner case (lower).
6. Remove the mass air flow sensor from the air cleaner case [upper (if necessary)]. Refer to EM-224, "Exploded View".
   CAUTION:
   - **Handle mass air flow sensor with care.**
   - **Do not shock it.**
   - **Do not disassemble it.**
   - **Do not touch the internal sensor element.**
7. Remove the turbocharger compressor intake pressure/temperature sensor from the air cleaner case [upper (if necessary)]. Refer to EM-222, "Exploded View".

INSPECTION AFTER REMOVAL

Inspect air duct and air cleaner case for cracks or tearing. Replace parts as necessary.

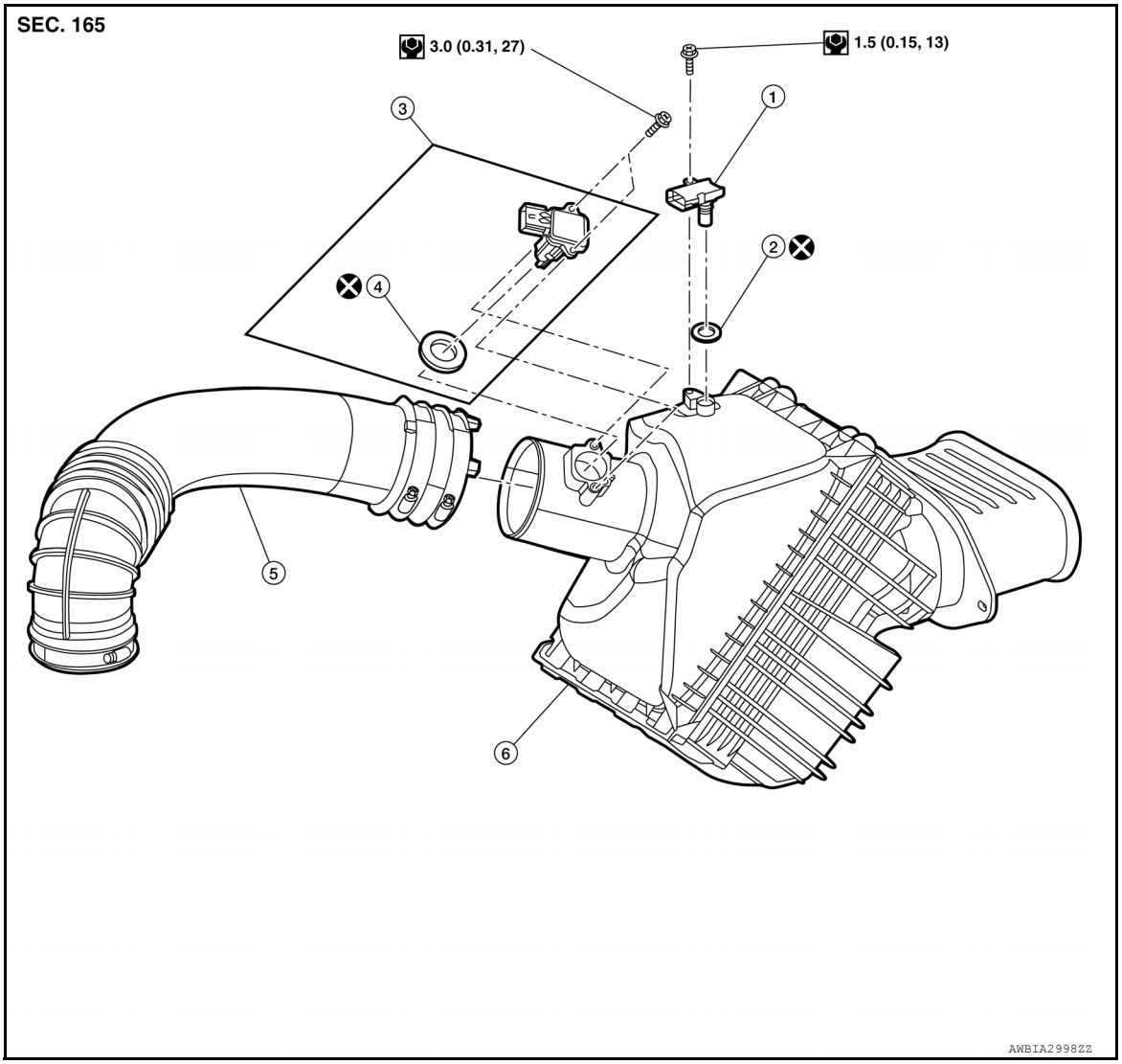
INSTALLATION

Installation is in the reverse order of removal.
- Align air duct tabs with mass air flow sensor on air cleaner case (upper) and at the air duct.
- Install clamps at each connection.

TURBOCHARGER COMPRESSOR INTAKE PRESSURE/TEMPURATURE SENSOR

Exploded View

INFOID:0000000014418595



1. Turbocharger compressor intake pressure/temperature sensor
2. O-ring
3. Mass air flow sensor
4. O-ring
5. Air duct
6. Air cleaner case

Removal and Installation

INFOID:0000000014418596

GENERAL INFORMATION

The turbocharger compressor intake pressure/temperature sensor is a combination sensor that monitors the temperature and pressure of the air entering the turbocharger.

INSPECTION BEFORE REMOVAL

- Use CONSULT to monitor the value of the turbocharger compressor intake pressure/temperature sensor with the key in the ON position and the engine off.
- The value of the turbocharger compressor air intake temperature sensor should be checked when the engine is cold, and should read within 5.5°C (10°F) of the local ambient air temperature.
- The value of the turbocharger compressor intake pressure should read within 1 kPa (0.3 in Hg) of the local barometric air pressure.

- Replace the turbocharger compressor intake pressure/temperature sensor if either value is out of specification.

REMOVAL

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".

   WARNING:
   Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:
   - **Wear appropriate goggles and protective clothing.**
   - **Always properly ventilate the area where the service is being performed.**
   - **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
   - **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
   - **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**
2. Clean the area around the turbocharger compressor intake pressure/temperature sensor.
3. Disconnect the turbocharger compressor intake pressure/temperature sensor harness connector from the engine harness and remove the bolt.
4. Remove the sensor from the engine by pulling straight up on the sensor.

   CAUTION:
   Do not reuse O-ring.

INSPECTION AFTER REMOVAL

Inspect the engine harness connector and the turbocharger compressor intake pressure/temperature sensor for the following:
- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins.

Replace or repair the connector or turbocharger compressor intake pressure/temperature sensor as necessary.

INSTALLATION

1. Install the turbocharger compressor intake pressure/temperature sensor by pressing firmly on the top of the sensor until the o-ring is fully seated and tighten the bolt.

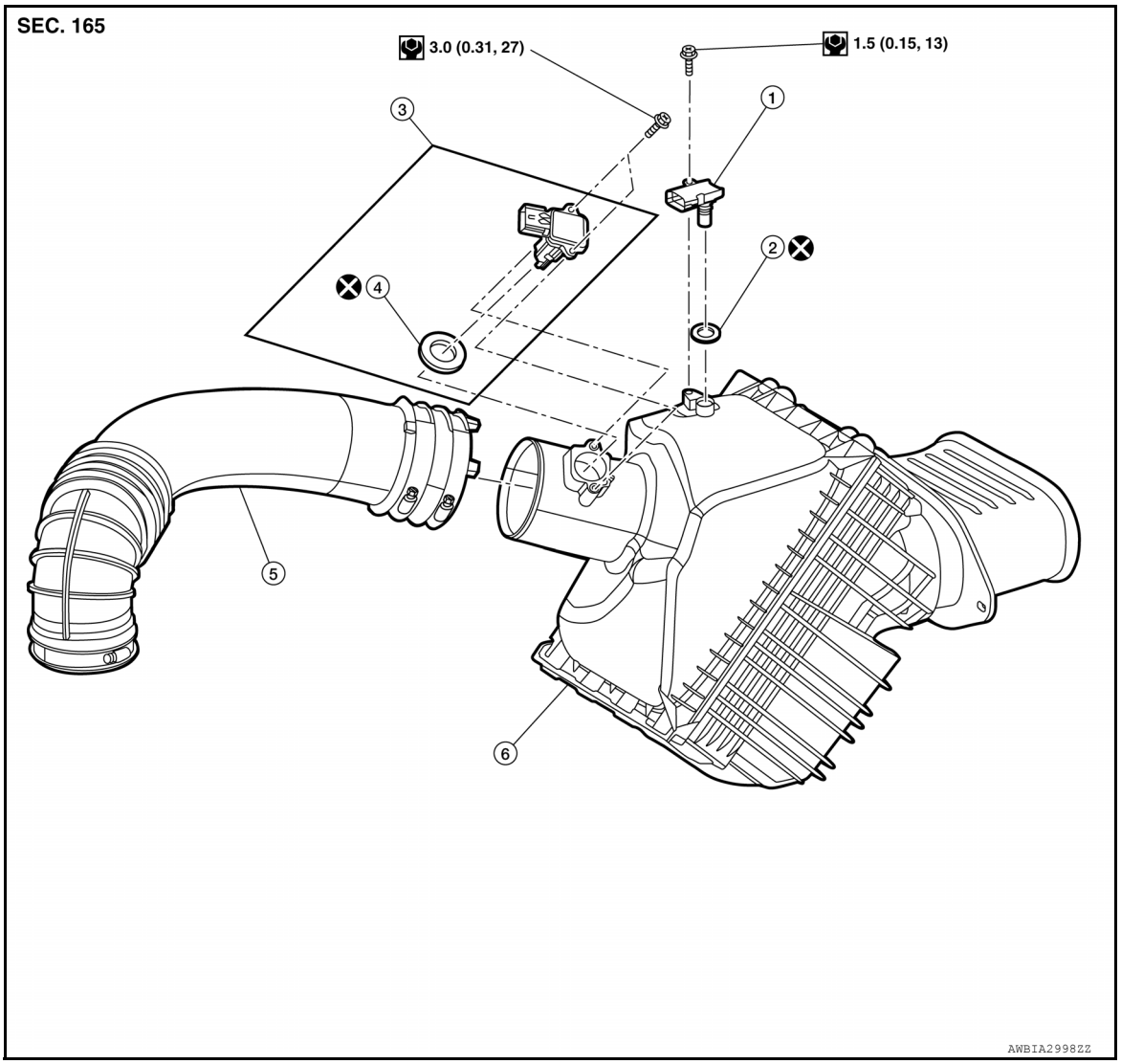
   CAUTION:
   The engine charge-air cooler outlet pressure/temperature sensor can be mistaken for the turbocharger compressor intake pressure-temperature sensor. Make sure the correct part number is being used before installing the sensor. Failure to do so could result in diagnostic trouble codes/ fault codes.
2. Connect the engine harness to the turbocharger compressor intake pressure/temperature sensor.
3. Connect the battery or batteries. Refer to PG-185, "Battery Disconnect".

   WARNING:
   Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:
   - **Wear appropriate goggles and protective clothing.**
   - **Always properly ventilate the area where the service is being performed.**
   - **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
   - **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
   - **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**
4. Operate the engine and check for leaks.

MASS AIR FLOW SENSOR

Exploded View

INFOID:0000000014418597



1. Turbocharger compressor intake pressure/temperature sensor
2. O-ring
3. Mass air flow sensor
4. O-ring
5. Air duct
6. Air cleaner case

Removal and Installation

INFOID:0000000014418598

GENERAL INFORMATION

- The mass airflow sensor is a hot wire anemometer and measures airflow when air passes around the wire and cools it. The current to the mass airflow sensor increases as the air cools it in order to maintain its temperature. The mass airflow sensor reports this air flow measurement to the engine control module (ECM) as a pulsed frequency output. The output frequency decreases as the airflow increases. The ECM then converts this frequency-based input into an airflow value of kilograms per minute.
- The mass airflow sensor is mounted on the air box which is located on the driver side of the engine compartment.

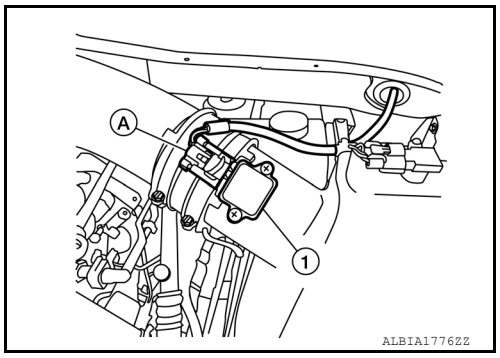
REMOVAL

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".

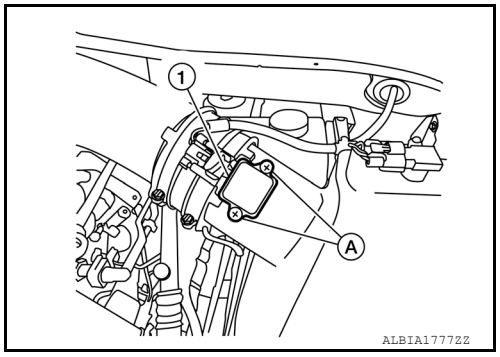
WARNING:

Battery acid and battery acid fumes are extremely dangerous and can cause severe burns and explosion. To help reduce the risk of personal injury;
- **Wear appropriate goggles and protective clothing.**
- **Always properly ventilate the area where the service is being performed.**
- **Never allow battery fluid to come in contact with skin, eyes, fabrics or painted surfaces.**
- **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
- **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**

2. Slide the locking tab on the connector sideways, then push down on the button toward the rear of the harness connector (A) and disconnect it from the mass air flow sensor (1).



3. Remove the bolts (A) and remove the mass air flow sensor (1).



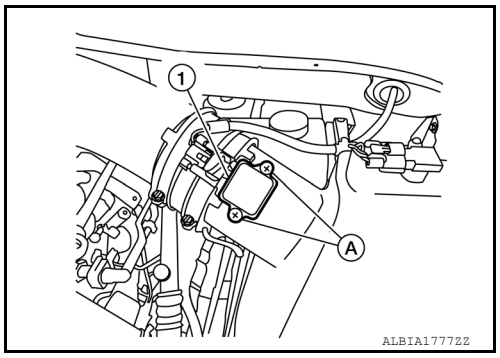
INSPECTION AFTER REMOVAL

- Inspect the harness connector and mass air flow sensor for the following:
- Oil or moisture on the sensing element
- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor.
- If **any** of the above are found, the mass air flow sensor or harness connector **must** be replaced.

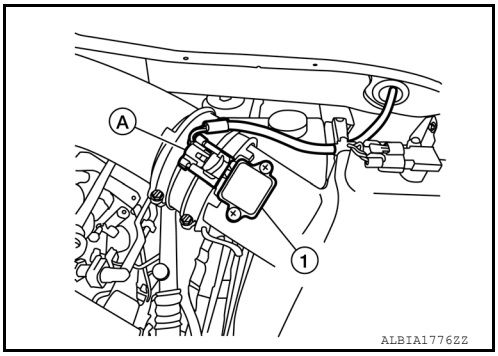
NOTE:
The mass air flow sensor can **not** be cleaned.

INSTALLATION

1. Install the mass air flow sensor (1) then tighten the bolts (A).



2. Connect the harness connector (A) to the mass air flow sensor (1).



3. Connect the battery or batteries. Refer to PG-185, "Battery Disconnect".

WARNING:

Battery acid and battery acid fumes are extremely dangerous and can cause severe burns and explosion. To help reduce the risk of personal injury;

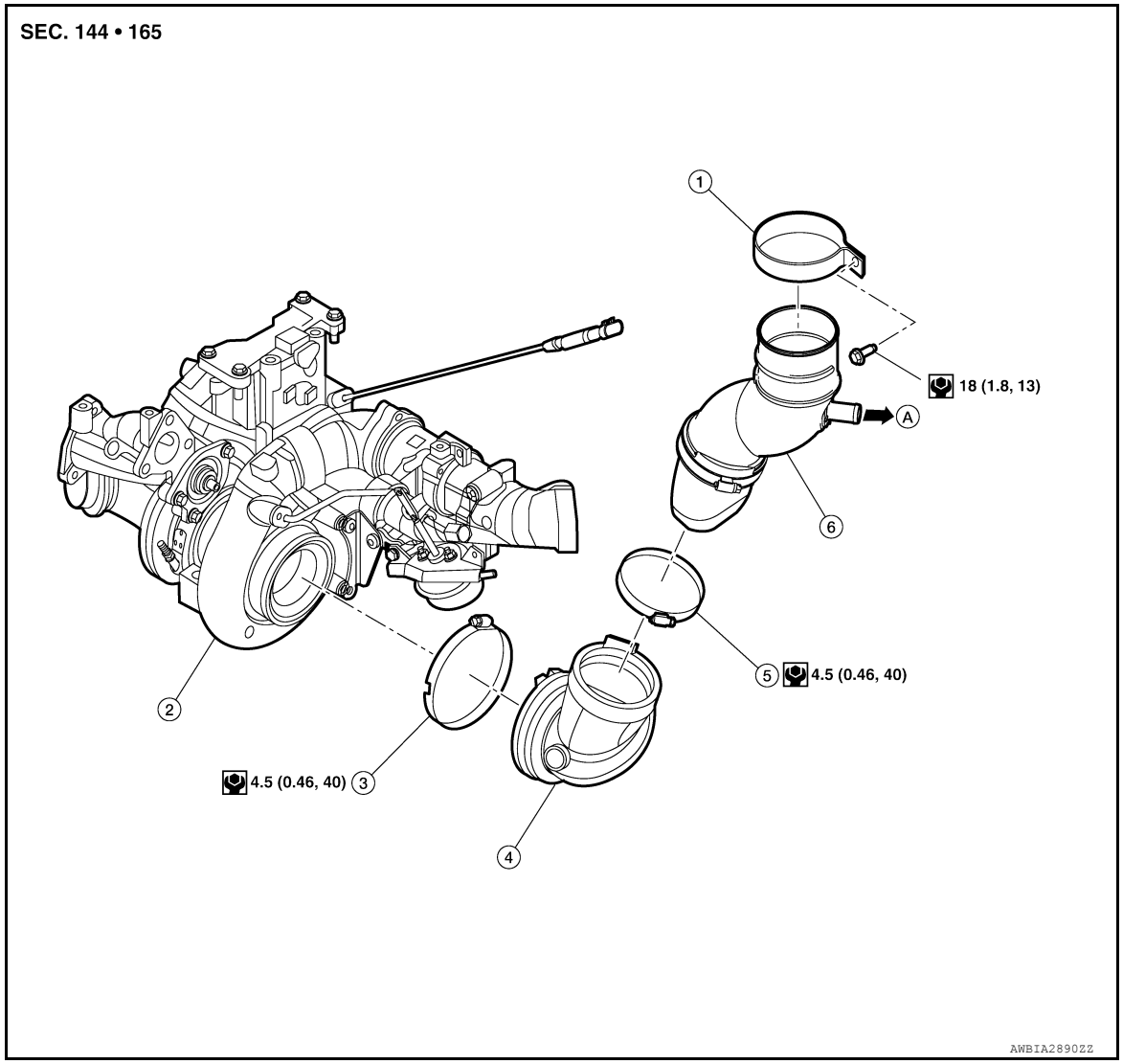
- **Wear appropriate goggles and protective clothing.**
- **Always properly ventilate the area where the service is being performed.**
- **Never allow battery fluid to come in contact with skin, eyes, fabrics or painted surfaces.**
- **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
- **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**

4. Operate the engine and check for leaks.

AIR INLET CONNECTION

Exploded View

INFOID:0000000014418599



1. Clamp
2. Low-pressure turbocharger
3. Clamp
4. Air inlet connection (lower)
5. Clamp
6. Air inlet connection (upper)
A. To crankcase breather tube

NOTE:
The air inlet connection (upper) and air inlet connection (lower) are serviced as an assembly.

Removal and Installation

INFOID:0000000014418600

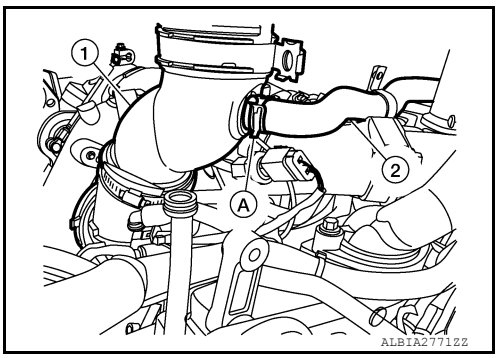
GENERAL INFORMATION

The air inlet connection connects the turbocharger air inlet to the air duct. Refer to EM-220, "Exploded View".

REMOVAL

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".
2. Remove the intake manifold. Refer to EM-239, "Removal and Installation".
   CAUTION:
   Brush away all loose dirt from around the area or the air inlet connections to reduce the possibility of contaminating the interior of the engine.

3. Remove the clamp (A) and disconnect the crankcase breather tube (2) from the air inlet connection [upper (1)].



4. Loosen the clamps that hold the air inlet connection (lower) to the low pressure turbocharger compressor housing and remove the air inlet connection as an assembly. Use the Tool to cover the low pressure turbocharger compressor opening.

CAUTION:

- **Do not allow any dirt or debris to enter the turbocharger.**
- **Brush away all loose dirt from around the area or the air inlet connections to reduce the possibility of contaminating the interior of the engine.**

Tool : — (J-54423)

INSPECTION AFTER REMOVAL

WARNING:

- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufactures recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**

- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**

- Clean the piping and connections with solvent or hot soapy water and dry with compressed air.
- Check the piping and connections for cracks, holes, and worn sections.
- If any damage is found, replace the damaged components.

INSTALLATION

Installation is in the reverse order of removal.

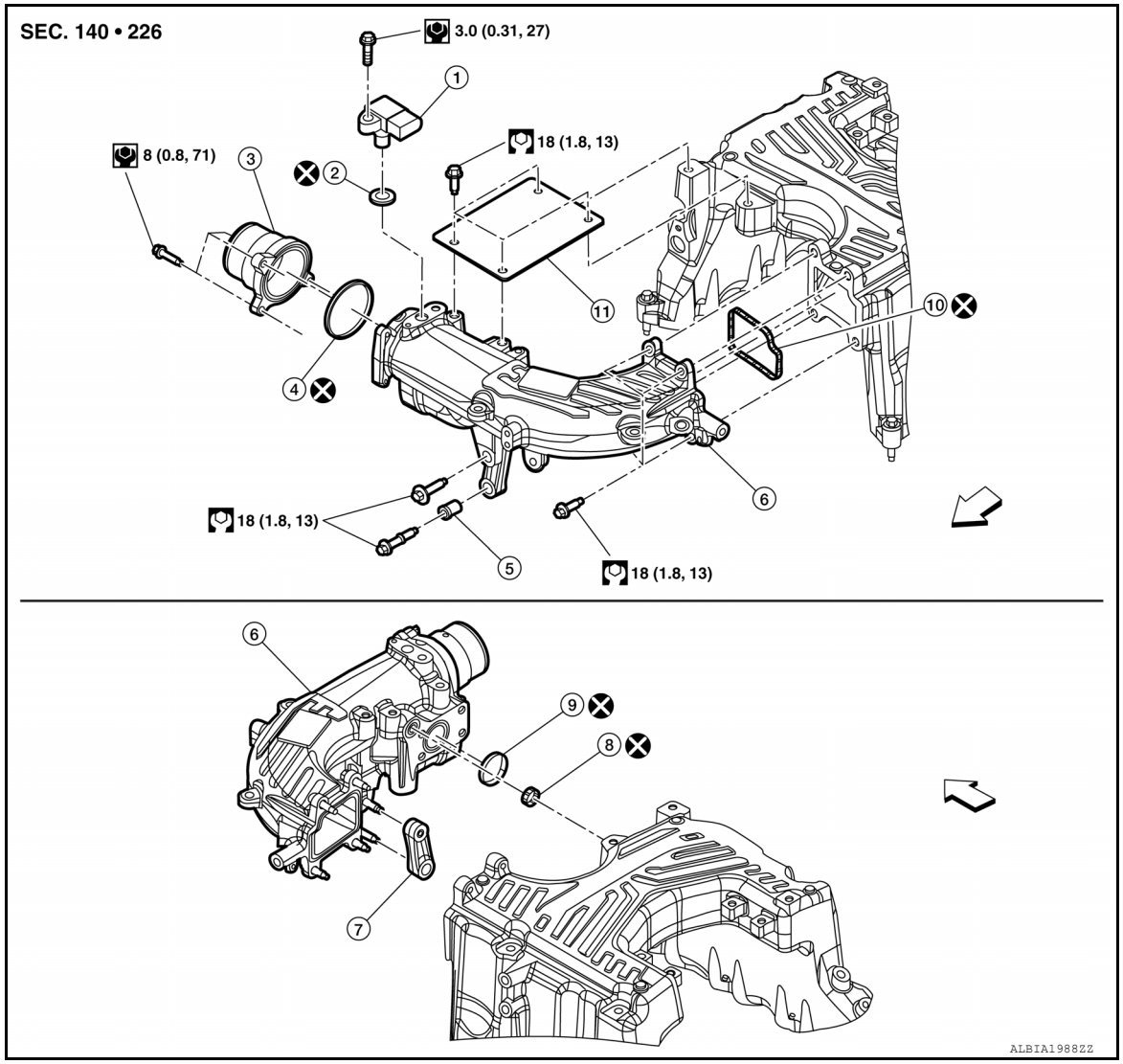
NOTE:

Operate the engine and check for leaks.

AIR INTAKE CONNECTION

Exploded View

INFOID:0000000014418601



1. Engine charge-air cooler outlet pressure/temperature sensor
2. O-ring
3. Air intake connection adapter
4. O-ring
5. Spacer
6. Air intake connection
7. Bracket
8. O-ring
9. O-ring
10. Air intake connection gasket
11. Cover plate

⇦ Front

Removal and Installation

INFOID:0000000014418602

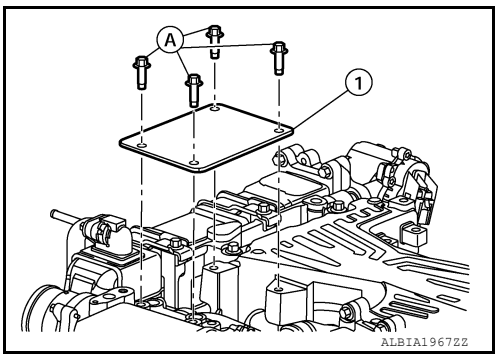
GENERAL INFORMATION

- The air intake connection is part of the air intake system. It is upstream of the air intake manifold.
- The air intake connection must be serviced as a subassembly of the intake manifold assembly.

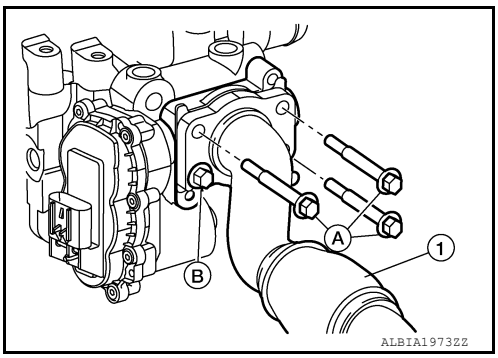
REMOVAL

1. Remove the intake manifold assembly. Refer to EM-239, "Removal and Installation".
2. Remove the EGR cooler and mounting bracket. Refer to EM-275, "Exploded View".
3. Brush away any loose dirt or debris to keep it from entering the air intake system.

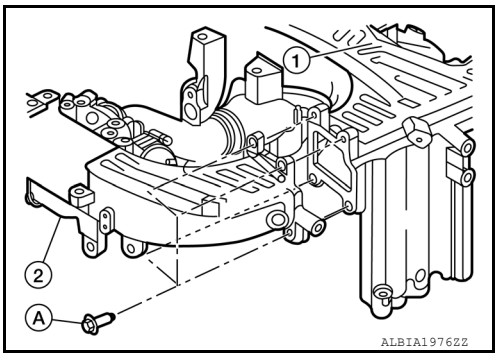
4. Remove the bolts (A) and cover plate (1) from the intake manifold.



5. Remove the bolts (A) and (B) connecting the EGR bypass tube (1) to the EGR bypass valve.

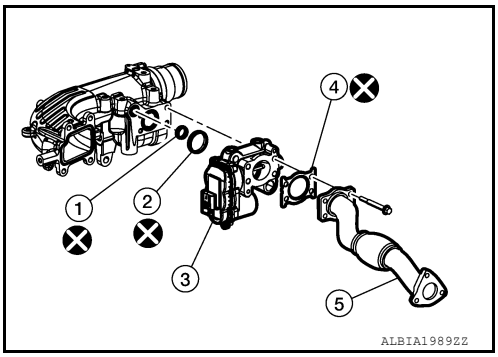


6. Disconnect the harness connector from the EGR bypass.
7. Remove the bolts (A) and then remove the air intake connection (2) from the intake manifold (1).
CAUTION:
Do not reuse the gasket.

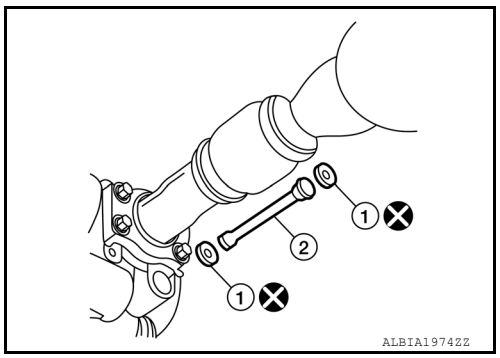


8. Remove the EGR bypass valve (3).
CAUTION:
Do not reuse the gasket (4) or O-rings (1) and (2).

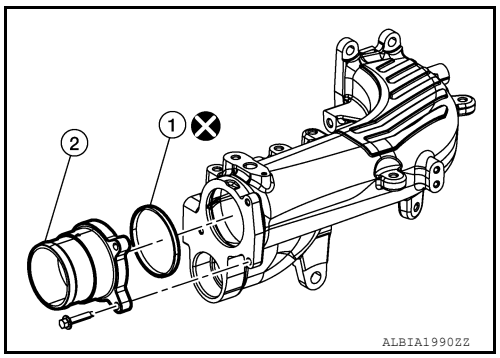
(5) : EGR bypass tube



9. Remove the coolant tube (2).
CAUTION:
Do not reuse the O-rings (1).



10. Remove the air intake connection adapter (2) from the air intake connection.
CAUTION:
Do not reuse the O-ring (1).



INSPECTION AFTER REMOVAL

WARNING:
- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturers recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**

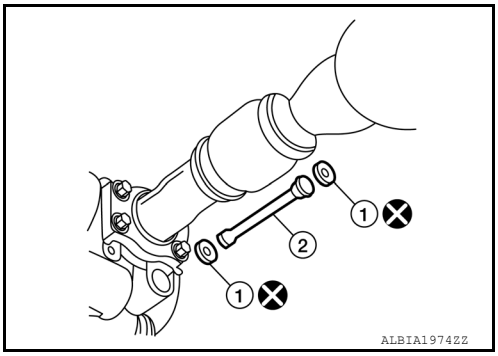
Air Intake Connection
- Use a wire brush to scrape off any soot and/or coolant deposits from the inside of the intake connection.
- Clean the soot from the inside of the intake connection with solvent. Dry with compressed air.
- Inspect the intake connection for cracks and other damage.
- Inspect the sealing surfaces for damage and debris. Clean or replace the component as necessary.

Air Intake Connection Adapter
- Clean the intake connection adapter with solvent and dry with compressed air.
- Inspect the intake connection adapter for debris on the sealing surfaces, cracks, and other damage.
- Inspect the mating surfaces for damage and debris. Clean or replace the component as necessary.

INSTALLATION

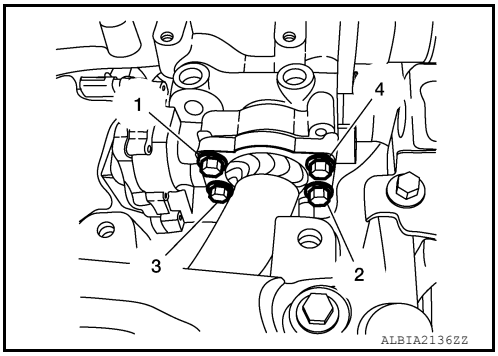
Installation is in the reverse order of removal.
CAUTION:
Do not reuse gaskets and O-rings.

- When installing the coolant tube (2), lubricate the O-rings (1) with a suitable water-based lubricant.
  CAUTION:
  Do not reuse the O-rings.



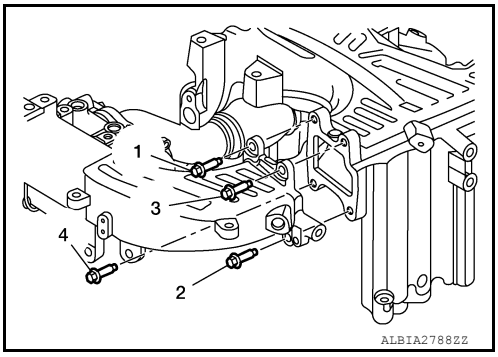
- Tighten the EGR bypass valve bolts to the specified torque in the sequence shown.

  Bolts : 18 N·m (1.8 kg-m, 13 ft-lb)



- Tighten air intake connection bolts to the specified torque in the sequence shown.

  Bolts : 18 N·m (1.8 kg-m, 13 ft-lb)

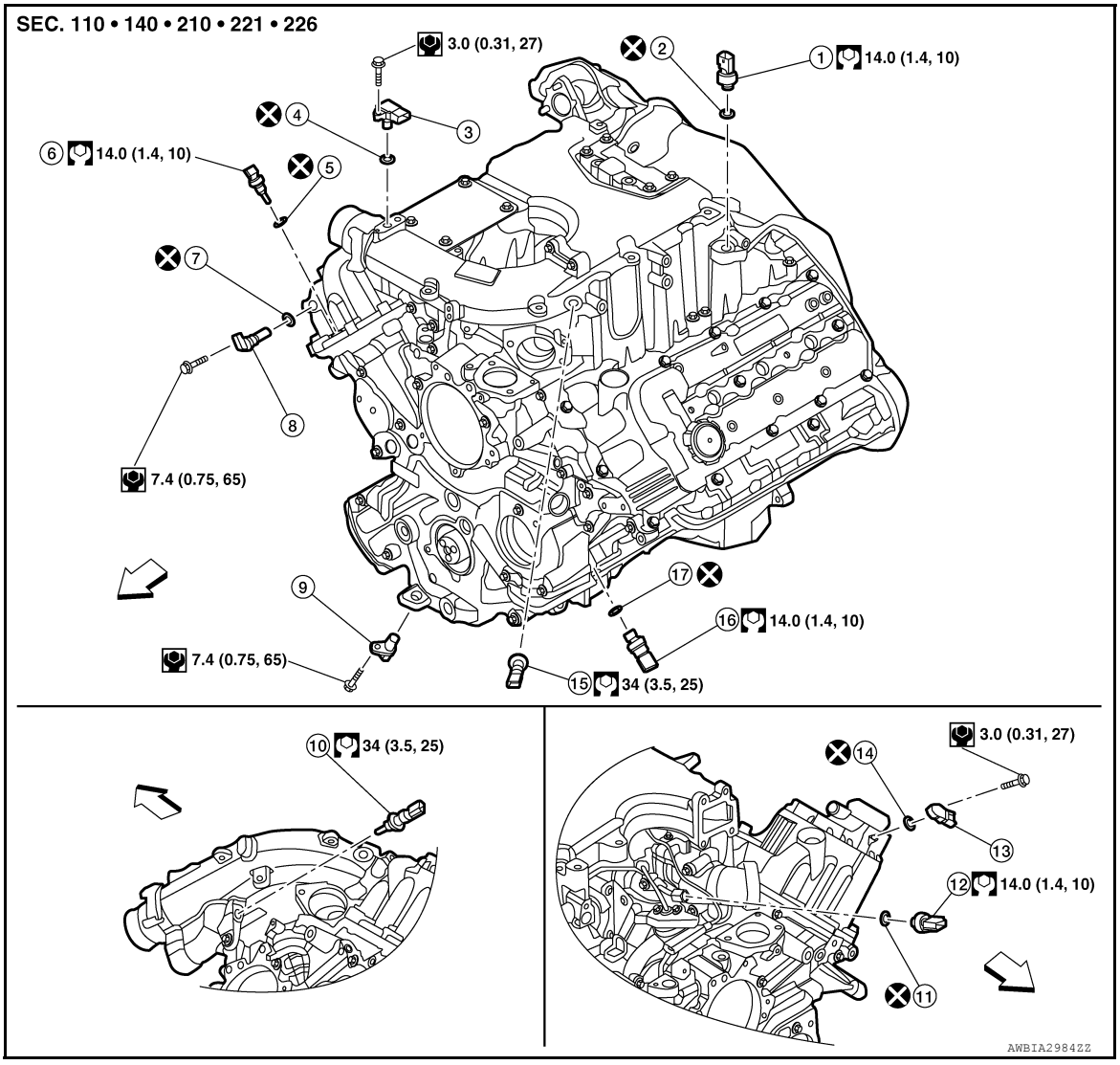


- Operate the engine and check for leaks.

ENGINE CHARGE-AIR COOLER OUTLET OUTLET PRESSURE/TEMPERATURE SENSOR

Exploded View

INFOID:0000000014418603



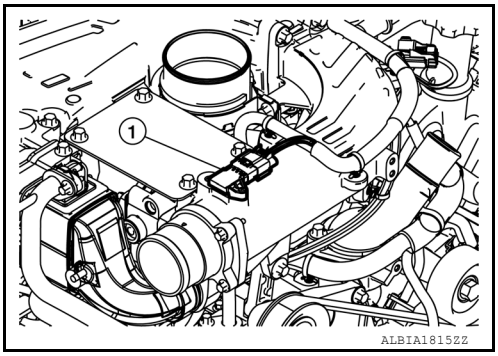
1. Exhaust gas pressure sensor
2. O-ring
3. Engine charge-air cooler outlet pressure/temperature sensor
4. O-ring
5. O-ring
6. Engine coolant temperature sensor
7. O-ring
8. Camshaft position sensor
9. Crankshaft position sensor
10. EGR temperature sensor
11. O-ring
12. Low pressure turbocharger boost pressure sensor
13. Crankcase pressure sensor
14. O-ring
15. Intake manifold air temperature sensor
16. Oil pressure switch
17. O-ring
⇦ Front

Removal and Installation

INFOID:0000000014418604

GENERAL INFORMATION

The engine charge-air cooler outlet pressure/temperature sensor (1) measures both the air temperature and pressure after the compressed air has passed through the charge-air cooler. The sensor is installed on the intake connection. Use the following procedure for a detailed component location view. Refer to EM-181, "INTAKE AIR SYSTEM : System Description".



INSPECTION BEFORE REMOVAL

- Use CONSULT to monitor the value of the engine charge-air cooler outlet pressure/temperature sensor with the key ON and the engine not running.
- The value of the engine charge air cooler outlet temperature sensor should be checked when the engine is cold, and should read within 5.5°C (10°F) of the local ambient air temperature.
- The value of the engine charge air cooler outlet pressure sensor should read within 1 kPa (0.01kg/cm^2, 0.15 psi) of the local barometric air pressure. Refer to EC-806, "CONSULT Function" (Boost Pressure).
- If either value is out of specification, replace the charge-air cooler outlet pressure/temperature sensor.

REMOVAL

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".

   WARNING:
   Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:
   - **Wear appropriate goggles and protective clothing.**
   - **Always properly ventilate the area where the service is being performed.**
   - **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
   - **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
   - **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**
2. Clean the area around the engine charge-air cooler outlet pressure/temperature sensor.
3. Disconnect the engine charge-air cooler outlet pressure/temperature sensor harness connector.
4. Remove the bolt and remove the engine charge-air cooler outlet pressure/temperature sensor.

   CAUTION:
   Do not reuse the o-ring.

INSPECTION AFTER REMOVAL

- Inspect the engine harness connector and the engine charge-air cooler outlet pressure/temperature sensor for the following:
- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor.
- Repair or replace parts as necessary.
- Inspect the tip of the sensor for soot and carbon buildup.

  WARNING:
  when using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:
  - **Do not exceed 30psi (270 kPa).**
  - **Wear appropriate eye protection and protective clothing including gloves.**
- Use compressed air to remove the soot from the sensor, if necessary.
- Do **not** replace the sensor for soot in the sensor.

INSTALLATION

1. Install the engine charge-air cooler outlet pressure/temperature sensor and tighten the bolt.
2. Install and tighten the bolt.

3. Connect the engine harness to the engine charge-air cooler outlet pressure/temperature sensor.
4. Connect the engine charge-air cooler outlet pressure/temperature sensor harness connector.
5. Connect the battery or batteries. Refer to PG-185, "Battery Disconnect".

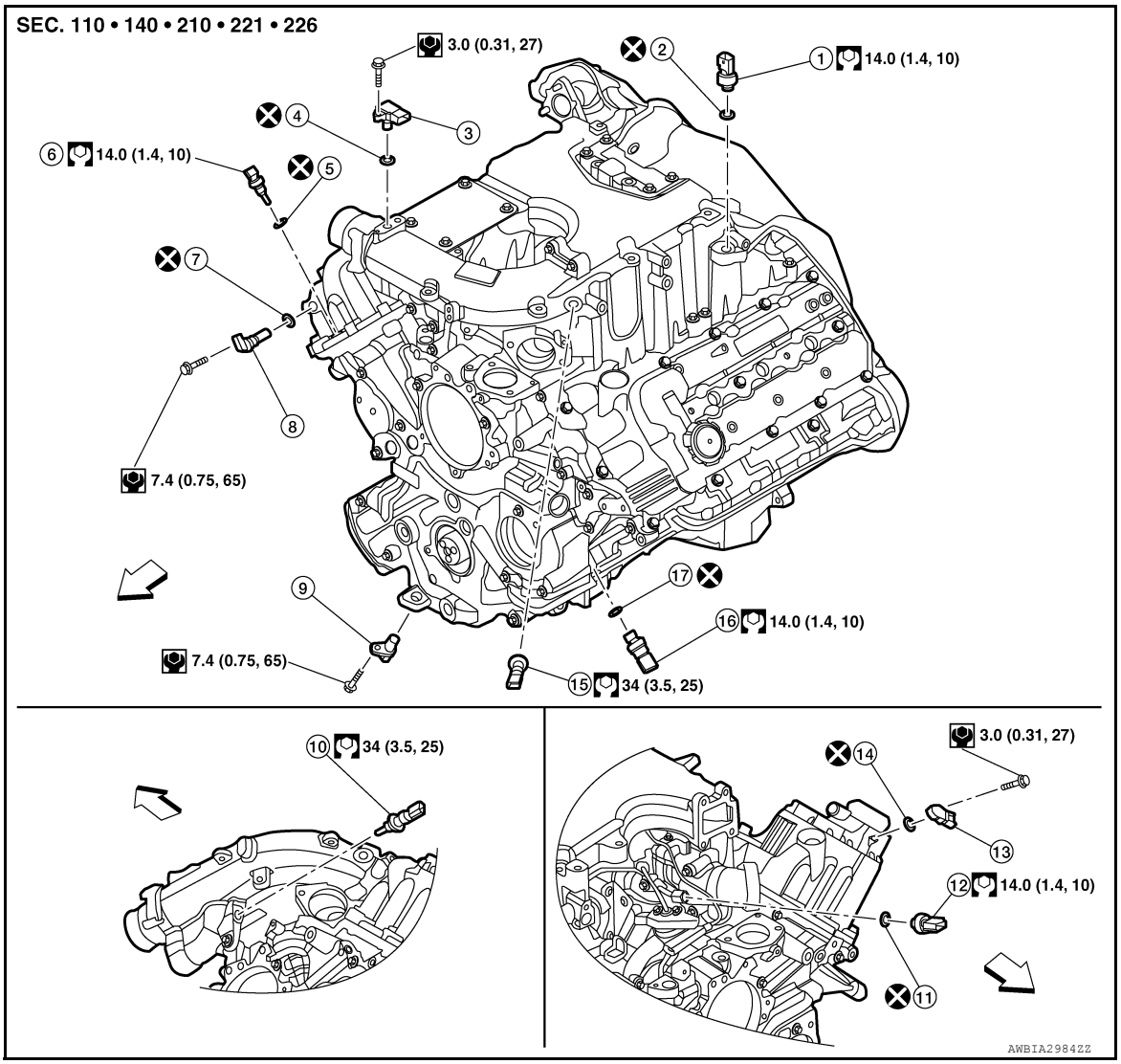
WARNING:
Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:
- **Wear appropriate goggles and protective clothing.**
- **Always properly ventilate the area where the service is being performed.**
- **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
- **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
- **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**

6. Operate the engine and check for leaks.

EGR TEMPERATURE SENSOR

Exploded View

INFOID:0000000014418605



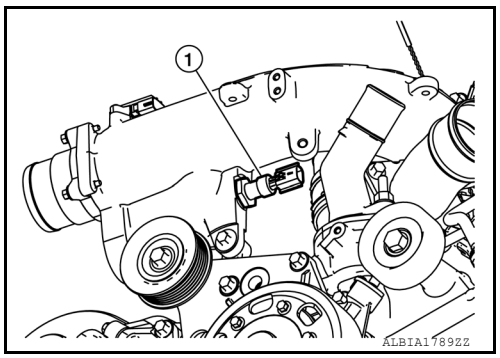
1. Exhaust gas pressure sensor
2. O-ring
3. Engine charge-air cooler outlet pressure/temperature sensor
4. O-ring
5. O-ring
6. Engine coolant temperature sensor
7. O-ring
8. Camshaft position sensor
9. Crankshaft position sensor
10. EGR temperature sensor
11. O-ring
12. Low pressure turbocharger boost pressure sensor
13. Crankcase pressure sensor
14. O-ring
15. Intake manifold air temperature sensor
16. Engine oil pressure switch
17. O-ring
⇦ Front

Removal and Installation

INFOID:0000000014418606

GENERAL INFORMATION

- The exhaust gas recirculation (EGR) temperature sensor (1) is a high temperature, thermistor based sensor, which changes resistance as a function of measured temperature. The EGR temperature sensor is used to measure the temperature of the exhaust gas that exits the cooled and non-cooled EGR circuits.
- The EGR temperature sensor is located on the intake connection, toward the front of the engine.



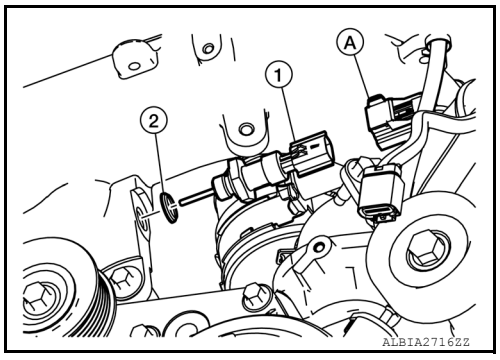
INSPECTION BEFORE INSTALLATION

- Use CONSULT to monitor the reading of the EGR temperature sensor with the key in the ON position and the engine off. Refer to EC-806, "CONSULT Function" (EGR Orifice Temp).
  NOTE:
  The reading of the EGR temperature sensor should be checked when the engine is cold.
- The EGR temperature sensor should read within 5.5°C (10°F) of the local ambient air temperature.
- Replace the EGR temperature sensor if the reading is out of specification.

REMOVAL

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".

   WARNING:
   Battery acid and battery acid fumes are extremely dangerous and can cause severe burns and explosion. To help reduce the risk of personal injury:
   - **Wear appropriate goggles and protective clothing.**
   - **Always properly ventilate the area where the service is being performed.**
   - **Never allow battery fluid to come in contact with skin, eyes, fabrics or painted surfaces.**
   - **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
   - **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**
2. Clean the area around the EGR temperature sensor.
3. Disconnect the EGR temperature sensor harness connector (A) and remove the EGR temperature sensor (1).

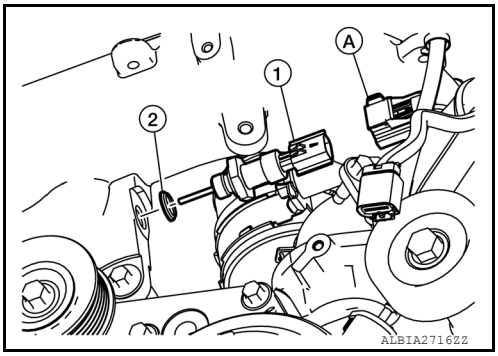


INSPECTION AFTER REMOVAL

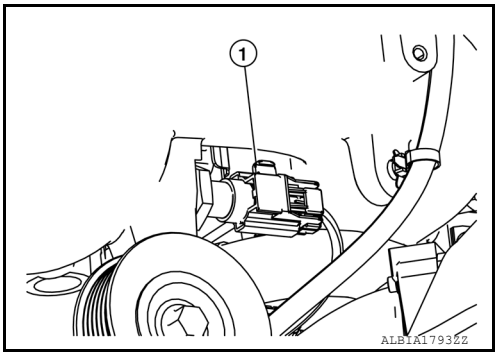
- Inspect the engine harness connector and sensor for the following:
  - Cracked or broken connector shell
  - Missing or damaged connector seals
  - Dirt, debris, or moisture in or on the connector pins
  - Corroded, bent, broken, pushed back, or expanded pins
  - Chipped, cracked, extruded, or damaged sensor.
- Repair or replace parts as necessary.

INSTALLATION

1. Install the EGR temperature sensor (1).
CAUTION:
Tighten the sensor using a suitable, being careful not to overtighten the sensor.
2. Connect the EGR temperature sensor harness connector (A).



3. Push the connectors together until they lock.
Slide the locking tab (1) to the lock position.



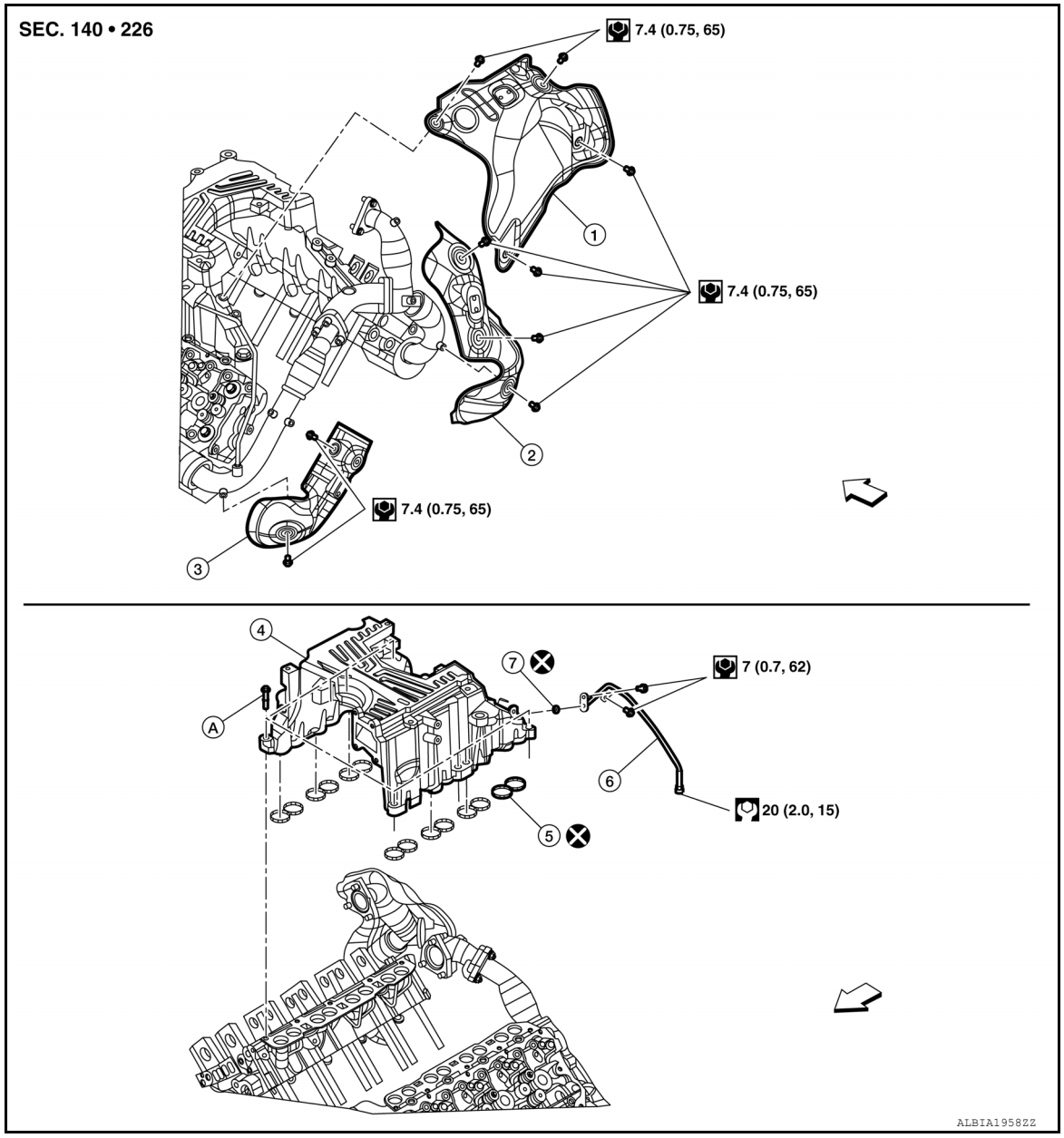
4. Connect the battery or batteries. Refer to PG-185, "Battery Disconnect".
WARNING:
Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:
- **Wear appropriate goggles and protective clothing.**
- **Always properly ventilate the area where the service is being performed.**
- **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
- **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
- **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**

5. Operate the engine and check for leaks.

INTAKE MANIFOLD

Exploded View

INFOID:0000000014418607



1.	Center heat shield	2.	Heat shield (RH)	3.	Heat shield (LH)
4.	Intake manifold	5.	Intake manifold gasket	6.	Exhaust pressure sensor tube
7.	O-ring	A.	Refer to INSTALLATION	⇦	Front

Removal and Installation

INFOID:0000000014418608

REMOVAL

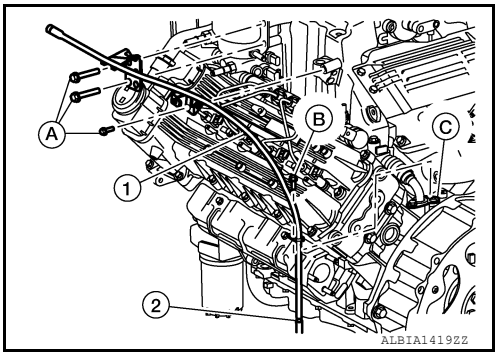
WARNING:

- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
- **Wear appropriate eye protection and protective clothing including gloves and a face shield.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**

- Do not exceed 30psi (207 kPa).
- Wear appropriate eye protection and protective clothing including gloves.

CAUTION:
Brush away all loose dirt from around the area of the air intake connections to avoid contamination of the engine.

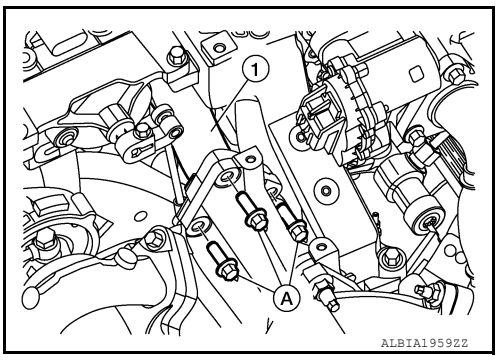
1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".
2. Drain the engine coolant. Refer to CO-47, "Changing Engine Coolant".
3. Remove the center heat shield. Refer to EX-32, "Removal and Installation".
4. Remove the air duct. Refer to EM-221, "Removal and Installation".
5. Remove the coolant reservoir. Refer to CO-52, "Removal and Installation".
6. Disconenct the air inlet and air outlet hoses from the engine. Refer to EM-256, "Exploded View".
7. Disconnect the following harness connectors:
   - Intake manifold air temperature sensor. Refer to EM-250, "Exploded View".
   - Engine charge-air cooler outlet pressure/temperature sensor. Refer to EM-233, "Exploded View".
   - EGR temperature sensor. Refer to EM-236, "Exploded View".
   - Exhaust gas pressure sensor. Refer to EM-304, "Exploded View".
   - Rotary turbine control valve actuator. Refer to EM-417, "Exploded View".
   - EGR bypass valve. Refer to EM-289, "Exploded View".
   - EGR valve. Refer to EM-286, "Exploded View".
8. Remove the engine oil dipstick tube bolts (A) and (B) and remove the engine oil dipstick tube (1) from the cylinder block.



   CAUTION:
   - **Do not reuse the O-ring.**
   - **The engine oil dipstick tube must be removed. Do not attempt to rotate it or move it to the side.**

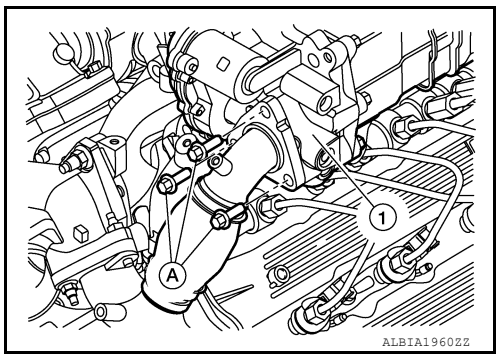
   NOTE:
   - Make sure the rubber O-ring (2) was removed from the cylinder block (C) with the engine oil dipstick tube.
   - Access to bolt in the cylinder block may be difficult and is often overlooked. Make certain to remove this bolt to avoid damaging the engine oil dipstick tube.
9. Remove the fuel filter housing (stage 2). Refer to FL-46, "Removal and Installation".
10. Remove the exhaust pressure sensor tube. Refer to EM-301, "Exploded View".

    CAUTION:
    - **Do not reuse the O-ring.**
    - **The exhaust pressure sensor tube must be removed. Do not attempt to rotate it or move it to the side.**
11. Remove the bolts (A) from the EGR bypass tube (1).

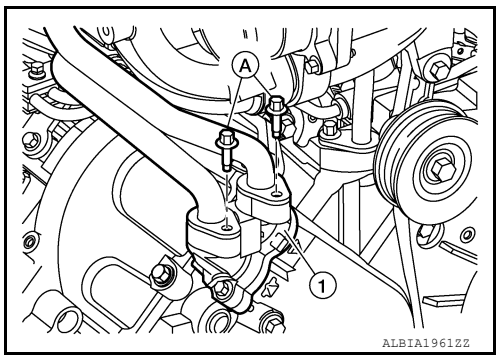


    CAUTION:
    - **Do not reuse the gasket.**
    - **Do not reuse bolts.**

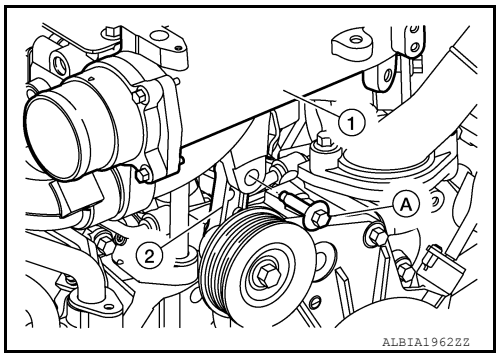
12. Remove the bolts (A) from the EGR valve (1).
CAUTION:
Do not reuse the gasket.



13. Disconnect the rotary turbine control valve linkage from the actuator. Refer to EM-419, "Exploded View".
14. Remove the bolts (A) from the water transfer connection (1).
CAUTION:
Do not reuse the O-rings.

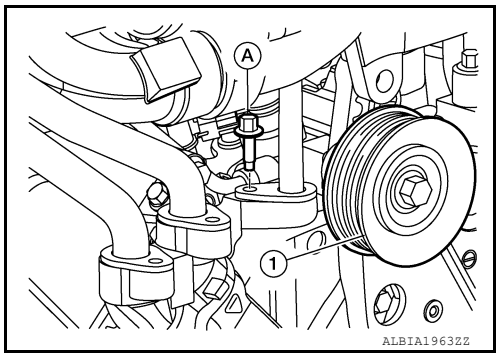


15. Remove the bolt (A) holding the air intake connection (1) to the air intake connection bracket (2) on the front cover.
NOTE:
It is **not** required to remove the bottom bolt from the air intake connection bracket.

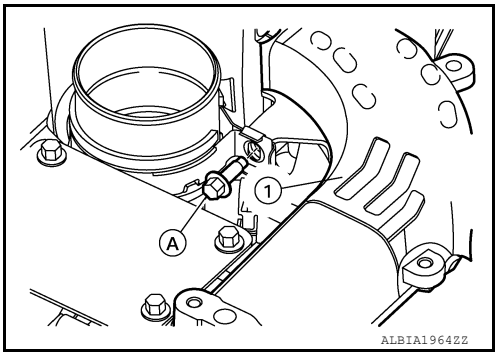


16. Remove the EGR bypass valve coolant tube bolt (A) from the front cover.
NOTE:
It is **not** required to remove the EGR bypass tube for intake manifold removal, but the tube **must** be installed separately during the intake manifold assembly installation.

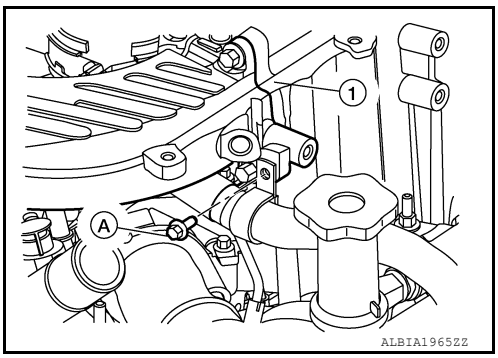
(1) : Idler pulley



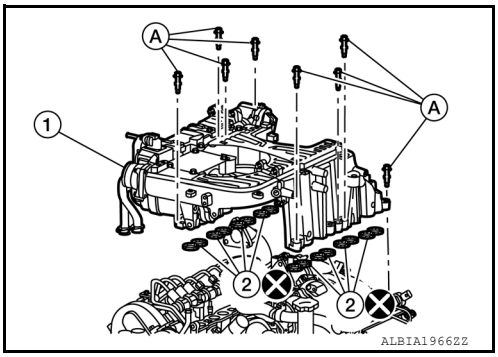
17. Remove the bolt (A) that secures the air inlet connection to the air intake connection (1).



18. Remove the breather tube clamp bolt (A) from the air intake connection (1).



19. Remove the intake manifold bolts (A) then remove the intake manifold assembly (1) and intake manifold gaskets (2).



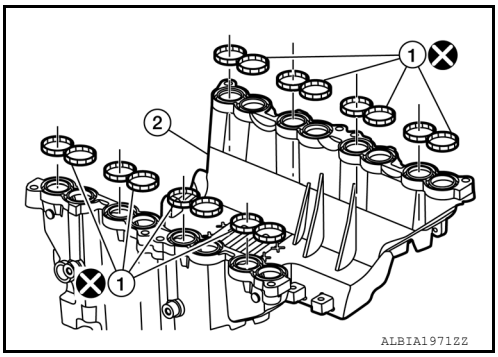
WARNING:
To avoid the risk of personal injury, use lifting equipment or acquire assistance when lifting components or assemblies that weight more than 23 kg (50 lbs).
CAUTION:
- **Do not reuse the intake manifold gaskets.**
- **Use the appropriate clean care kits to seal all air and coolant openings. Debris entering the air and cooling systems can damage the engine.**
- **Use compressed air to blow out any coolant that remains on top of the glow plugs. If coolant is not removed, the glow plug will corrode.**
- **Do not bump or crush the glow plug harness connectors when removing intake manifold assembly.**

NOTE:
When removing the intake manifold assembly, cap all open air handling components with Tool.

Tool : — (J-54423)

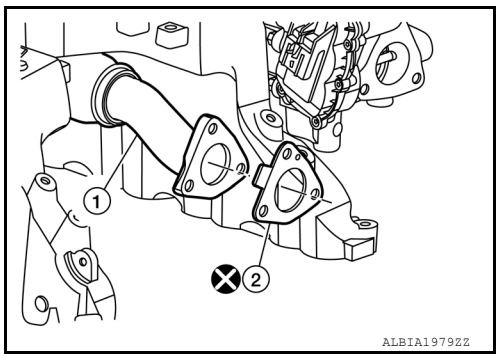
INSTALLATION

1. Install the intake manifold gaskets (1) in the intake manifold (2).

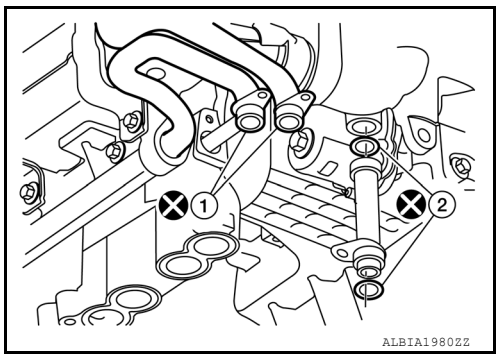


CAUTION:
Do not reuse the intake manifold gaskets.
NOTE:
Be sure all gaskets are in place and properly seated.

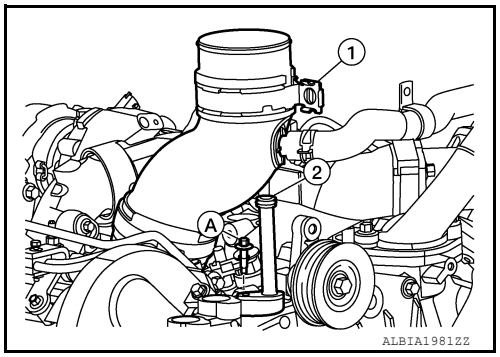
2. Install a new gasket (2) onto the EGR bypass exhaust transfer tube (1).
CAUTION:
Do not reuse the gasket.



3. Use a suitable water-based lubricant to lubricate the EGR cooler return and supply line O-rings (1) and the EGR bypass valve coolant tube O-rings (2).
CAUTION:
Do not reuse the O-rings.

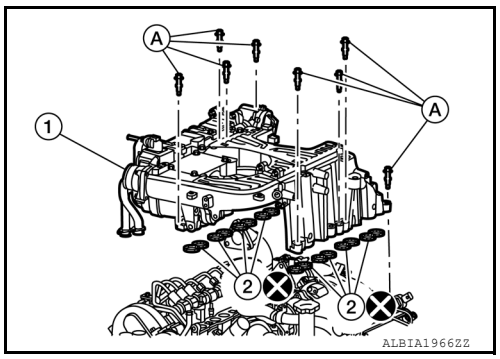


4. Install the EGR bypass valve coolant tube (2) and bolt (A) to the front cover.
NOTE:
Be sure that the air inlet clamp (1) is moved away for installing the intake manifold.



5. Lower the intake manifold (1) onto the engine. Be sure the EGR cooler coolant return and supply lines fit into the water transfer connection. Be sure the EGR bypass valve coolant tube fits into the front cover.
WARNING:
- **To avoid the risk of personal injury, use lifting equipment or acquire assistance when lifting components or assemblies that weight more than 23 kg (50 lbs).**
- **Do not bump or crush the glow plug harness connectors when removing intake manifold assembly.**

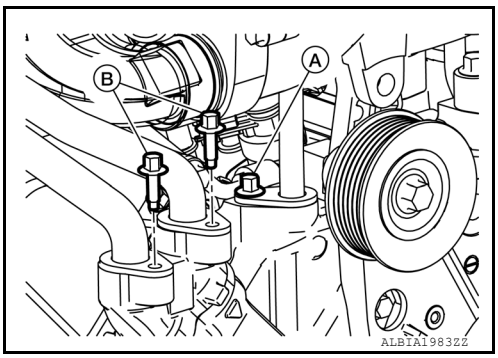
NOTE:
Check that all intake manifold gaskets (2) are in place and properly seated.



(A) : Bolts

6. Install the EGR cooler return and supply line bolts (B) and EGR bypass coolant tube bolt (A).

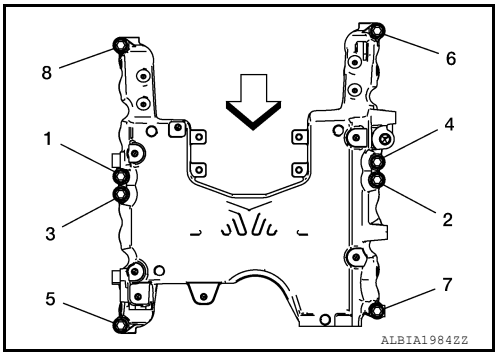
Bolts (A) and (B) : 7.4 N·m (0.75 kg-m, 65 in-lb)



7. Install the intake manifold bolts and tighten in the order shown.

Intake manifold bolts : 18 N·m (1.8 kg-m, 13 ft-lb)

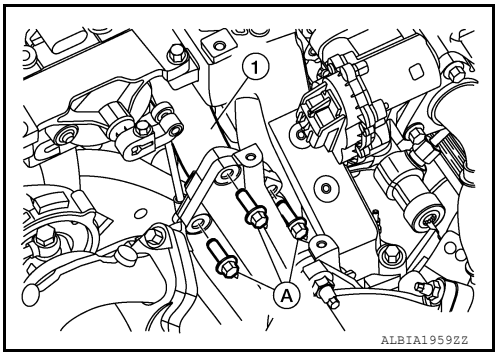
⇦ : Front



8. Apply a coating of anti-seize and install bolts (A) for the EGR bypass tube (1) and tighten to the specified torque.

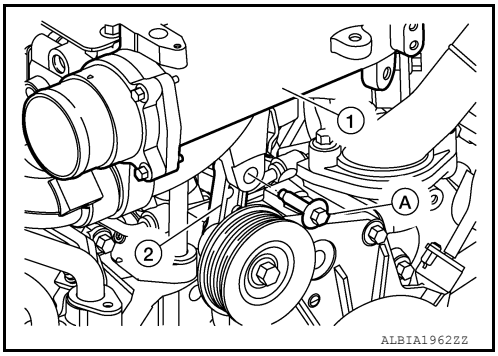
CAUTION:
- **Do not reuse the gasket.**
- **Do not reuse bolts.**

Bolts (A) : 18 N·m (1.8 kg-m, 13 ft-lb)



9. Install bolt (A) holding the air intake connection (1) to the air intake connection bracket (2).

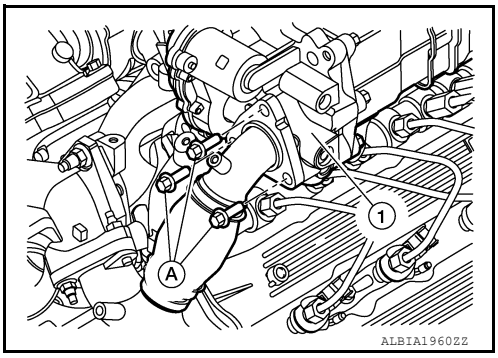
Bolt (A) : 18 N·m (1.8 kg-m, 13 ft-lb)



10. Install bolts (A) for the EGR valve (1) and tighten to the specified torque.

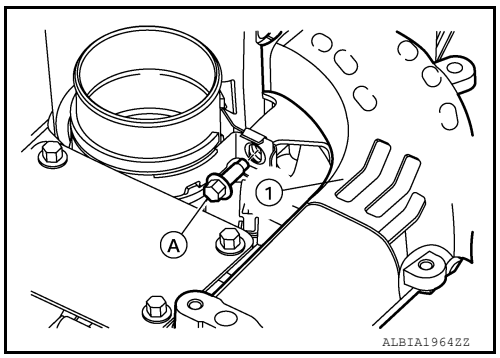
CAUTION:
Do not reuse the gasket.

Bolts (A) : 23 N·m (2.3 kg-m, 17 ft-lb)



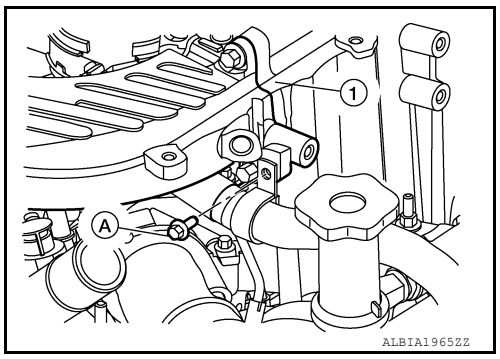
11. Install the bolt (A) that secures the air inlet connection to the air intake connection (1).

Bolt (A) : 4.5 N·m (0.46 kg-m, 40 in-lb)



12. Install the breather tube clamp bolt (A) from the air intake connection (1).

Bolt (A) : 7.4 N·m (0.75 kg-m, 65 in-lb)



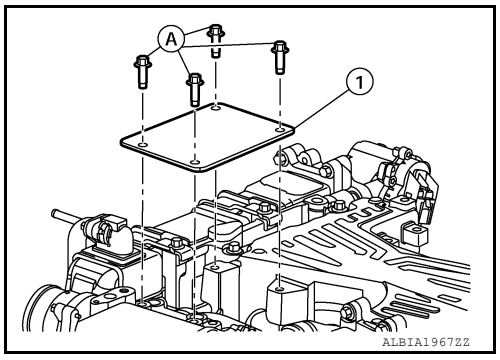
13. Installation of the remaining components is in the reverse order of removal.
NOTE:
- Use CONSULT to calibrate the rotary turbine control valve actuator . Refer to EC-902, "Description".
- Operate the engine and check for leaks.

Disassembly

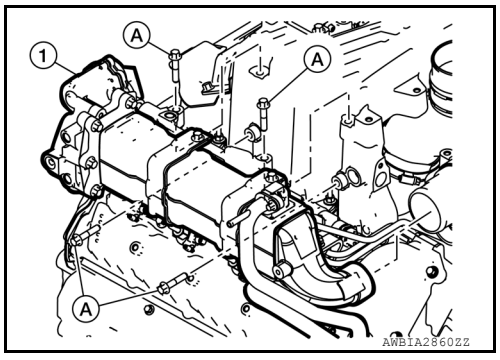
INFOID:0000000014418609

DISASSEMBLY

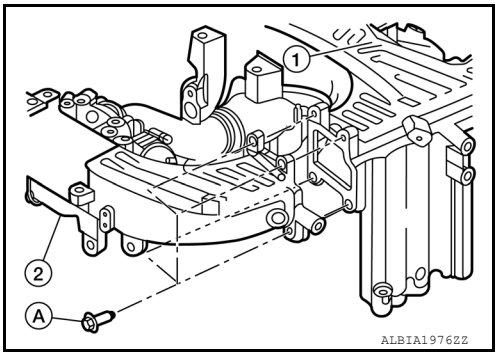
1. Remove the rotary turbine control valve actuator. Refer to EM-417, "Exploded View" .
2. Remove bolts (A) and remove the cover plate (1) from the intake manifold.



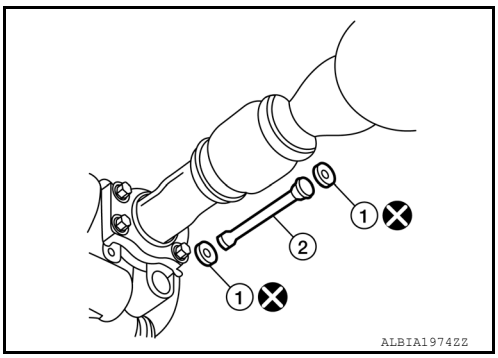
3. Remove the EGR bracket bolts (A), and the EGR cooler assembly (1) from the intake manifold.
CAUTION:
Do not reuse the O-rings.



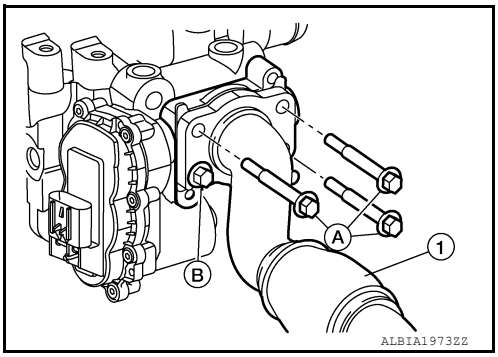
4. Remove the bolts (A) and then remove the air intake connection (2) from the intake manifold (1).
CAUTION:
Do not reuse the gasket.



5. Remove the coolant tube [2 (if necessary)].
CAUTION:
Do not reuse the O-rings (1).

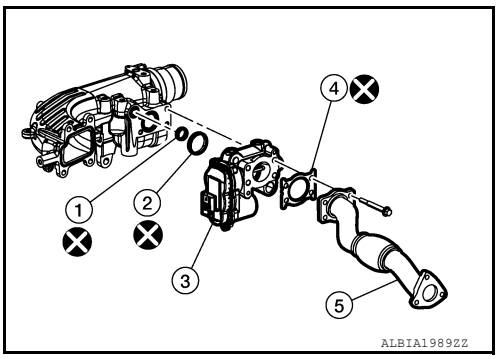


6. Remove the bolts (A) and (B) connecting the EGR bypass tube (1) to the EGR bypass valve after removing the air intake connection (if necessary).



7. Remove the EGR bypass valve (3) from the air intake connection (if necessary).
CAUTION:
Do not reuse the gasket (4) or O-rings (1) and (2).

(5) : EGR bypass tube



8. Remove the exhaust gas pressure sensor. Refer to EM-304, "Exploded View".
9. Remove the intake manifold air temperature sensor. Refer to EM-250, "Exploded View".
10. Remove the EGR temperature sensor. Refer to EM-236, "Exploded View".

Inspection After Disassembly

INFOID:0000000014418610

INSPECTION AFTER DISASSEMBLY

CAUTION:
- **Remove the intake manifold cover on the cylinder head during cleaning and cover the ports after cleaning.**

- **Do not use a wire brush, gasket scraper, or putty knife to clean the surfaces. Damage to the components can result.**
- Clean the intake manifold and cylinder head mating surfaces with a contact cleaner and a clean cloth. Do **not** allow any gasket material or debris to drop into the cylinder head.
- Inspect the air intake manifold for cracks or other damage. If damage is present, replace component as necessary.
- Clean and inspect the air intake connection. If damage is present, replace component as necessary.

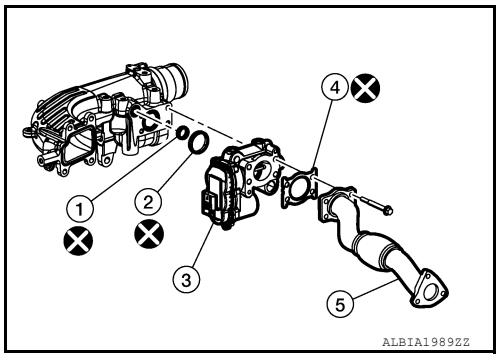
Assembly

INFOID:0000000014418611

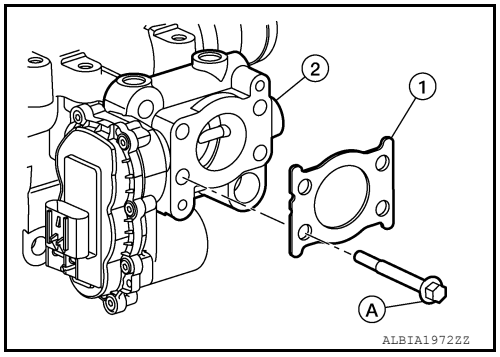
ASSEMBLY

1. Before installing EGR bypass valve (3) onto air intake connection, install gaskets (1) and (2).
   CAUTION:
   Do not reuse the EGR bypass valve gaskets.

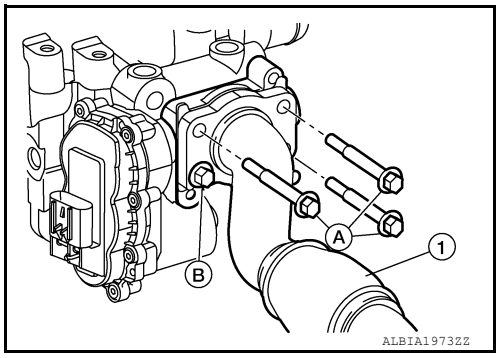
   (4) : EGR bypass valve Gasket
   (5) : EGR bypass tube



2. Install bolt (A) in the lower left hole of the gasket (1) and EGR bypass valve (2), as shown. Do not tighten the bolt and leave a gap to allow the exhaust transfer tube flange to be slid into place.
   CAUTION:
   Do not reuse the gasket.

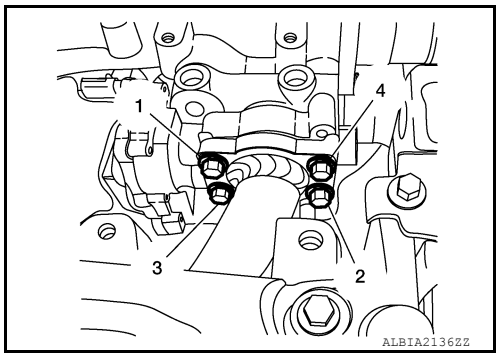


3. Slide the exhaust transfer tube (1) over the installed bolt (B) and install the remaining bolts (A).

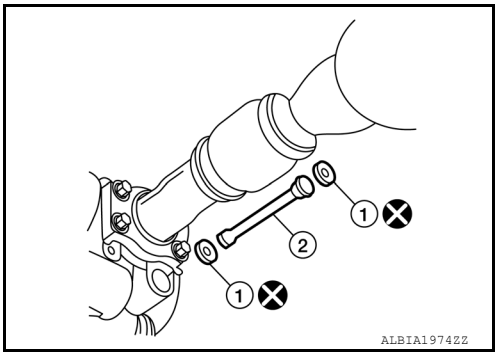


4. Tighten EGR bypass valve bolts in the following sequence.

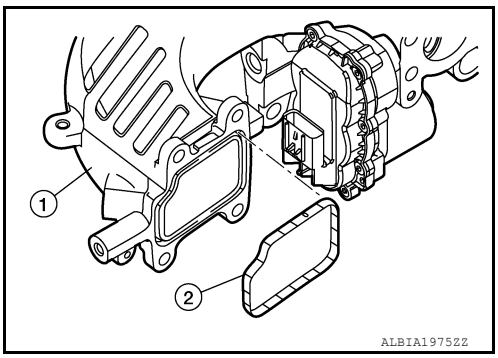
   EGR bypass valve bolts : 18 N·m (1.8 kg-m, 13 ft-lb)



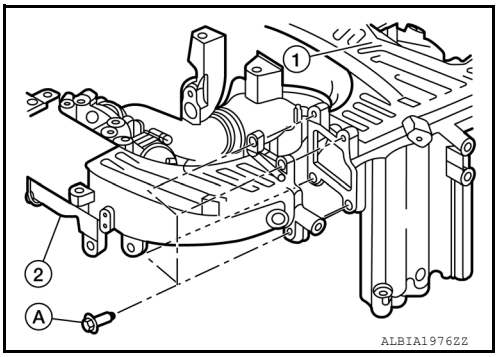
5. Install the coolant tube (2) into the exhaust bypass valve.
CAUTION:
Do not reuse the O-rings (1).
NOTE:
Lubricate the O-ring with a suitable water-based lubricant.



6. Install a new gasket (2) into the air intake connection (1).
CAUTION:
Do not reuse gasket.
NOTE:
Be sure gaskets are in place and properly seated.

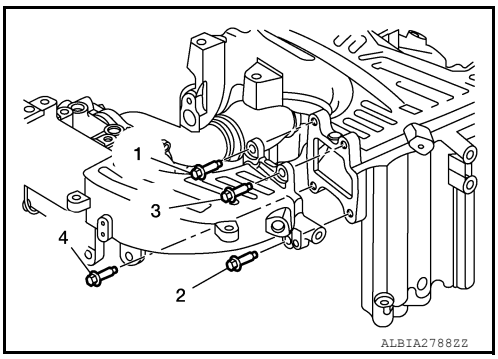


7. Install the air intake connection (2) onto the intake manifold (1) and tighten bolts (A).
NOTE:
Be sure the coolant tube is aligned and installs into the intake manifold.

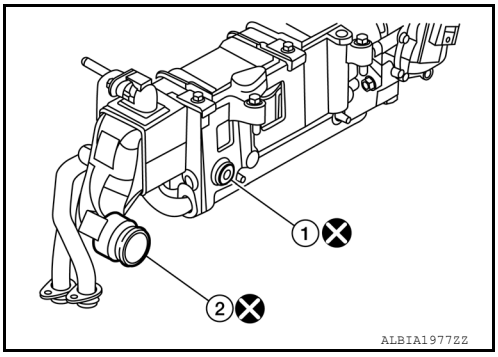


8. Tighten air intake connection bolts in the sequence shown to the specified torque.

Air intake connection bolts : 18 N·m (1.8 kg-m, 13 ft-lb)



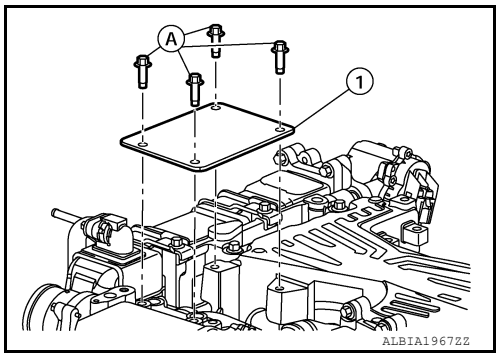
9. Lubricate the O-rings (1) and (2) with a suitable water-based lubricant.
CAUTION:
Do not reuse the O-rings.



10. Install the EGR cooler assembly. Refer to EM-275, "Exploded View".

11. Install the cover plate (1) and bolts (A) onto the intake manifold assembly.

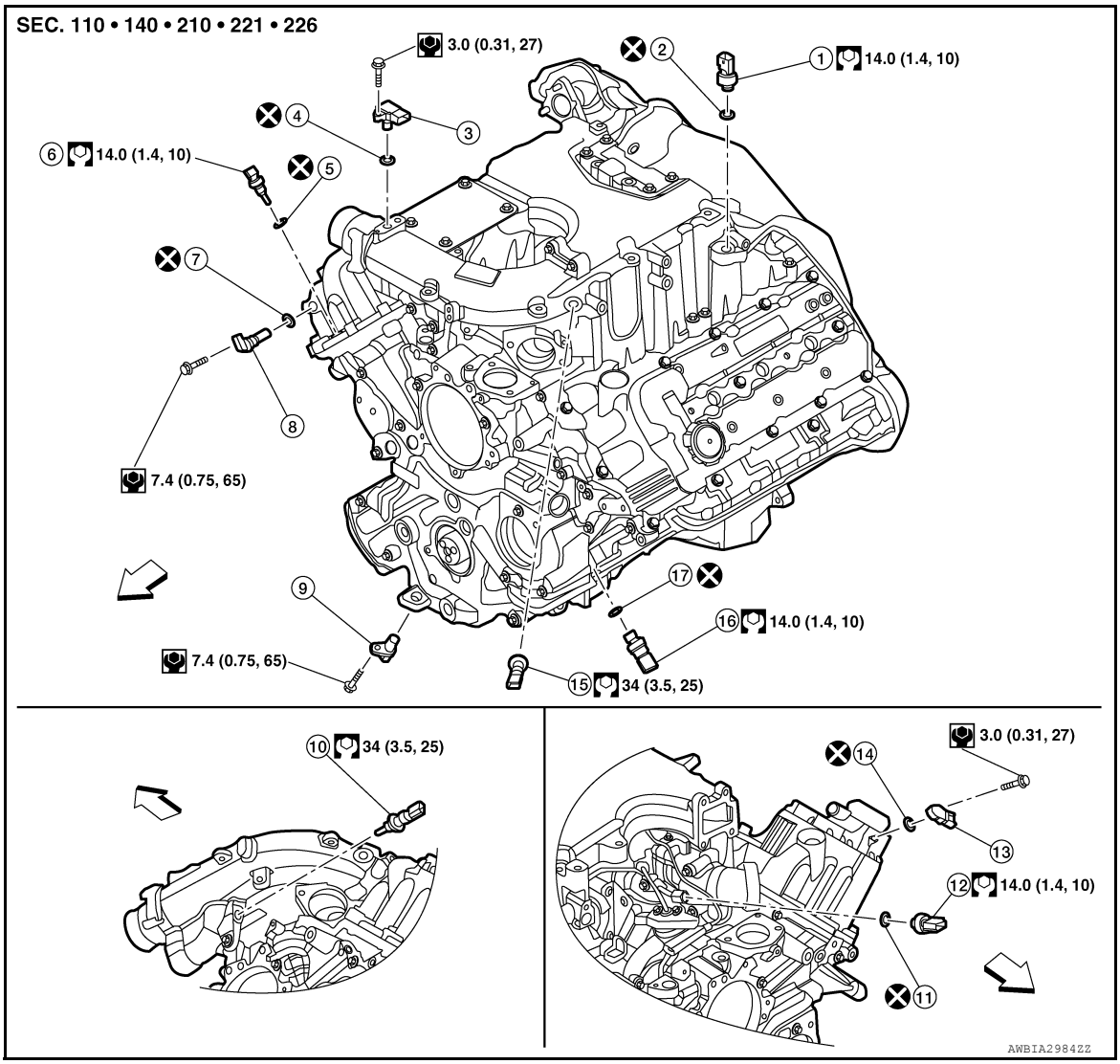
Cover plate bolts : 18 N·m (1.8 kg-m, 13 ft-lb)



INTAKE MANIFOLD AIR TEMPERATURE SENSOR

Exploded View

INFOID:0000000014418612



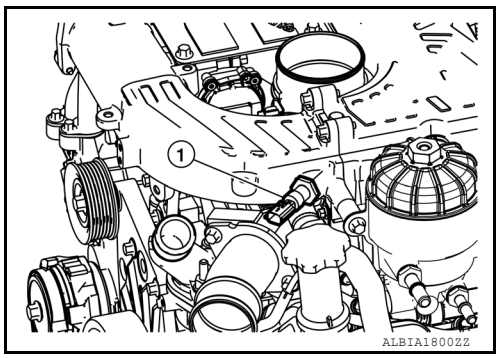
1. Exhaust gas pressure sensor
2. O-ring
3. Engine charge-air cooler outlet pressure/temperature sensor
4. O-ring
5. O-ring
6. Engine coolant temperature sensor
7. O-ring
8. Camshaft position sensor
9. Crankshaft position sensor
10. EGR temperature sensor
11. O-ring
12. Low pressure turbocharger boost pressure sensor
13. Crankcase pressure sensor
14. O-ring
15. Intake manifold air temperature sensor
16. Engine oil pressure switch
17. O-ring
⇦ Front

Removal and Installation

INFOID:0000000014418613

GENERAL INFORMATION

- The intake manifold temperature sensor (1) is a high temperature, thermistor based sensor, which changes resistance as a function of measured temperature. The intake manifold air temperature sensor is used to measure the temperature of the combined fresh air and exhaust recirculation flows entering the intake manifold.



- The intake manifold air temperature sensor is located on the intake connection, toward the front of the engine. Refer to EM-181, "INTAKE AIR SYSTEM : System Description".

INSPECTION BEFORE REMOVAL

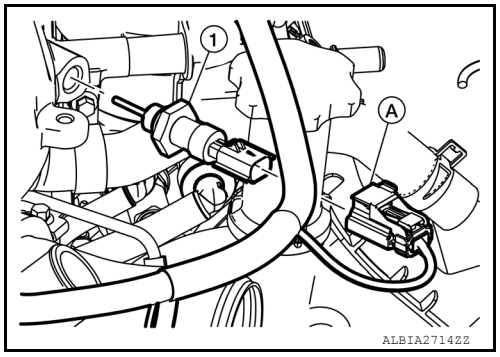
- Use an electronic service tool to monitor the value of the intake manifold air temperature sensor with the key in the ON position and the engine off. Refer to EC-806, "CONSULT Function" (Intake Manifold Temp).
- The value of the intake manifold air temperature sensor should read within 5.5°C (10°F) of the local ambient air temperature.
- Replace the intake manifold air temperature sensor if the value is out of specification.

NOTE:
The value of the intake manifold air temperature sensor should be checked when the engine is cold.

REMOVAL

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".

   WARNING:
   Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:
   - **Wear appropriate goggles and protective clothing.**
   - **Always properly ventilate the area where the service is being performed.**
   - **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
   - **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
   - **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**
2. Clean the area around the intake manifold air temperature sensor.
3. Disconnect the intake manifold air temperature sensor harness connector (A).
4. Remove the intake manifold air temperature sensor (1).



INSPECTION AFTER REMOVAL

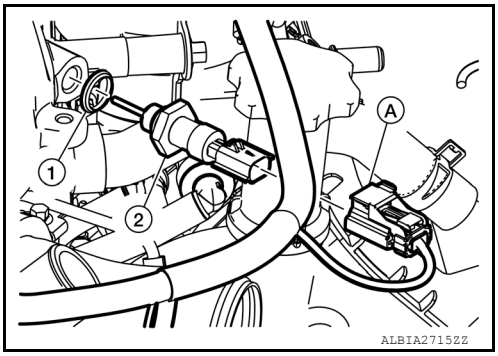
- Inspect the engine harness connector and sensor for the following:
- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor.
- Repair or replace parts as necessary.

INSTALLATION

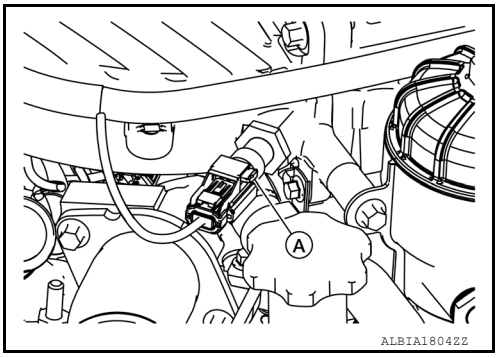
1. Install the intake manifold air temperature sensor (2) and connect the harness connector (A).

CAUTION:
Do not reuse O-ring.

(1) : O-ring



2. Push the connectors together until they lock and slide the tab (A) to the lock position.



3. Connect the battery or batteries. Refer to PG-185, "Battery Disconnect".

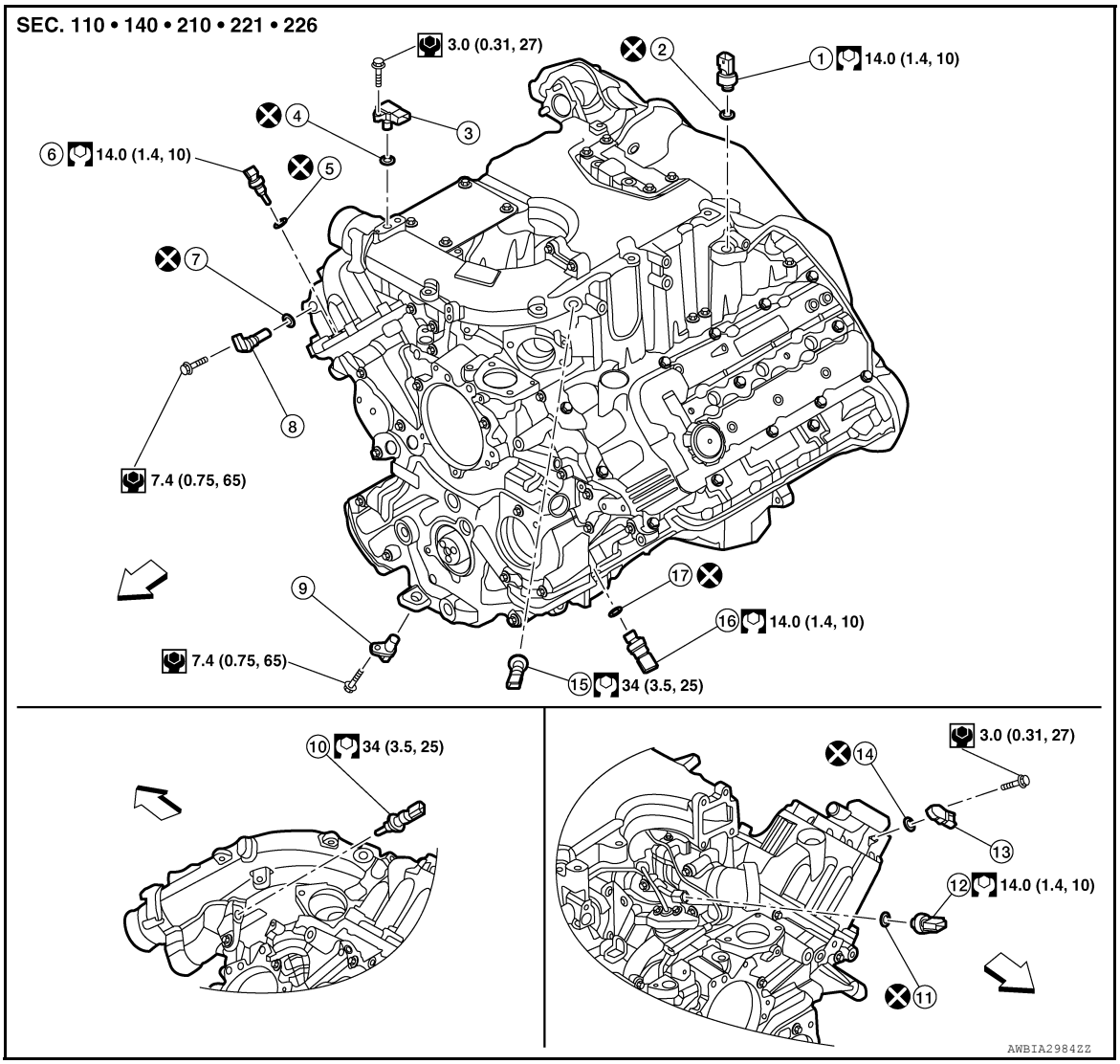
WARNING:
Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:
- **Wear appropriate goggles and protective clothing.**
- **Always properly ventilate the area where the service is being performed.**
- **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
- **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
- **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**

4. Operate the engine and check for leaks.

LOW PRESSURE TURBOCHARGER BOOST PRESSURE SENSOR

Exploded View

INFOID:0000000014418614



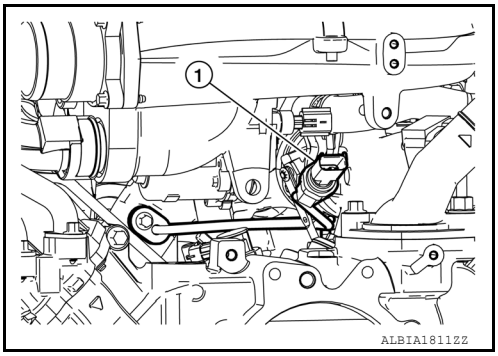
1. Exhaust gas pressure sensor	2. O-ring	3. Engine charge-air cooler outlet pressure/temperature sensor
4. O-ring	5. O-ring	6. Engine coolant temperature sensor
7. O-ring	8. Camshaft position sensor	9. Crankshaft position sensor
10. EGR temperature sensor	11. O-ring	12. Low pressure turbocharger boost pressure sensor
13. Crankcase pressure sensor	14. O-ring	15. Intake manifold air temperature sensor
16. Engine oil pressure switch	17. O-ring	⇦ Front

Removal and Installation

INFOID:0000000014418615

GENERAL INFORMATION

- The low-pressure turbocharger boost pressure sensor (1) monitors the pressure of the compressed air after it has gone through the low-pressure compressor turbocharger and before it enters the high-pressure compressor turbocharger. The sensed pressure is converted to a voltage signal and that information is passed on to the engine control module (ECM) through the engine harness.



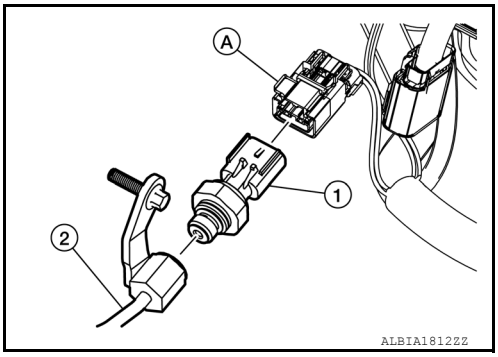
- The low-pressure turbocharger boost sensor is threaded to the low-pressure turbocharger boost pressure sensor tube and is inside the vee of the engine. Refer to EM-181, "INTAKE AIR SYSTEM : System Description".

INSPECTION BEFORE REMVOAL

- Use an electronic service tool to monitor the value of the low-pressure turbocharger boost pressure sensor with the key in the ON position and the engine OFF.
- The value of the low-pressure turbocharger boost pressure sensor should read within 5 percent of the local barometric air pressure when the local ambient air temperature is between -40°C (-40°F) and 40°C (104°F).
- Replace the low-pressure turbocharger boost pressure sensor if the value is out of specification.

REMOVAL

1. Gently slide the locking tab (A) on the connector sideways with a suitable tool and disconnect the harness connector.
2. Use a suitable tool to remove the low-pressure turbocharger boost pressure sensor (1) from the low-pressure turbocharger boost pressure sensor tube (2).
   CAUTION:
   To avoid damage, do not kink or bend fuel, lubrication air intake and exhaust tubing or lines. Ensure all tubes and lines are routed and installed properly and care is given during the disassembly and assembly process. Failure to do so can result in damage to the tubes, lines or surrounding components.



INSPECTION AFTER REMOVAL

Inspect the engine harness connector and sensor for the following:

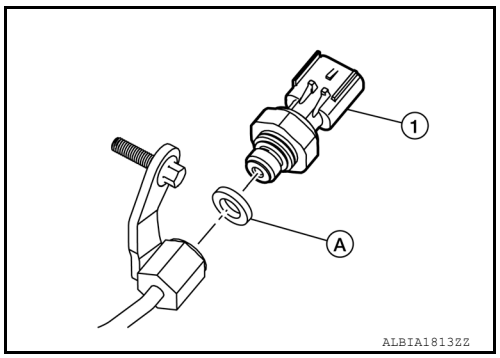
- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor.

Repair or replace parts as necessary.

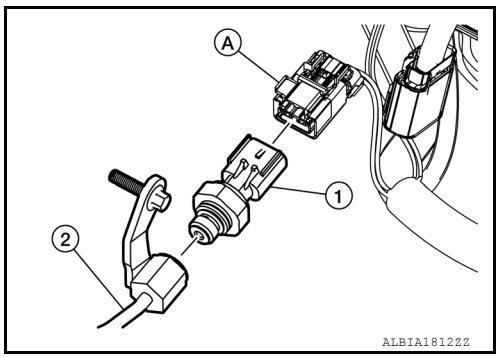
INSTALLATION

CAUTION:
To avoid damage, do not kink or bend fuel, lubrication air intake and exhaust tubing or lines. Ensure all tubes and lines are routed and installed properly and care is given during the disassembly and assembly process. Failure to do so can result in damage to the tubes, lines or surrounding components.

1. Make sure the low-pressure turbocharger boost pressure sensor (1) has an O-ring (A).
CAUTION:
Do not reuse O-ring.



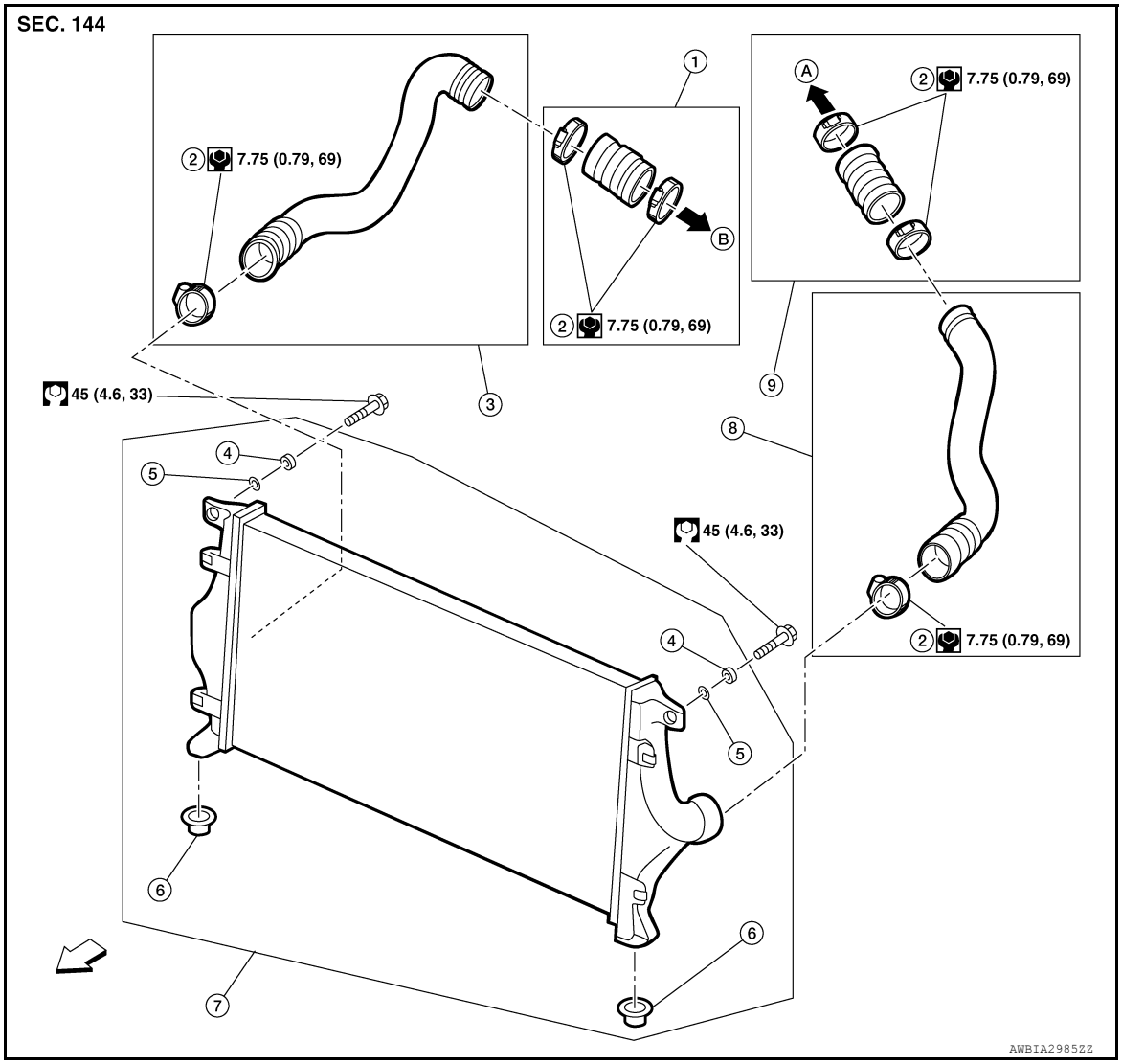
2. Install the low-pressure turbocharger boost pressure sensor (1) into low-pressure turbocharger boost pressure sensor tube (2) and tighten the sensor.
NOTE:
Do **not** to overtighten the sensor.
3. Connect the low-pressure turbocharger boost pressure sensor harness connector and slide the locking tab (A).



CHARGE AIR COOLER

Exploded View

INFOID:0000000014418616



1. Air outlet hose	2. Clamp	3. Air outlet tube
4. Mounting rubber	5. Collar	6. Rubber mount
7. Charge air cooler	8. Air inlet tube	9. Air inlet hose
A. To turbocharger compressor outlet connection	B. To air intake connection adapter	⇦ Front

Removal and Installation

INFOID:0000000014418617

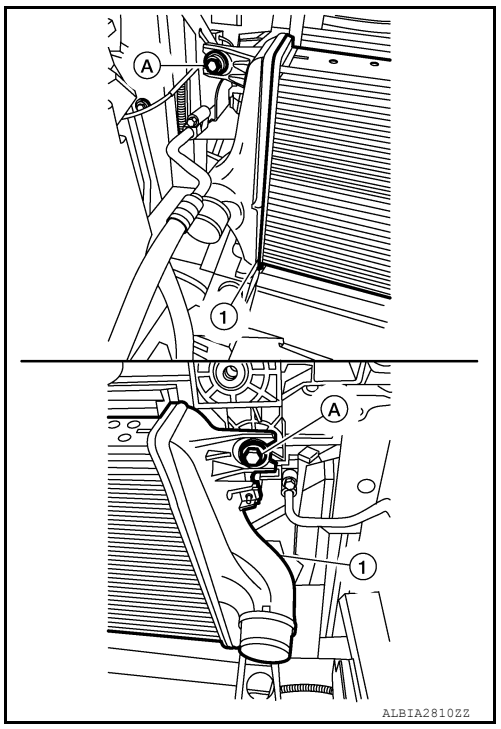
REMOVAL

CAUTION:

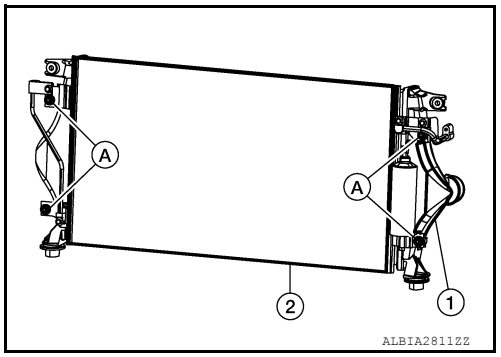
When removing charge-air cooler, cover openings with a shop cloth or other suitable material.

1. Remove the radiator. Refer to CO-49, "Removal and Installation".

2. Remove the bolts (A) that secure the top of the charge-air cooler (1).



3. Discharge refrigerant. Refer to HA-19, "Recycle Refrigerant".
4. Remove bolt and disconnect high-pressure pipe from condenser.
   CAUTION:
   Cap or wrap the joint of the pipe with suitable material such as vinyl tape to avoid the entry of air.
5. Remove bolt and disconnect high-pressure flexible hose from condenser.
   CAUTION:
   Cap or wrap the joint of the pipe with suitable material such as vinyl tape to avoid the entry of air.
6. Remove the charge-air cooler and condenser as an assembly.
7. If necessary, remove bolts (A) and separate the charge-air cooler (1) from the condenser (2).



INSPECTION AFTER REMOVAL

Check air passages of charge-air cooler core and fins for clogging, leaks or deformation. Clean or replace charge-air cooler if necessary.

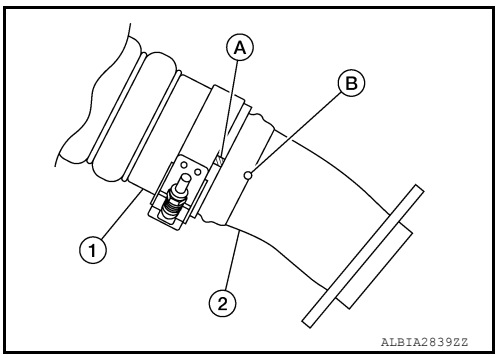
NOTE:
Be careful not to damage core fins.

INSTALLATION

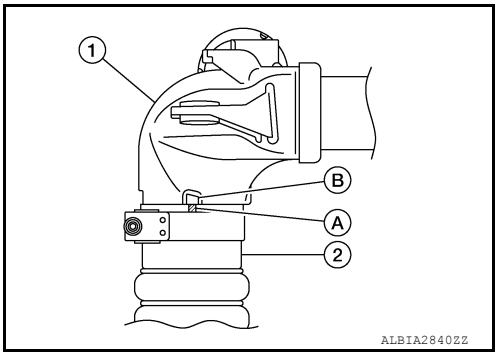
Installation is in the reverse order of removal.

CAUTION:
- **Do not reuse O-rings.**
- **Apply A/C oil to the O-ring of the high-pressure flexible hose for installation.**
- **After charging refrigerant, check for leaks. Refer to HA-19, "Recycle Refrigerant".**

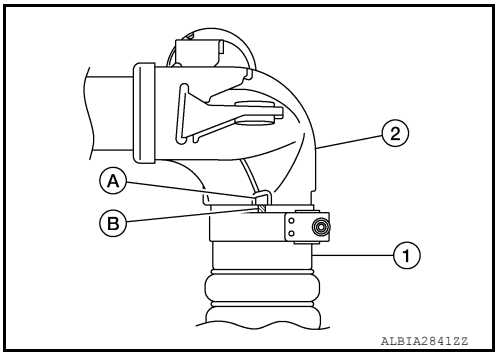
- Align mating mark (A) on air inlet hose (1) to mating mark (B) on turbocharger compressor outlet connection (2).



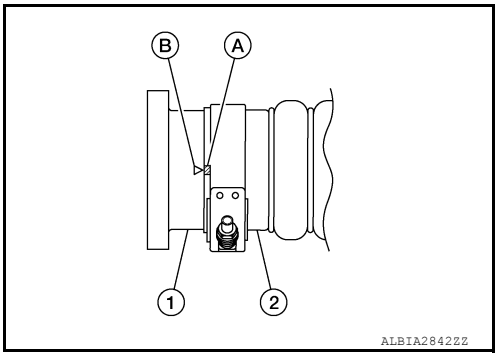
- Align mating mark (A) on air inlet hose (2) to mating mark (B) on charge air cooler outlet connection (1).



- Align mating mark (B) on air outlet hose (1) to mating mark (A) on charge air cooler inlet connection (2).



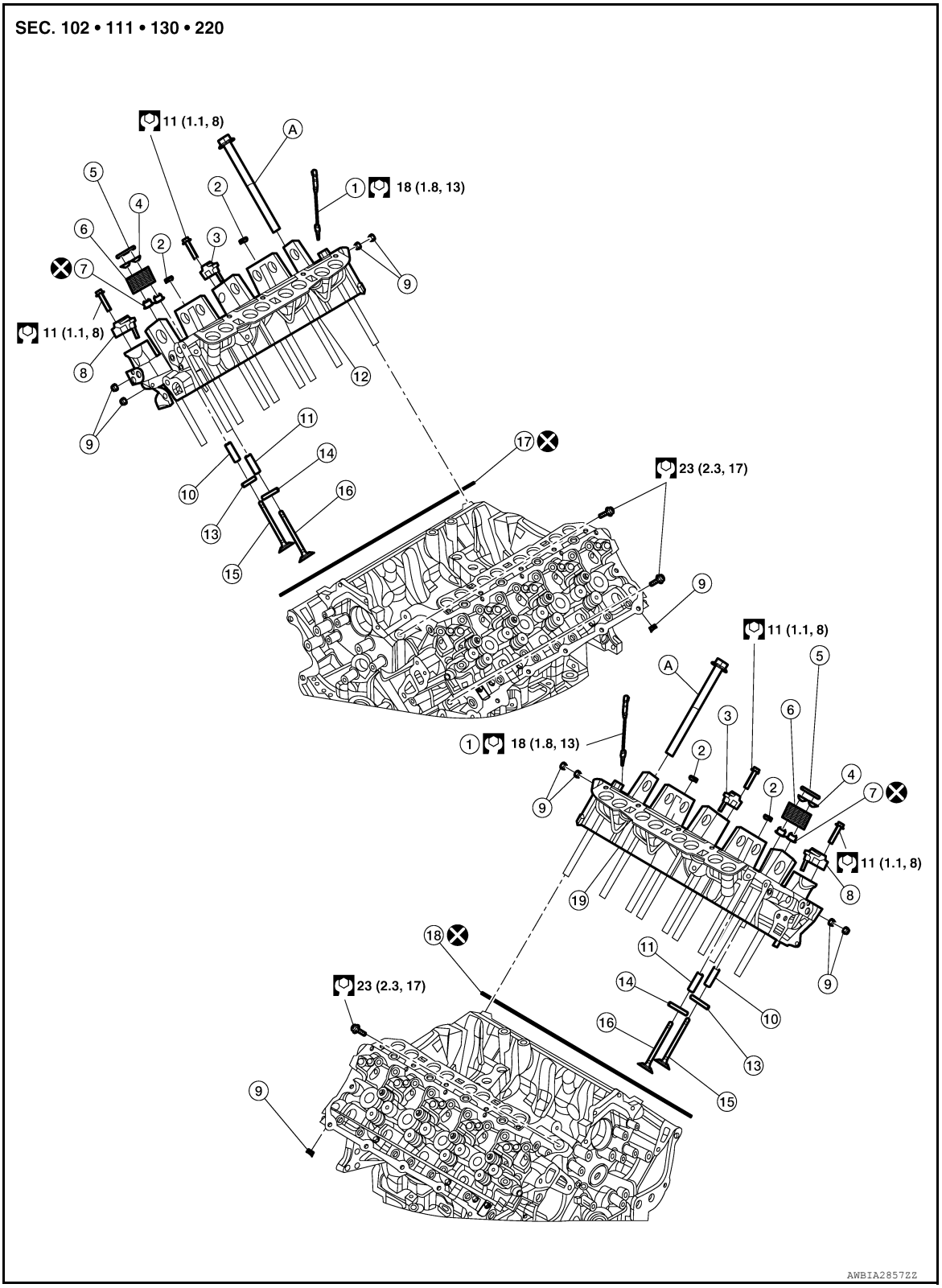
- Align mating mark (A) on air outlet hose (2) to mating mark (B) on air intake connection adapter (1).



GLOW PLUG

Exploded View

INFOID:0000000014418618



1. Glow plug
2. Welch plug
3. Camshaft cap
4. Valve spring retainer
5. Valve collet
6. Valve spring
7. Valve guide seal
8. Camshaft cap
9. Welch plug

10. Exhaust valve stem guide
11. Intake valve stem guide
12. Cylinder head (bank 1)
13. Exhaust valve insert
14. Intake valve insert
15. Exhaust valve
16. Intake valve
17. Cylinder head gasket (bank 1)
18. Cylinder head gasket (bank 2)
19. Cylinder head (bank 2)
A. Refer to INSTALLATION

CAUTION:
Valve collet and valve (intake or exhaust) are serviced as an assembly.

Removal and Installation

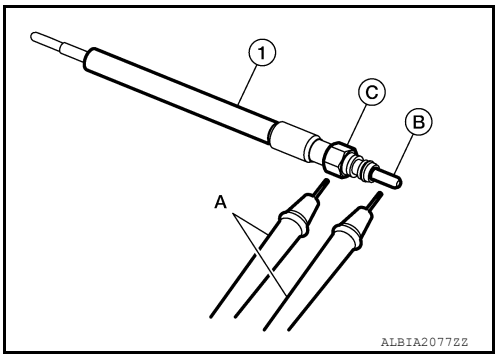
INFOID:0000000014418619

GENERAL INFORMATION

- Glow plugs provide a direct heat source to the combustion chamber. This allows for the intake air to get up to temperature allowing the engine to start at cold ambient temperatures. There is one glow plug per cylinder and they are electrically connected via a harness to the glow plug control module. For a detailed wiring schematic, see the engine wiring diagram. Refer to EC-856, "Wiring Diagram".
- Each glow plug has one electrical connector pin at the top of the glow plug body and is grounded through the seat to the glow plug in the cylinder head. A glow plug that is **not** properly tightened into the cylinder head can cause open circuit fault codes to set.
- When the glow plug control module commands the glow plugs to the pre-glow state, the WAIT to START lamp/engine warming lamp will be commanded by the ECM to turn ON. The WAIT to START lamp can stay ON up to 4 seconds.
  NOTE:
  Allow the WAIT to START lamp/Engine Warming lamp to shut off before cranking the engine or a long crank to start could occur.
- See the following procedure for a detailed component view. Refer to EM-182, "INTAKE AIR SYSTEM : Overview".

RESISTANCE CHECK

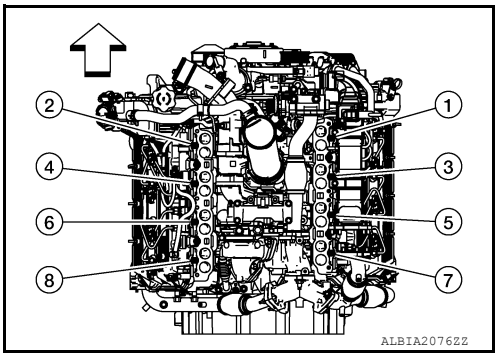
- Adjust the suitable tool (A) to lowest resistance scale to measure resistance (touch the red and black leads together and read the display to make sure the suitable tool can measure less than 1 ohm). If the suitable tool does **not** read less than 0.6 ohms, use this value as the 0 ohm reference point when taking a test measurement for a resistance of less than 1 ohm.
- Touch one probe of the suitable tool at the hex nut (C) of the glow plug (1), as shown, and the other probe to the glow plug tip (B) where the glow plug connector connects.
- The resistance **must** be less than 2 ohms. If the specification is **not** correct, the glow plug **must** be replaced.



REMOVAL

- The illustration shows the location of the glow plugs.
  NOTE:
  Glow plug numbers correspond to cylinder number.

⇦ : Front



GLOW PLUGS (1, 3, 5, 6, 7)

CAUTION:
Apply penetrating oil to the threads on the nut of the glow plug to be removed. Allow some time for the oil to soak the glow plug threads. Failure to do so could cause the glow plug to break when attempting to remove it from the cylinder head.

1. Remove the intake manifold. Refer to EM-239, "Removal and Installation".
2. Disconnect the harness connector from the glow plug.

CAUTION:
Pull glow plug harness connectors straight out to avoid damaging harness connector.

3. Remove the glow plug.

GLOW PLUGS (4, 8)

CAUTION:
Apply penetrating oil to the threads on the nut of the glow plug to be removed. Allow some time for the oil to soak the glow plug threads. Failure to do so could cause the glow plug to break when attempting to remove it from the cylinder head.

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".
2. Disconnect the harness connector from glow plug.
   CAUTION:
   Pull glow plug harness connectors straight out to avoid damaging harness connector.
3. Remove the glow plug.

GLOW PLUG (2)

CAUTION:
Apply penetrating oil to the threads on the nut of the glow plug to be removed. Allow some time for the oil to soak the glow plug threads. Failure to do so could cause the glow plug to break when attempting to remove it from the cylinder head.

1. Remove the fuel filter housing (Stage 2). Refer to FL-46, "Removal and Installation".
2. Disconnect the harness connector glow plug.
   CAUTION:
   Pull glow plug harness connectors straight out to avoid damaging harness connector.
3. Remove the glow plug.

INSPECTION AFTER REMOVAL

- **Any** of the following conditions require the glow plug to be replaced:
- Cracks or bubbling of the surface anywhere in the glow plug, including the ceramic tip.
- Corroded glow plug body and threads (distinguished by white or red color).
- Chipped or broken electrical connection tip or ceramic tip.
- Bent glow plug body or glow plug ceramic tip area.

INSTALLATION

Installation is in the reverse order of removal.

CAUTION:
- **Make sure there is no debris or moisture on the glow plug threads and cylinder head threads. Failure to do so could cause overtightening of the glow plug.**
- **Do not use a hard-wired brush to clean the cylinder head threads because damage can result.**

NOTE:
Before installation, clean the threads of the glow plug with a lint-free rag. Clean the cylinder head threads with a nylon brush.

1. Hand tighten the glow plugs before applying final torque.
2. Fully tighten the glow plugs to the specified torque.

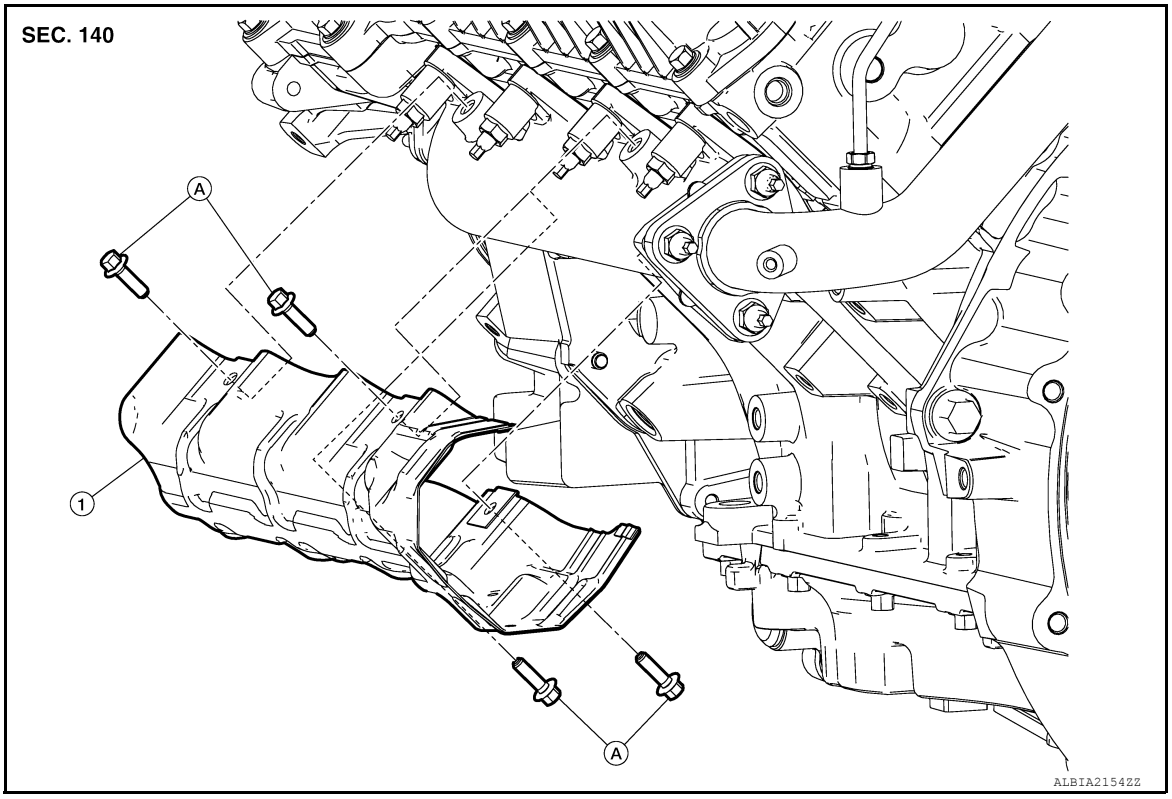
Glow plug torque : 18 Nm (1.8 kg-m, 13 ft-lb)

HEAT SHIELD

Exploded View

INFOID:0000000014418620

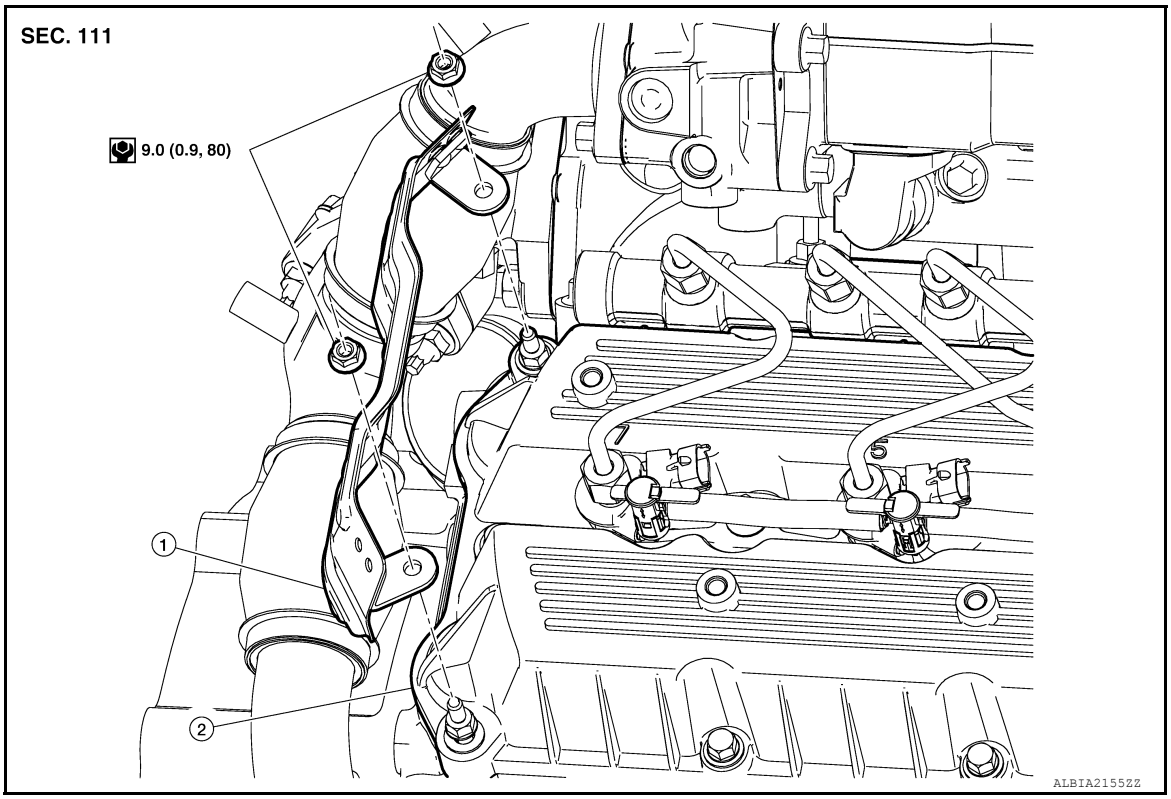
Exhaust Manifold Heat Shield



1. Exhaust manifold heat shield (bank 2)
A. Refer to INSTALLATION

NOTE:
Bank 2 shown, bank 1 similar.

Rocker Cover Heat Shield



1. Rocker cover heat shield
2. Rocker cover (bank 1)

Removal and Installation

INFOID:0000000014418621

GENERAL INFORMATION

WARNING:

Exhaust system components can become hot enough during operation and testing to cause burns or ignite and melt combustible materials. The exhaust and exhaust components can remain hot after the vehicle stops moving and has been shut down. To avoid the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning repairs or service. Make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

CAUTION:

Wear goggles and protective clothing to reduce the possibility of personal injury.

Heat shields reduce heat exposure to various components from the exhaust and exhaust gas recirculation (EGR) components.

EXHAUST MANIFOLD HEAT SHIELD

Removal

1. Remove the wheel and tire. Refer to WT-69, "Removal and Installation".
2. Remove the fender protector. Refer to EXT-41, "Removal and Installation - Front Fender Protector".
3. Remove the bolts and remove the exhaust manifold heat shield.

INSPECTION AFTER REMOVAL

WARNING:

When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:

- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- Inspect the heat shield for cracks or other damage.
- Replace the heat shield if any damage is found.
- Wash the heat shield in a hot, soapy water solution or steam clean if desired.

- Dry with compressed air.

Installation
Installation is in the reverse order of removal.
NOTE:
For the exhaust manifold heat shield bolts, apply anti-seize to bolts before installation.

ROCKER COVER HEAT SHIELD

Removal
- Remove the nuts and remove the rocker cover heat shield.

INSPECTION AFTER REMOVAL

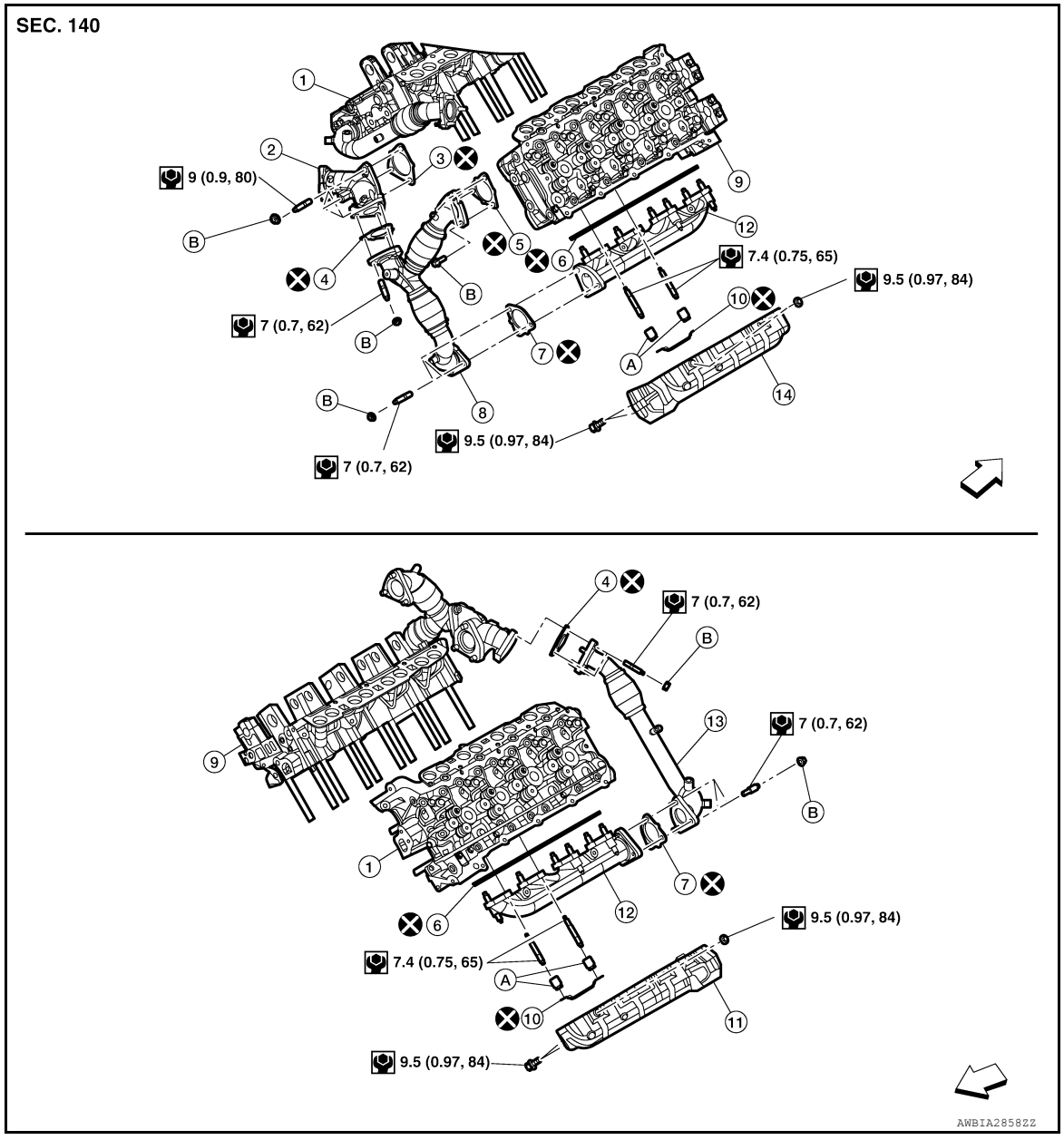
WARNING:
When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- Inspect the heat shield for cracks or other damage.
- Replace the heat shield if any damage is found.
- Wash the heat shield in a hot, soapy water solution or steam clean if desired.
- Dry with compressed air.

Installation
Installation is in the reverse order of removal.
NOTE:
For the rocker cover heat shield bolts, apply anti-seize to bolts before installation.

EXHAUST MANIFOLD

Exploded View

INFOID:0000000014418622



1. Cylinder head (bank 2)
2. Exhaust manifold collector pipe
3. Exhaust manifold collector pipe gasket
4. Transfer tube gasket B
5. Transfer tube gasket A
6. Exhaust manifold gasket
7. Transfer tube gasket C
8. Transfer tube (bank 1)
9. Cylinder head (bank 1)
10. Lockplate
11. Exhaust manifold heat shield (bank 2)
12. Exhaust manifold
13. Transfer tube (bank 2)
14. Exhaust manifold heat shield (bank 1)
A. Refer to INSTALLATION
B. Refer to EM-271, "Removal and Installation".
⇦ Front

Removal and Installation - Bank 1

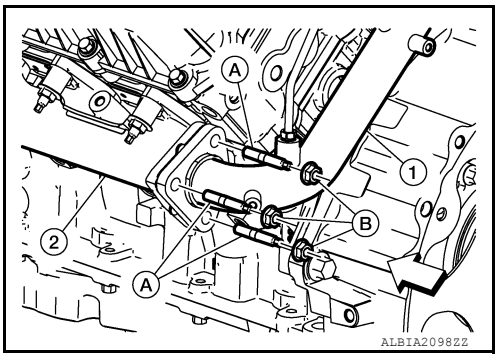
INFOID:0000000014418623

REMOVAL

CAUTION:
Brush away all dirt from the area of the air handling connections to avoid contamination to the interior of the engine. Perform the work when the exhaust system has completely cooled down.

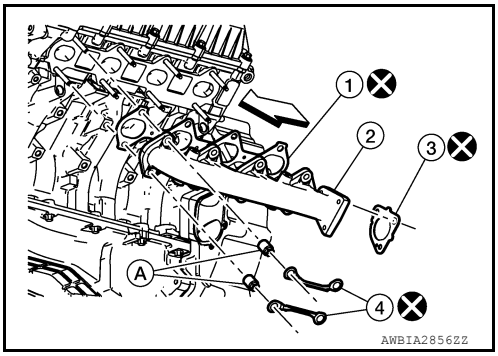
1. Remove the exhaust manifold heat shield. Refer to EX-24, "Exploded View".
2. Remove the heat shields [(RH) and (center)]. Refer to EX-32, "Removal and Installation".
3. Remove the studs (A) and nuts (B) connecting the exhaust manifold (2) to the exhaust transfer tube (1).
   NOTE:
   - Apply penetrating oil to the exhaust manifold and transfer tube studs and nuts before removal.
   - Bank 2 shown, bank 1 similar

   ⇦ : Front



4. Remove the exhaust manifold lock plates (4) and nuts (A).
   NOTE:
   - Bank 2 shown. Bank 1 similar

   ⇦ : Front



5. Remove the exhaust manifold (2). Remove and discard the exhaust manifold gasket (1) and exhaust outlet gasket (3).
   CAUTION:
   Do not reuse the following:
   - **Lock plates**
   - **Exhaust manifold gasket**
   - **Exhaust manifold outlet gasket**
6. Remove the exhaust manifold studs (if necessary).

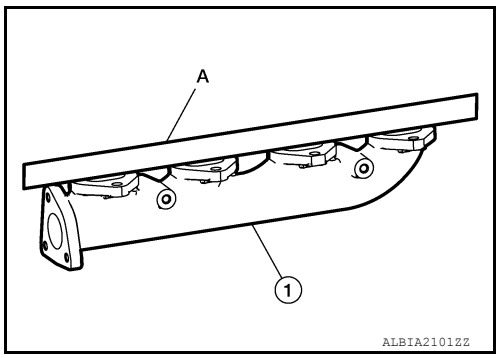
INSPECTION AFTER REMOVAL

WARNING:
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
  - Wear appropriate eye protection and protective clothing including gloves and a face shield.
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- Clean the exhaust manifold with solvent and dry with compressed air.
- Inspect the exhaust manifold for cracks or other damage.
- If damage is found, the exhaust manifold **must** be replaced.
  NOTE:
  If the exhaust manifold is damaged, check for charge-air leaks. A charge-air leak can cause progressive damage to the exhaust manifold.
- Inspect the exhaust manifold heat shield for cracks.
- Replace the heat shield if damage is found.

- Use a suitable tool (A) to check the exhaust manifold (1) mounting surfaces for flatness.

Limit : Refer to EM-529, "EXHAUST MANIFOLD"

- Lay the suitable tool on the edge across all ports and measure the flatness with a feeler gauge.
- If any port measures out of specification, replace the exhaust manifold.



INSTALLATION

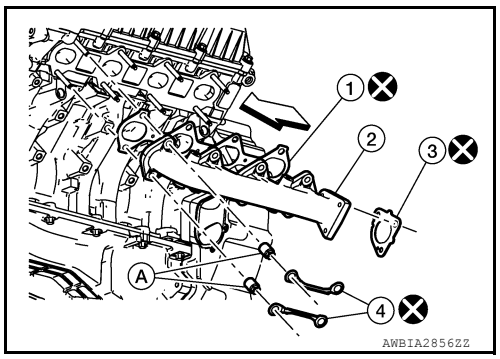
1. Install the exhaust manifold studs (if removed).

Exhaust Manifold Studs : 7.4 Nm (0.75 kg-m, 65 in-lb)

2. Install the exhaust manifold (2) and hand tighten nuts (A).

CAUTION:
Do not reuse the following:
- **Lock plates (4).**
- **Exhaust manifold gasket (1).**
- **Exhaust manifold outlet gasket (3).**

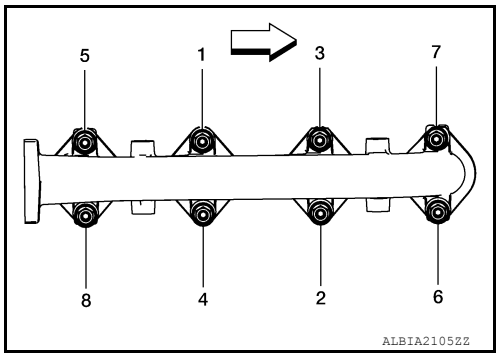
NOTE:
Apply anti-seize to the nut and stud threads.
Bank 2 shown, bank 1 similar



3. Tighten the exhaust manifold nuts in the sequence shown.

Exhaust manifold nuts : 40 N·m (4.1 kg-m, 30 ft- lb)

⇦ : Front



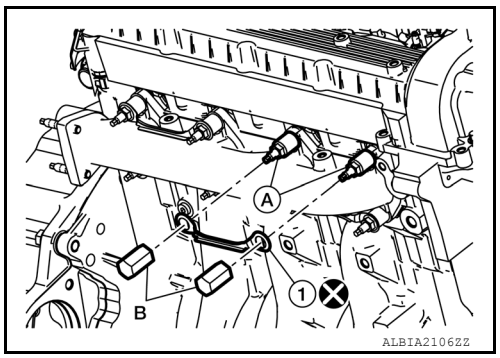
4. Retighten nuts 1-4 in the sequence shown to the specified torque.

Exhaust manifold nuts : 40 N·m (4.1 kg-m, 30 ft-lb)

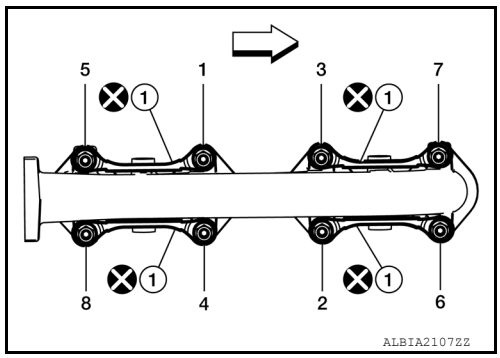
5. Position new lock plates (1) onto the bank 1 exhaust manifold nuts (A) and install Tools (B).

CAUTION:
Do not reuse lock plates.

Tool : — (J-54425)



6. Secure the lock plates (1) as follows:
CAUTION:
Do not reuse lock plates.
- Tighten both Tools in unison by alternating between the two, until the lock plates are fully installed. This will prevent the lock plate from moving out of position while installing.
- Remove the Tools.



⇦ : Front

NOTE:
- One lock plate is used for two nuts, corresponding to nuts 6 and 2, 4 and 8, 7and 3, 1and 5.
- Do **not** overtighten.

Tool : — (J-54425)

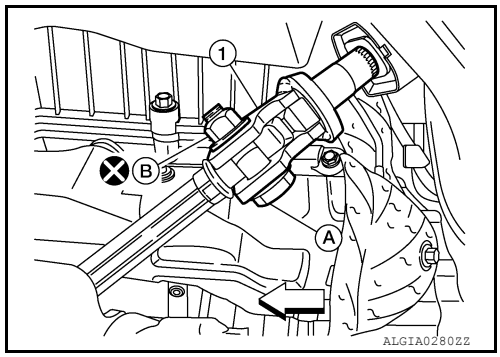
7. Installation of the remaining components is in the reverse order of removal.
NOTE:
- Idle the engine until it reaches operating temperature. Allow the engine to idle at operating temperature for 10 minutes.
- Inspect the joint for any noticeable leaks.

Removal and Installation - Bank 2

INFOID:0000000014418624

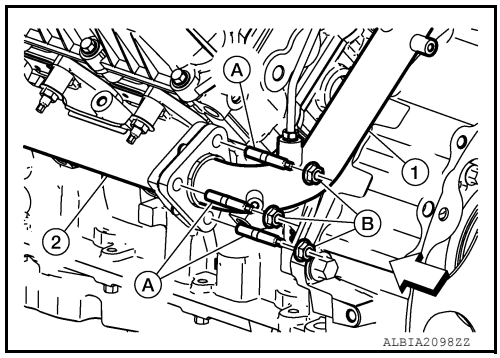
REMOVAL
CAUTION:
Brush away all dirt from the area of the air handling connections to avoid contamination to the interior of the engine. Perform the work when the exhaust system has completely cooled down.

1. Remove the exhaust manifold heat shield. Refer to EM-265, "Exploded View".
2. Remove the heat shield [(LH)and (center)]. Refer to EX-32, "Removal and Installation".
3. Remove the nut (B) and the pinch bolt (A) from the intermediate shaft lower joint (1).
CAUTION:
Do not reuse nut.



⇦ : Front

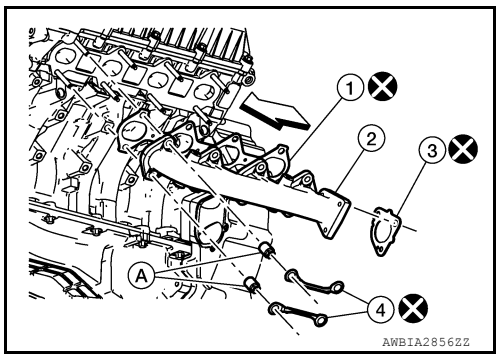
4. Remove the studs (A) and nuts (B) connecting the exhaust manifold (2) to the exhaust transfer tube (1).
NOTE:
- Apply penetrating oil to the exhaust manifold and transfer tube studs and nuts before removal.
- Bank 2 shown. Bank 1 similar



⇦ : Front

5. Remove the exhaust manifold lock plates (4) and nuts (A).

⇦ : Front



6. Remove the exhaust manifold (2). Remove and discard the exhaust manifold gasket (1) and exhaust outlet gasket (3).
CAUTION:
Do not reuse the following:
- **Lock plates**
- **Exhaust manifold gasket**
- **Exhaust manifold outlet gasket**

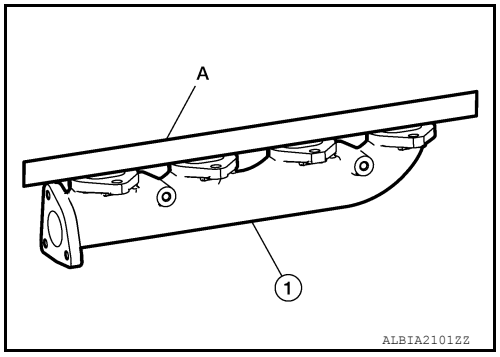
7. Remove the exhaust manifold studs (if necessary).

INSPECTION AFTER REMOVAL

WARNING:
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
  - Wear appropriate eye protection and protective clothing including gloves and a face shield.
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- Clean the exhaust manifold with solvent and dry with compressed air.
- Inspect the exhaust manifold for cracks or other damage.
- If damage is found, the exhaust manifold **must** be replaced.
  NOTE:
  If the exhaust manifold is damaged, check for charge-air leaks. A charge-air leak can cause progressive damage to the exhaust manifold.
- Inspect the exhaust manifold heat shield for cracks.
- Replace the heat shield if damage is found.

- Use a suitable tool (A) to check the exhaust manifold (1) mounting surfaces for flatness.

Limit : Refer to EM-529, "EXHAUST MANIFOLD".



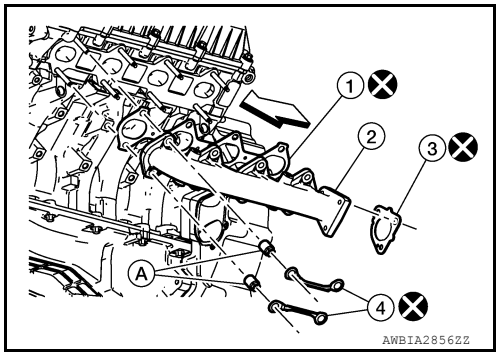
- Lay the suitable tool on the edge across all ports and measure the flatness with a feeler gauge.
- If any port measures out of specification, replace the exhaust manifold.

INSTALLATION

1. Install the exhaust manifold studs (if removed).

Exhaust Manifold Studs : 7.4 Nm (0.75 kg-m, 65 in-lb)

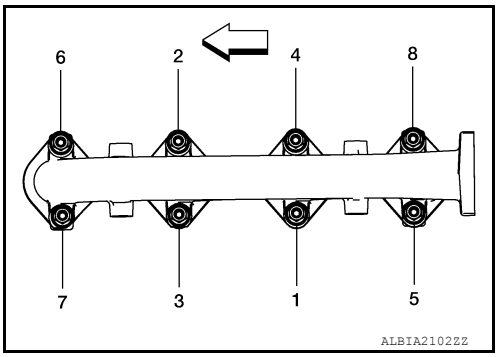
2. Install the exhaust manifold (2) and hand tighten nuts (A).
CAUTION:
Do not reuse the following:
- **Lock plates (4).**
- **Exhaust manifold gasket (1).**
- **Exhaust manifold outlet gasket (3).**
NOTE:
Apply anti-seize to the nut and stud threads.



3. Tighten the exhaust manifold nuts in the sequence shown.

Exhaust Manifold Nuts : 40 Nm (4.1 kg-m, 30 ft- lb)

⇦ : Front



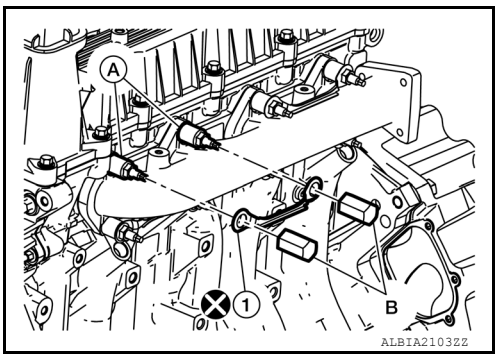
4. Retighten nuts 1-4 in the sequence shown to the specified torque.

Exhaust Manifold Nuts : 40 Nm (4.1 kg-m, 30 ft- lb)

5. Position new lock plates (1) onto the exhaust manifold nuts (A) and install Tools (B).

CAUTION:
Do not reuse lock plates.

Tool : — (J-54425)



6. Secure the lock plates (1) as follows:

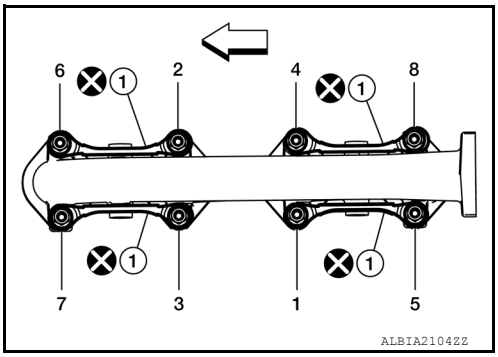
CAUTION:
Do not reuse lock plates.

- Tighten both Tools in unison by alternating between the two, until the lock plates are fully installed. This will prevent the lock plate from moving out of position while installing.
- Remove the Tool.

⇦ : Front

NOTE:
- One lock plate is used for two nuts, corresponding to nuts 6 and 2, 4 and 8, 7 and 3, 1 and 5.
- Do **not** overtighten.

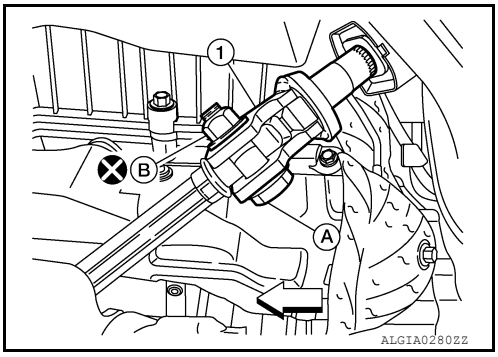
Tool : — (J-54425)



7. Install pinch bolt (A) and nut (B) into intermediate shaft lower joint finger tight, then torque to specification. Pinch bolt is directional. Refer to ST-43, "Exploded View".

CAUTION:
Do not reuse nut.

⇦ : Front



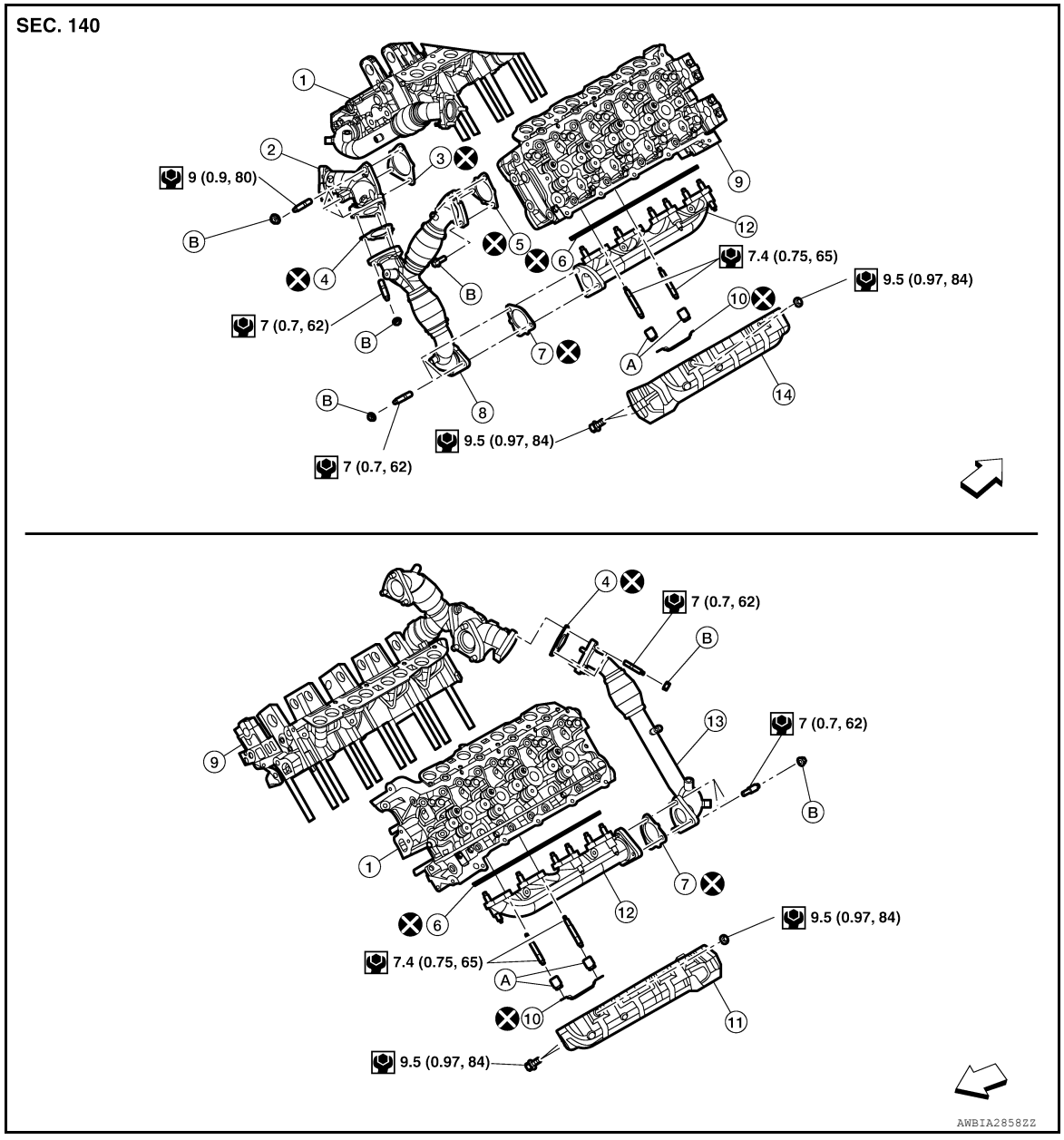
8. Installation of the remaining components is in the reverse order of removal.

NOTE:
- Idle the engine until it reaches operating temperature. Allow the engine to idle at operating temperature for 10 minutes.
- Inspect the joint for any noticeable leaks.

EXHAUST TRANSFER TUBE

Exploded View

INFOID:0000000014418625



1. Cylinder head (bank 2)
2. Exhaust manifold collector pipe
3. Exhaust manifold collector pipe gasket
4. Transfer tube gasket B
5. Transfer tube gasket A
6. Exhaust manifold gasket
7. Transfer tube gasket C
8. Transfer tube (bank 1)
9. Cylinder head (bank 1)
10. Lock plate
11. Exhaust manifold heat shield (bank 2)
12. Exhaust manifold
13. Transfer tube (bank 2)
14. Exhaust manifold heat shield (bank 1)

A. Refer to INSTALLATION

B. Refer to EM-271, "Removal and Installation".

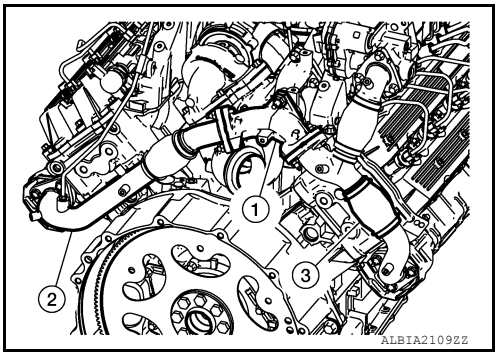
⇦ Front

Removal and Installation

INFOID:0000000014418626

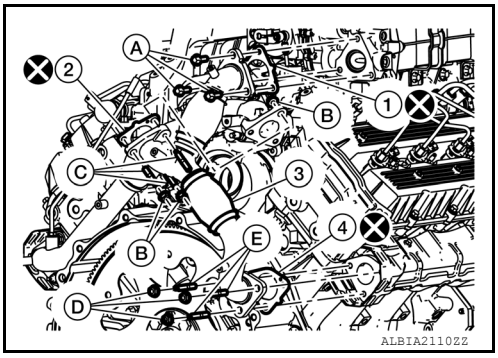
GENERAL INFORMATION

The exhaust transfer tubes are made of the following assemblies:
- Transfer tube [bank 1 (3)].
- Transfer tube [bank 2 (2)].
- Exhaust manifold collector pipe (1).



REMOVAL

1. Remove the heat shields [(RH), (LH) and (center)]. Refer to EX-32, "Removal and Installation".
2. Remove the wheel and tire using power tool. Refer to WT-69, "Removal and Installation".
3. Remove the fender protector. Refer to EXT-41, "Removal and Installation - Front Fender Protector".
4. Remove the nuts (D) connecting the transfer tube [bank 1 (3)] to the exhaust manifold.
5. Remove the nuts (B) and studs (C) connecting the right transfer tube (3) to the collector pipe.
6. Remove the bolts (A) connecting the transfer tube [bank 1 (3)] to the EGR valve.
7. Remove the transfer tube [bank 1 (3)] and discard the gaskets (1), (2), and (4).



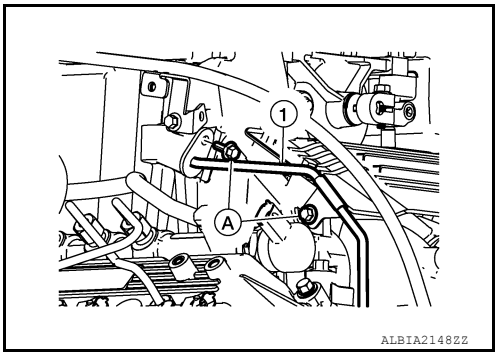
CAUTION:
- **Use caution to not drop any foreign material into the turbocharger.**
- **Do not reuse the gaskets (1), (2), and (4).**

8. Use compressed air to clean around the fittings where the exhaust gas pressure sensor tube connects to the intake manifold.

WARNING:
When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**

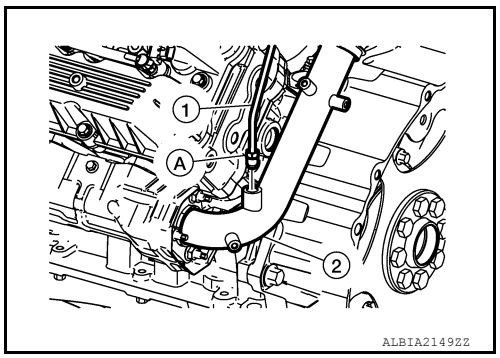
NOTE:
Apply a suitable penetrating oil to the exhaust gas pressure sensor tube connection at the transfer tube (bank 2).

9. Remove the bolts (A) securing the exhaust gas pressure sensor tube (1) to the intake manifold.

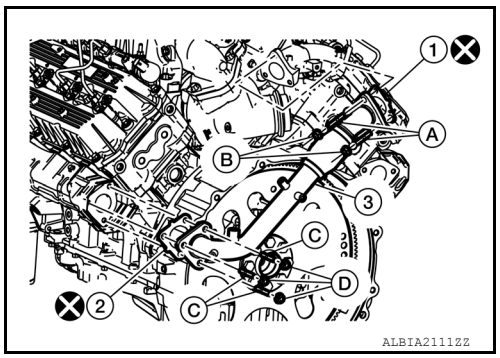


CAUTION:
Do not reuse the O-ring.

10. Remove the nut (A) connecting the exhaust pressure sensor tube (1) to the transfer tube [bank 2 (2)] and remove the exhaust pressure sensor tube (1).

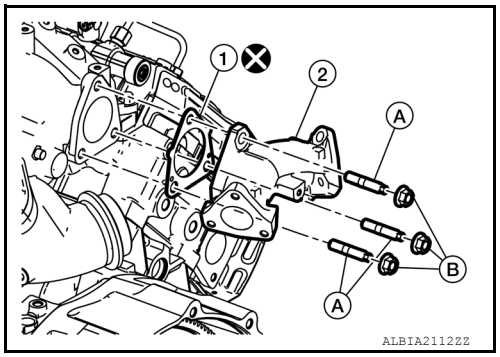


11. Remove the nuts (B) and studs (A) connecting the transfer tube [bank 2 (3)] to the exhaust manifold collector pipe.
12. Remove the nuts (D) connecting the transfer tube [bank 2 (3)] to the exhaust manifold.
13. Remove the transfer tube [bank 2 (3)] and discard the gaskets (1) and (2).
    CAUTION:
    Do not reuse the gaskets (1) and (2).
14. Remove studs [C (if necessary)].



15. Remove the exhaust manifold collector pipe using the following steps (if necessary):

a. Remove the nuts (B) connecting the exhaust manifold collector pipe (2) to the turbocharger.
b. Remove the exhaust manifold collector pipe and discard the gasket (1).
    CAUTION:
    - **Use caution to not drop any foreign material into the turbocharger.**
    - **Do not reuse the gasket.**
c. Remove studs (A).



INSPECTION AFTER REMOVAL

- Scrape the gasket surfaces free of gasket material.
  NOTE:
  - It is common for the transfer tubes to have a buildup of carbon on their inside surfaces. This buildup is normal and does **not** need to be removed.
  - If the turbocharger will be off of the engine for a prolonged period of time, cap all openings with Tool or tape over the openings where Tool is not applicable in the EGR bypass tube and the EGR valve to prevent debris from entering the EGR and air intake system.

Tool : — (J-5443)

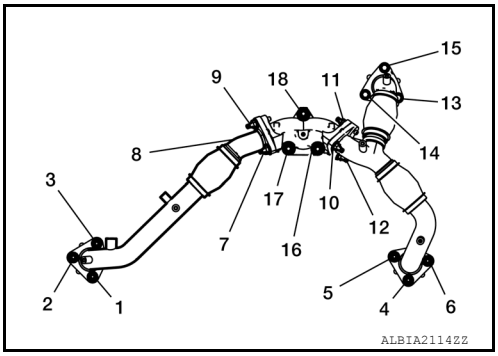
- Inspect the transfer tubes for cracks, distortion, corrosion, or soot streaking on the outside of the collection pipe, which indicates an EGR leak.

INSTALLATION

Installation is in the reverse order of removal.
NOTE:
- If any studs were removed, install and tighten them prior to tube assembly.
- Apply a coating of anti-seize to studs, nuts and bolts before installation.
- Hand-tighten nuts and bolts during installation.

- Tighten the nuts and bolts to specified torque in the sequence shown.

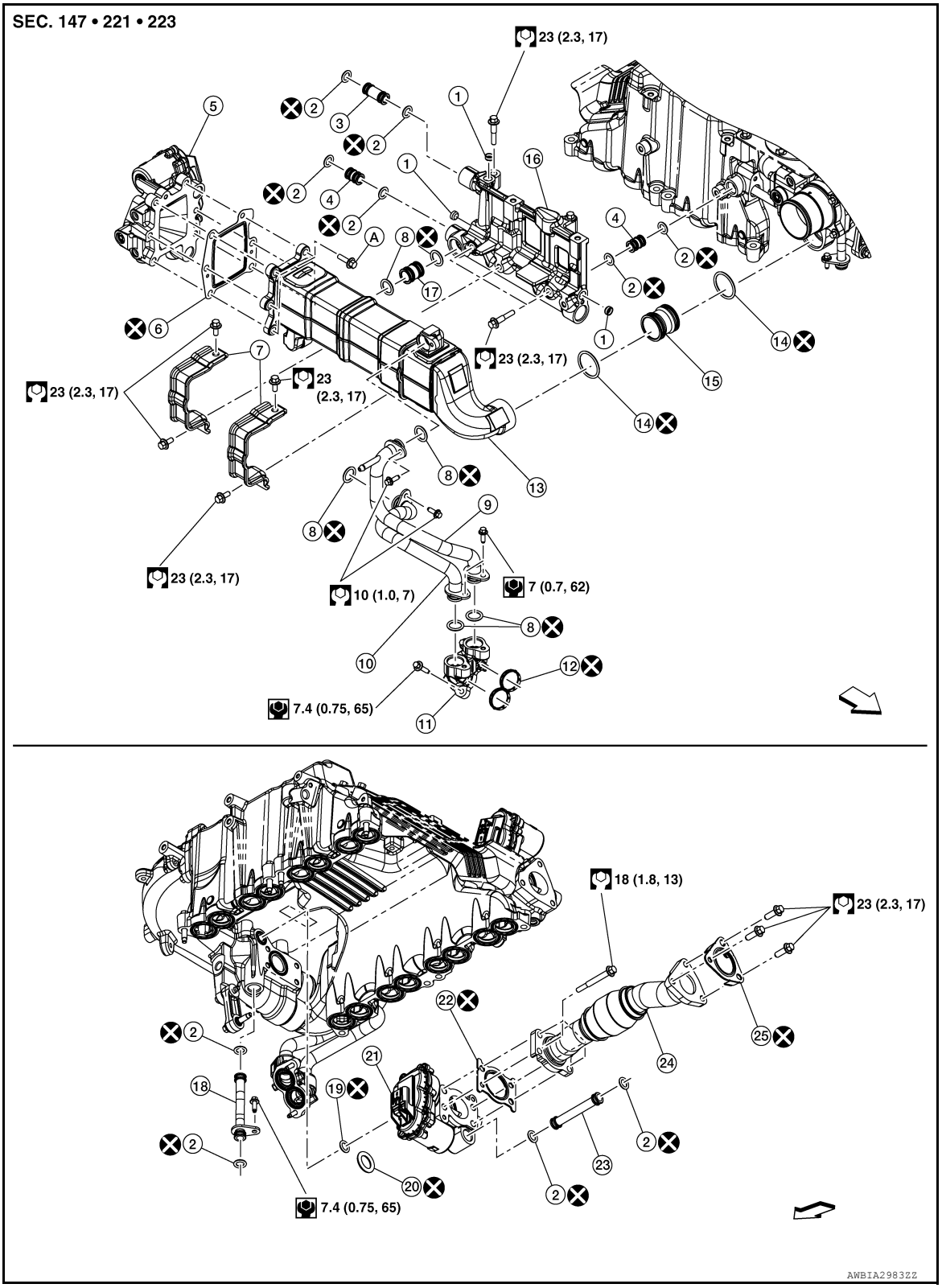
Nuts 1 through 12	**: 40 N·m (4.1 kg-m, 30 ft-lb)**
Bolts 13 through 15	**: 23 N·m (2.3 kg-m, 17 ft-lb)**
Nuts 16 through 18	**: 46 N·m (4.7 kg-m, 34 ft-lb)**



EGR COOLER

Exploded View

INFOID:0000000014418627



1. Welch plug
2. O-ring
3. Coolant tube
4. Coolant tube
5. EGR valve
6. EGR valve gasket
7. EGR cooler mounting strap
8. O-ring
9. EGR cooler return line

10. EGR cooler supply line
11. Water transfer connection
12. Water transfer connection gasket
13. EGR cooler
14. O-ring
15. Intake air connection jumper tube
16. EGR mounting bracket
17. Coolant tube
18. EGR bypass valve coolant tube
19. O-ring
20. O-ring
21. EGR bypass valve
22. EGR bypass valve gasket
23. Coolant tube
24. EGR bypass tube
25. EGR bypass tube gasket
A. Refer to INSTALLATION
⇦ Front

CAUTION:
- **EGR cooler is serviced as a kit with EGR valve gasket and O-rings.**
- **EGR valve is serviced as a kit with EGR valve gasket and O-rings.**
- **EGR bypass valve is serviced as a kit with EGR bypass valve gasket and O-rings.**

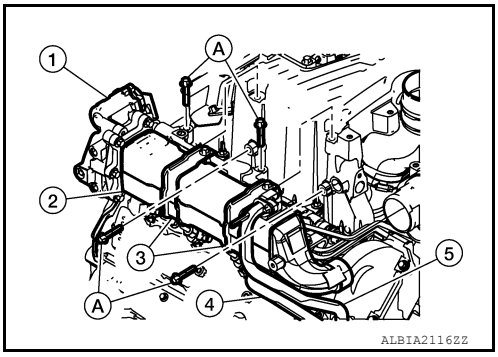
Removal and Installation

INFOID:0000000014418628

GENERAL INFORMATION

- The exhaust gas recirculation (EGR) cooler is best serviced as an assembly of the EGR cooler and adjacent components.
- The EGR cooler assembly includes the following components:

(1) : EGR valve
(2) : EGR cooler
(3) : EGR cooler mounting straps
(4) : EGR cooler supply line
(5) : EGR cooler return line
(A) : Bolts



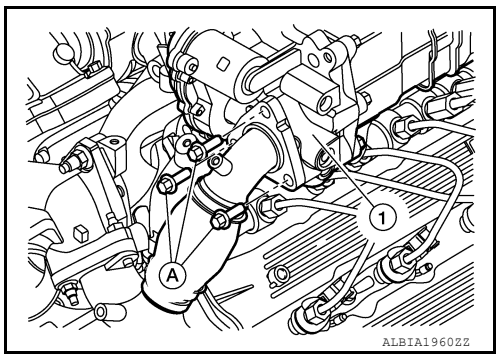
REMOVAL

WARNING:
When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**

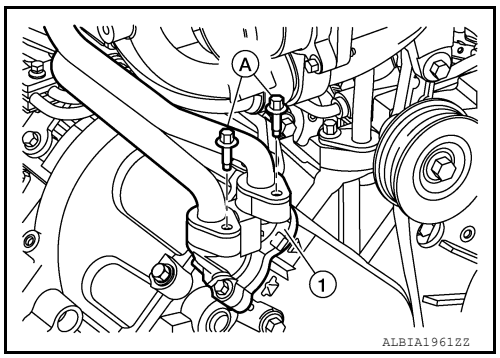
1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".
2. Partially drain the engine coolant. Refer to CO-47, "Changing Engine Coolant".
   WARNING:
   To avoid the risk of personal injury, do not remove the radiator cap when the engine is hot. Serious burns could occur from high-pressure engine coolant escaping from the radiator. Wrap a thick cloth around the cap. Slowly turn it a quarter of a turn to release built-up pressure. Carefully remove the radiator cap by turning it all the way.
3. Remove the heat shield (RH). Refer to EX-32, "Removal and Installation".
4. Remove the coolant reservoir. Refer to CO-52, "Removal and Installation".
5. Remove the air outlet hose. Refer to EM-256, "Exploded View".
   NOTE:
   Brush away all loose dirt from the around the area of the air handling connections to avoid contamination of the interior of the engine.

6. Remove the bolts (A) that connect the exhaust transfer tube (RH) to the EGR valve (1).

CAUTION:
Do not reuse the gasket.

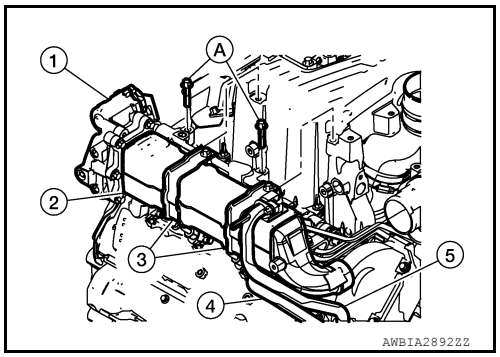


7. Remove the bolts (A) that connect the EGR cooler return and supply lines to the water inlet connection (1) on the front cover.



8. Disconnect the harness connector from the EGR valve.
9. Remove the EGR bracket bolts (A) and the EGR cooler assembly (1) from the intake manifold.

(2) : EGR cooler
(3) : EGR cooler mounting straps
(4) : EGR cooler supply line
(5) : EGR cooler return line



CAUTION:
Use compressed air to blow out any coolant that remains on top of the glow plugs. If coolant is not removed, the glow plug will corrode.

INSPECTION AFTER REMOVAL

WARNING:
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturers recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- **Some solvents are flammable and toxic. Read the manufacturer's instructions before using.**

EGR cooler inspection
- Prior to cleaning, inspect the EGR cooler for internal leaks.
- Check for coolant, or signs of coolant, (light colored deposits) in the EGR valve. Check for small amounts of soot in the coolant that has been drained from the vehicle.
- Inspect the EGR cooler for signs of external leaks or cracks.

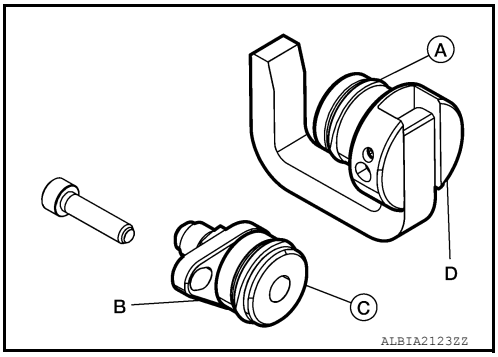
Cleaning EGR cooler
- Use solvent to clean the soot from the inside of the EGR cooler.
- Use compressed air to dry the inside of the EGR cooler.

- If any solvents or cleaners entered the coolant side of the EGR cooler, use clean water to flush the coolant side of the cooler to prevent these solvents or cleaners from entering the cooling system.

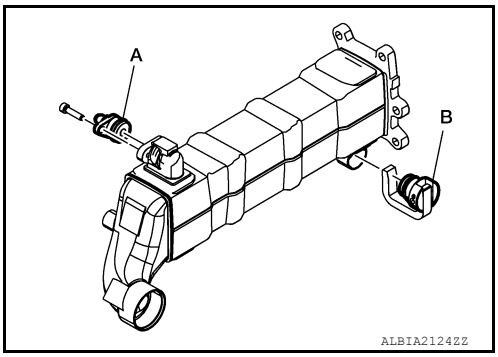
PRESSURE TEST

1. The Tool contains an outlet plug (B) and an inlet plug (D) to pressure test the EGR cooler.
   NOTE:
   Lubricate the O-rings (A) and (C) on the plugs with suitable water-based lubricant.

   Tool B and D : — (J-54414)



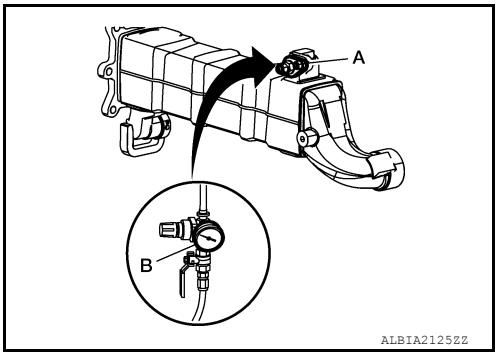
2. Install the outlet plug (A) into the EGR cooler outlet and install the inlet plug (B) into the EGR cooler inlet.



3. Install Tool (B) and hose assembly onto the Tool (A) on the coolant outlet of the EGR cooler.
   WARNING:
   When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:
   - **Do not exceed 30 psi (207 kPa).**
   - **Wear appropriate eye protection and protective clothing including gloves.**

   NOTE:
   Install a ball-type shutoff valve onto the inlet side of the air pressure regulator to allow the air supply to be shut off during testing.

   Tool A : — (J-54414)
   Tool B : — (J-54429)



4. Make sure the air pressure regulator and ball type valve are closed. Connect a compressed air supply to the pressure regulator.
   - Apply 50 psi of air pressure to the EGR cooler.
   - Inspect for air escaping the EGR cooler assembly as a result of loose lines and fittings by spraying the exterior of the EGR cooler and all lines and fittings with a mixture of mild soap and water.
5. Shut the air supply OFF to the regulator by using the ball valve and disconnect the compressed air supply.
6. Record the time at which the air supply was shut off and the air pressure shown on the air pressure regulator gauge.
7. Periodically check the fittings for air leaks using the mixture of soap and water. If there are any air leaks found during the test, fix the leak and start the test over.
8. Measure and record the air pressure after 20 minutes.
   - If there is no pressure drop, the cooler is reusable.
   - If the measured pressure drop is greater than 138 kPa (1.41 kg/cm^2, 20 psi), replace the EGR cooler.
   - If the measured pressure drop is 138 kPa (1.41 kg/cm^2, 20 psi) or less, check all of the fittings for air leaks to make sure that no air leaks are found on the test equipment and test again.

- If the measured pressure drop is greater than 3.45 kPa (0.0352 kg/cm^2, 0.5 psi) on the second test and there are no air leaks found on the test equipment, replace the EGR cooler.

If the EGR cooler is not usable, check the following items:
- Pressure check the cooling system for leaks. Leaks can be in the coolant plumbing as well as on the engine which can cause EGR cooler malfunction.
- Verify there are no issues with the cooling system (coolant leaks, water pump damage, fan drive damage, or similar).
- Inspect the turbocharger turbine housing for signs of coolant deposits. Coolant deposits can typically be identified as dried white deposits coating the insides of the housings.
- Inspect the EGR valve inlet and outlet for signs of coolant deposits. Clean if coolant is found.
- Inspect the air intake connection for coolant.
- Inspect the exhaust pressure sensor tube.
- If there is coolant contamination in the engine lubricating oil, change the engine lubricating oil.

NOTE:
- If damage resulted in a hydraulic lock, it can be necessary to remove the injectors and evacuate the coolant from the cylinder(s).
- If damage resulted in a hydraulic lock and the coolant level reached the intake manifold, it can be necessary to replace the charge-air cooler.

If the EGR cooler is reusable:
- Remove the parts supplied in the service kit.
- Proceed to the Clean and Inspect for Reuse section of this procedure.
- Proceed to the Assemble, Install, and Finishing Steps sections of this procedure.

INSTALLATION

Installation is in the reverse order of removal.

NOTE:

Operate the engine and check for leaks.

Disassembly and Assembly

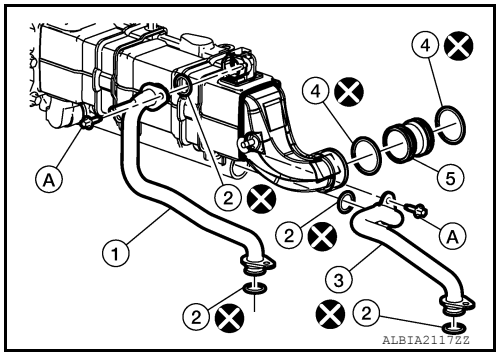
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DISASSEMBLY

1. Remove the bolts (A) and remove the EGR cooler supply line (3) and EGR cooler return line (1) from the EGR cooler support.
2. Remove the intake air connection jumper tube (5).

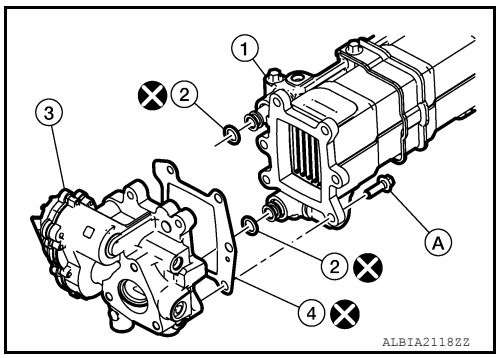
CAUTION:

Do not reuse the O-rings (2) and (4).

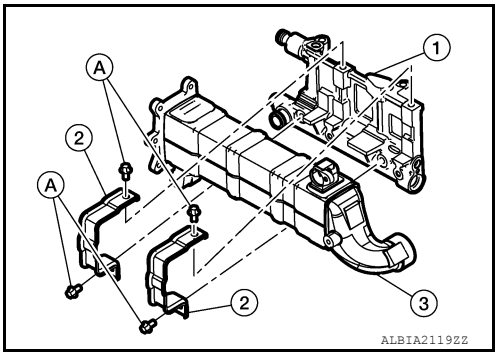


3. Remove the bolts (A) and remove the EGR valve (3) from the EGR cooler (1).

CAUTION:
- **Do not reuse the O-rings (2).**
- **Do not reuse gasket (4).**

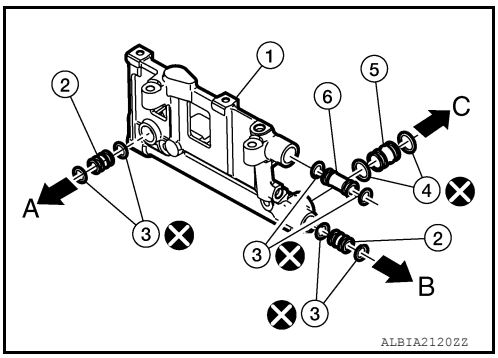


4. Remove the bolts (A) and EGR cooler mounting straps (2) connecting the EGR cooler (3) to the EGR cooler mounting bracket (1).



5. Remove the coolant tubes (2), (5) and (6) from the cooler mounting bracket (1) and discard the O-rings (3) and (4).
CAUTION:
Do not reuse the O-rings.

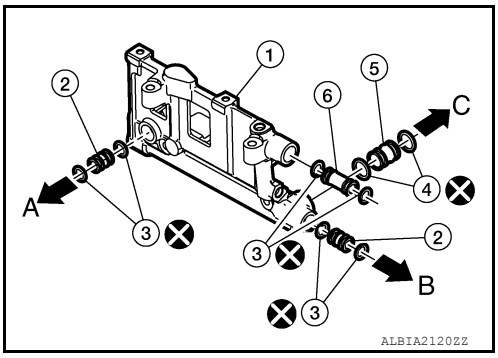
(A) : To intake manifold
(B) : To EGR valve
(C) : To EGR cooler



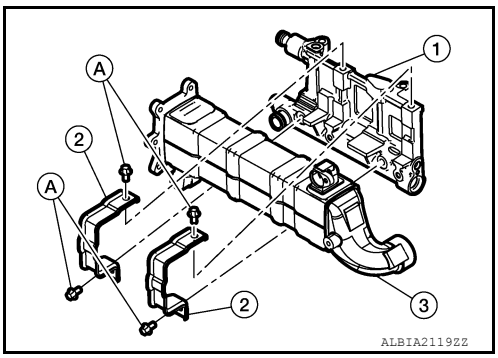
ASSEMBLY

1. Install the coolant tubes (2), (5) and (6) into the EGR cooler mounting bracket (1).
CAUTION:
Do not reuse the O-rings.
NOTE:
Lubricate the O-rings with a suitable water-based lubricant.

(3) : O-ring
(4) : O-ring
(A) : To intake manifold
(B) : To EGR valve
(C) : To EGR cooler

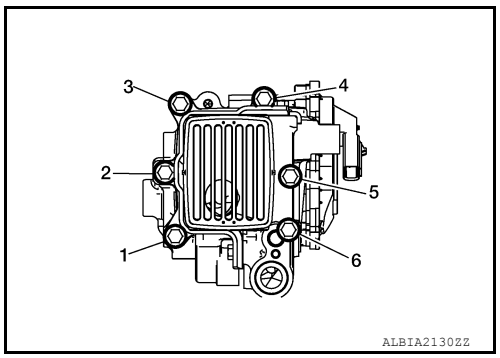


2. Install the EGR cooler (3), EGR cooler mounting straps (2), and bolts (A) onto the EGR mounting bracket (1).

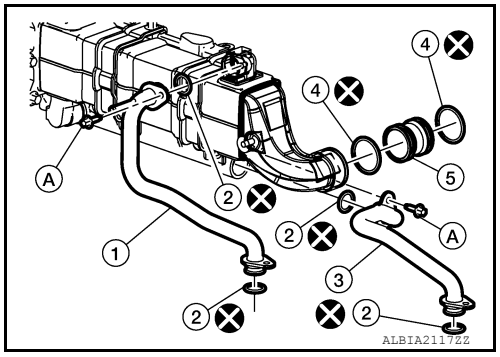


3. Install the EGR valve onto the EGR cooler and tighten the bolts in the sequence shown.
CAUTION:
Do not reuse the gasket or O-rings.

Step 1	**: 13 N·m (1.3 kg-m, 10 ft-lb)**
Step 2	**: 26 N·m (2.7 kg-m, 19 ft-lb)**



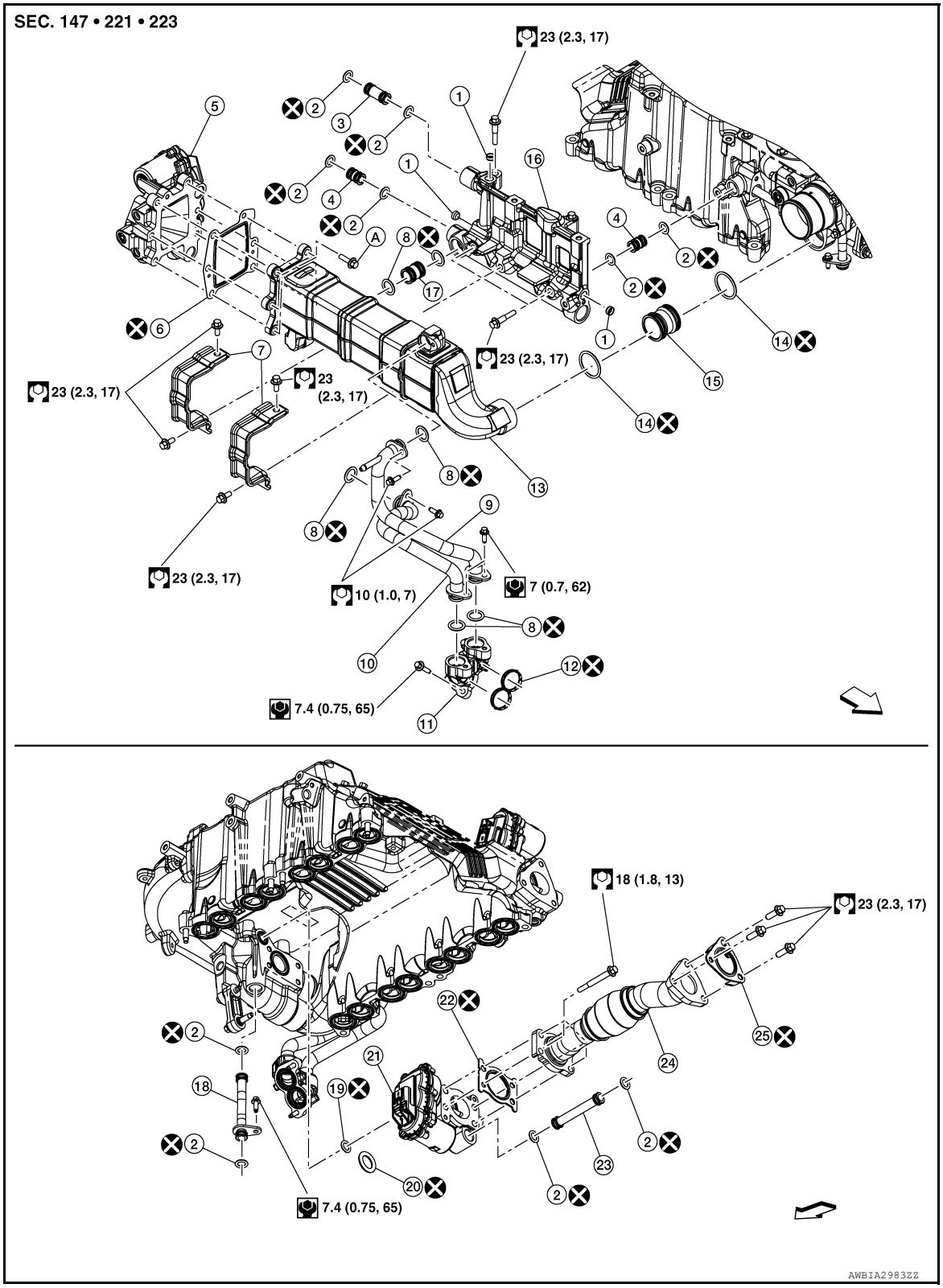
4. Install the EGR intake air connection jumper tube (5) into the EGR cooler outlet.
5. Install O-rings onto each end of the EGR coolant return (1) and supply lines (3).
6. Install the EGR cooler return and supply lines and the bolts (A) into the EGR cooler.
CAUTION:
Do not reuse the O-rings.
NOTE:
Lubricate O-rings (2) and (4) with a suitable water-based lubricant.



EGR COOLER COOLANT LINES

Exploded View

INFOID:0000000014418630



1. Welch plug
2. O-ring
3. Coolant tube
4. Coolant tube
5. EGR valve
6. EGR valve gasket
7. EGR cooler mounting strap
8. O-ring
9. EGR cooler return line

10. EGR cooler supply line
11. Water transfer connection
12. Water transfer connection gasket
13. EGR cooler
14. O-ring
15. Intake air connection jumper tube
16. EGR mounting bracket
17. Coolant tube
18. EGR bypass valve coolant tube
19. O-ring
20. O-ring
21. EGR bypass valve
22. EGR bypass valve gasket
23. Coolant tube
24. EGR bypass tube
25. EGR bypass tube gasket
A. Refer to INSTALLATION
⇦ Front

CAUTION:
- **EGR cooler is serviced as a kit with EGR valve gasket and O-rings.**
- **EGR valve is serviced as a kit with EGR valve gasket and O-rings.**
- **EGR bypass valve is serviced as a kit with EGR bypass valve gasket and O-rings.**

Removal and Installation - EGR cooler return line

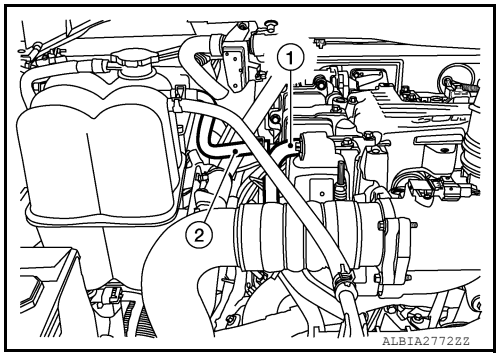
INFOID:0000000014418631

REMOVAL

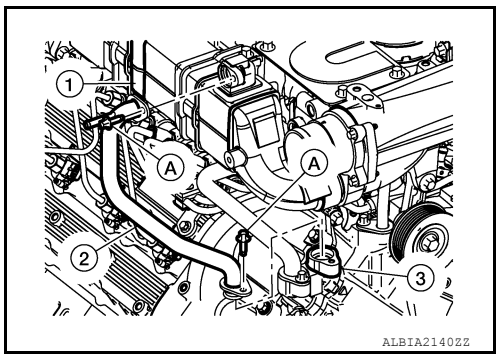
WARNING:
- **Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
- **To avoid the risk of personal injury, do not remove the radiator cap when the engine is hot. Serious burns could occur from high-pressure engine coolant escaping from the radiator. Wrap a thick cloth around the cap. Slowly turn it a quarter of a turn to release built-up pressure. Carefully remove the radiator cap by turning it all the way.**

CAUTION:
Brush away any dirt from the area around the air handling connections to avoid contamination of the interior of the engine.

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".
2. Partially drain the engine coolant. Refer to CO-47, "Changing Engine Coolant".
3. Disconnect the reservoir tank hose (2) from the EGR cooler return line (1).



4. Remove the bolts (A) from the EGR cooler return line (2) that attach it to the EGR cooler (1) and the water transfer connection (3).



5. Remove the EGR cooler return line.
CAUTION:
Do not reuse the O-rings.

INSPECTION AFTER REMOVAL

WARNING:

- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufactures recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- Clean the tubes with solvent and dry with compressed air.
- Inspect the tubes for cracks, leaks, and distortion.
- Replace any damaged components.
- Inspect the EGR cooler line bores in the EGR cooler, as well as the EGR cooler coolant line/connection tube sealing areas for signs of distortion, cracks, or other damage. Replace as necessary.

INSTALLATION

Installation is in the reverse order of removal.

NOTE:

- Lubricate O-rings with a suitable water-based lubricant before installation.
- Operate the engine and check for leaks.

Removal and Installation - EGR cooler supply line

INFOID:0000000014418632

REMOVAL

WARNING:

- **Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
- **To avoid the risk of personal injury, do not remove the radiator cap when the engine is hot. Serious burns could occur from high-pressure engine coolant escaping from the radiator. Wrap a thick cloth around the cap. Slowly turn it a quarter of a turn to release built-up pressure. Carefully remove the radiator cap by turning it all the way.**

CAUTION:

Brush away any dirt from the area around the air handling connections to avoid contamination of the interior of the engine.

1. Remove the EGR cooler. Refer to EM-276, "Removal and Installation".
   NOTE:
   EGR cooler must be removed to remove the EGR coolant supply line.
2. Remove the remaining bolts and remove the EGR cooler supply line.
   CAUTION:
   Do not reuse the O-rings.

INSPECTION AFTER REMOVAL

WARNING:

- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufactures recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- Clean the tubes with solvent and dry with compressed air.
- Inspect the tubes for cracks, leaks, and distortion.
- Replace any damaged components.
- Inspect the EGR cooler line bores in the EGR cooler, as well as the EGR cooler coolant line/connection tube sealing areas for signs of distortion, cracks, or other damage. Replace as necessary.

INSTALLATION

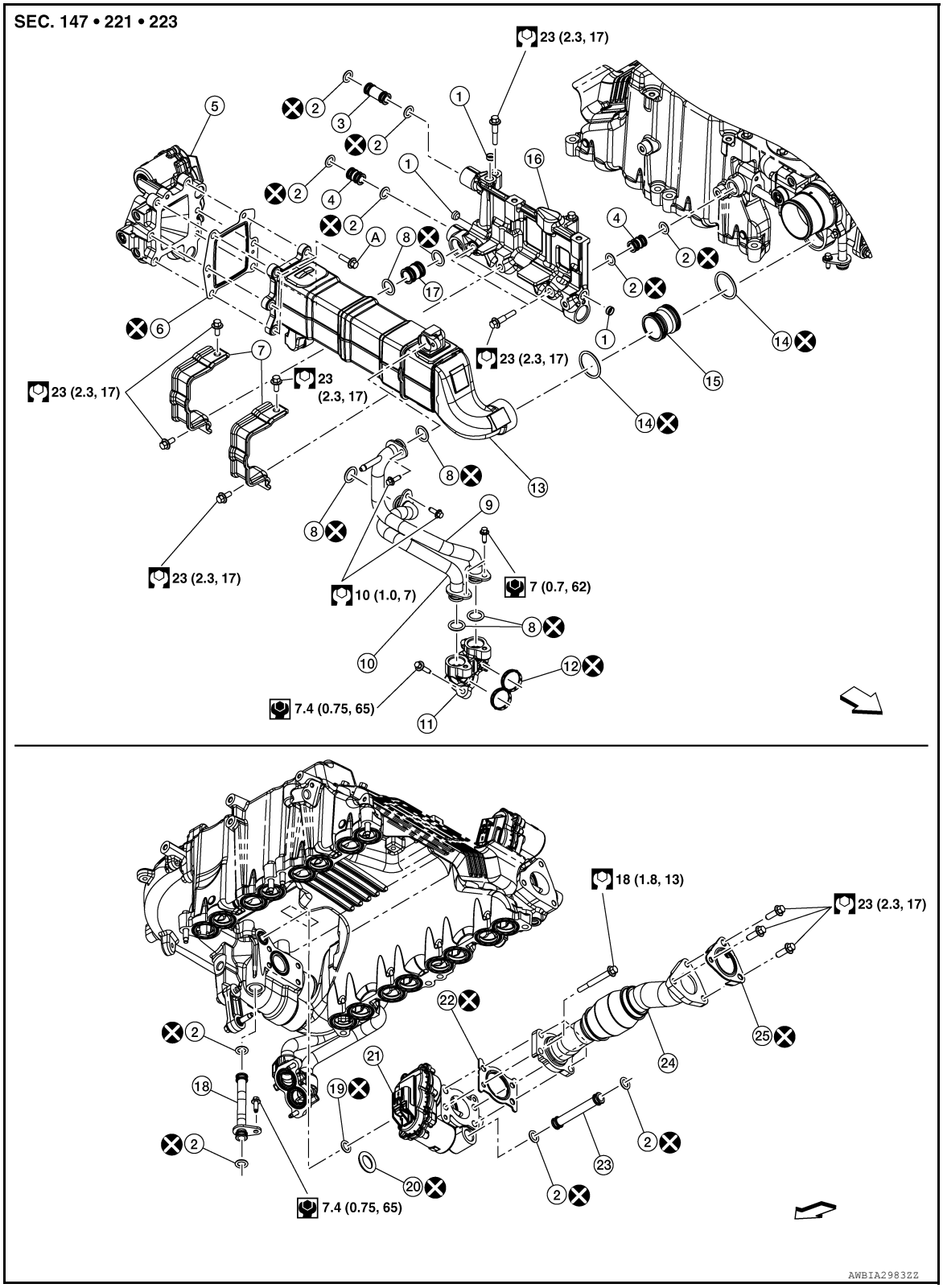
Installation is in the reverse order of removal.

NOTE:
- Lubricate O-rings with a suitable water-based lubricant before installation.
- The EGR cooler coolant supply line must be installed in conjunction with the EGR cooler.
- Operate the engine and check for leaks.

EGR VALVE

Exploded View

INFOID:0000000014418633



1. Welch plug
2. O-ring
3. Coolant tube
4. Coolant tube
5. EGR valve
6. EGR valve gasket
7. EGR cooler mounting strap
8. O-ring
9. EGR cooler return line

10. EGR cooler supply line
11. Water transfer connection
12. Water transfer connection gasket
13. EGR cooler
14. O-ring
15. Intake air connection jumper tube
16. EGR mounting bracket
17. Coolant tube
18. EGR bypass valve coolant tube
19. O-ring
20. O-ring
21. EGR bypass valve
22. EGR bypass valve gasket
23. Coolant tube
24. EGR bypass tube
25. EGR bypass tube gasket
A. Refer to INSTALLATION
⇦ Front

CAUTION:
- **EGR cooler is serviced as a kit with EGR valve gasket and O-rings.**
- **EGR valve is serviced as a kit with EGR valve gasket and O-rings.**
- **EGR bypass valve is serviced as a kit with EGR bypass valve gasket and O-rings.**

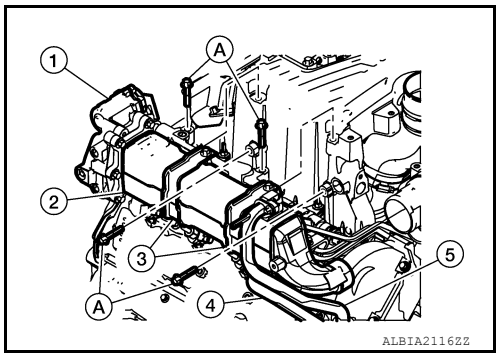
Removal and Installation

INFOID:0000000014418634

GENERAL INFORMATION

- The exhaust gas recirculation (EGR) cooler is best serviced as an assembly of the EGR cooler and the bracket.
- The EGR cooler assembly includes the following components:

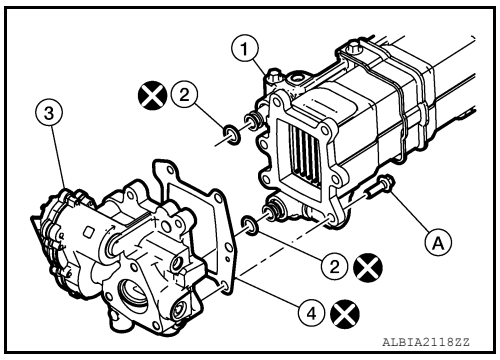
(1) : EGR valve
(2) : EGR cooler
(3) : EGR cooler mounting straps
(4) : EGR cooler supply line
(5) : EGR cooler return line
(A) : Bolts



REMOVAL

NOTE:
Brush away all loose dirt from the around the area of the air handling connections to avoid contamination of the interior of the engine.

1. Remove the EGR cooler assembly. Refer to EM-276, "Removal and Installation".
2. Remove the bolts (A) and separate the EGR valve (3) from the EGR cooler assembly (1).
   CAUTION:
   Do not reuse the EGR valve gasket (4) or O-rings (2).



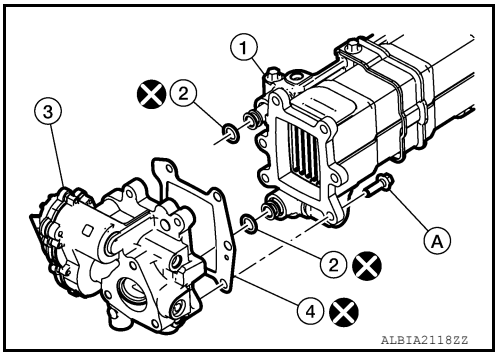
INSPECTION AFTER REMOVAL

CAUTION:
Cleaning the EGR valve may result in damage to the component.
- Do **not** clean the EGR valve. If debris is the root cause for the malfunction, the component **must** be replaced.
- Inspect the EGR valve for any damage to the valve, housing, and electrical connections. If damage is found, the EGR valve **must** be replaced.
  NOTE:
  The EGR valve is **not** repairable and should **not** be disassembled.

INSTALLATION

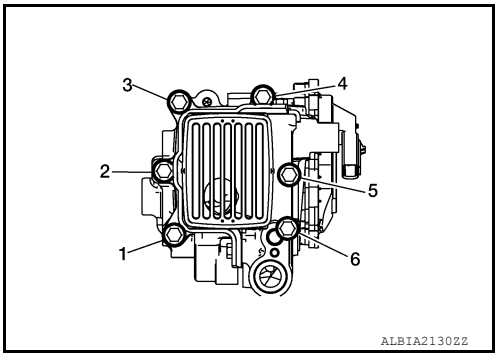
1. Install the EGR valve (3) and hand tighten the bolts (A).
CAUTION:
Do not reuse the EGR valve gasket (4) or O-rings (2).

(1) : EGR cooler assembly
(2) : O-ring
(4) : Gasket



2. Tighten the bolts to specification in the sequence shown.

Step 1 **: 13 N·m (1.3 kg-m, 10 ft-lb)**
Step 2 **: 26 N·m (2.7 kg-m, 19 ft-lb)**

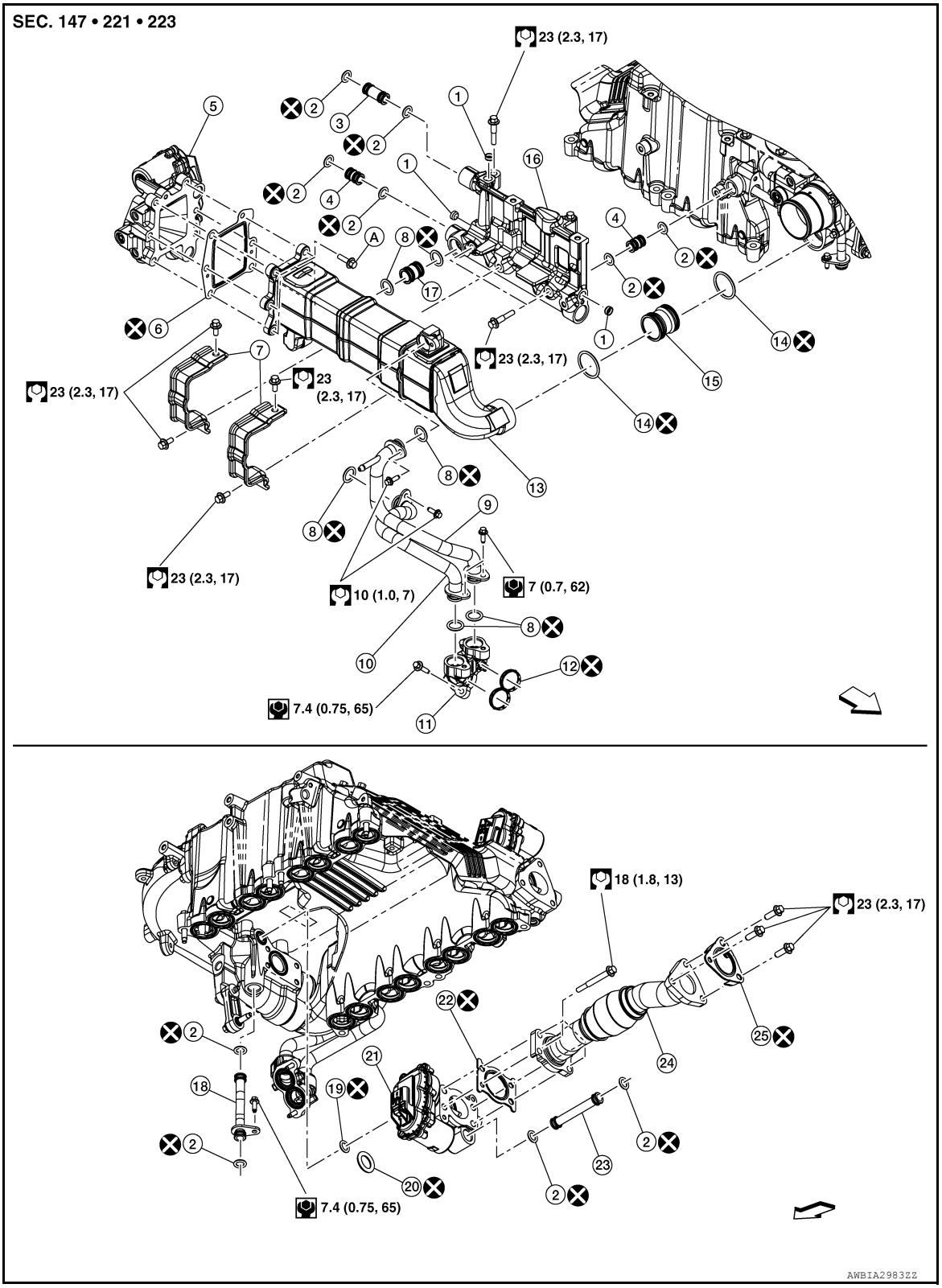


3. Installation of the remaining components is in the reverse order of removal.
NOTE:
Operate the engine and check for leaks.

EGR BYPASS VALVE

Exploded View

INFOID:0000000014418635



1. Welch plug
2. O-ring
3. Coolant tube
4. Coolant tube
5. EGR valve
6. EGR valve gasket
7. EGR cooler mounting strap
8. O-ring
9. EGR cooler return line

10. EGR cooler supply line
11. Water transfer connection
12. Water transfer connection gasket
13. EGR cooler
14. O-ring
15. Intake air connection jumper tube
16. EGR mounting bracket
17. Coolant tube
18. EGR bypass valve coolant tube
19. O-ring
20. O-ring
21. EGR bypass valve
22. EGR bypass valve gasket
23. Coolant tube
24. EGR bypass tube
25. EGR bypass tube gasket
A. Refer to INSTALLATION
⇦ Front

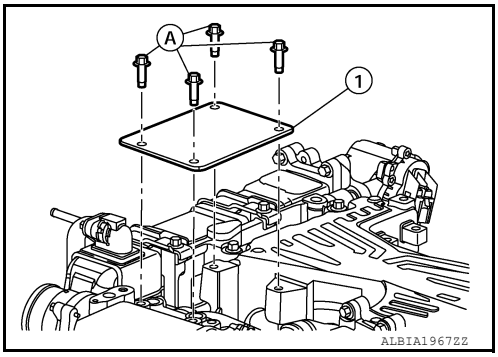
CAUTION:
- **EGR cooler is serviced as a kit with EGR valve gasket and O-rings.**
- **EGR valve is serviced as a kit with EGR valve gasket and O-rings.**
- **EGR bypass valve is serviced as a kit with EGR bypass valve gasket and O-rings.**

Removal and Installation

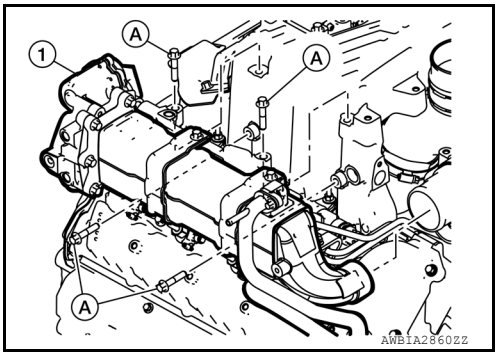
INFOID:0000000014418636

REMOVAL

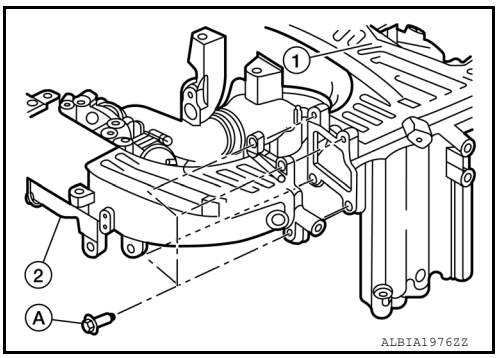
1. Remove the intake manifold. Refer to EM-239, "Removal and Installation".
2. Remove bolts (A) and remove the cover plate (1) from the intake manifold.



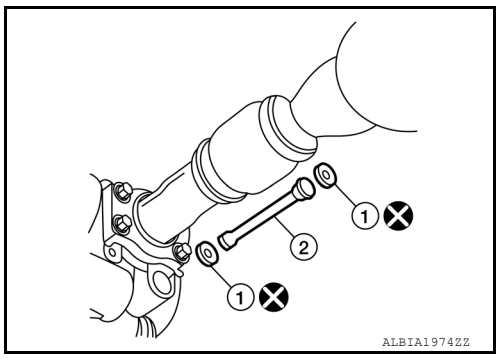
3. Remove the EGR bracket bolts (A), and the EGR cooler assembly (1) from the intake manifold.
   CAUTION:
   Do not reuse the O-rings.



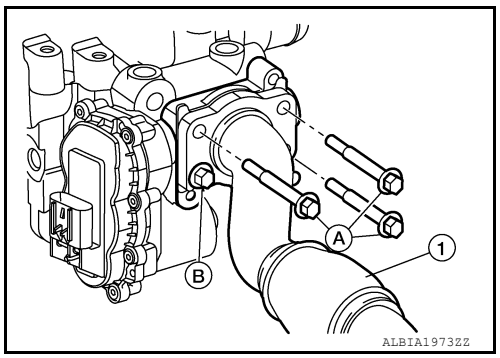
4. Remove the bolts (A) and then remove the air intake connection (2) from the intake manifold (1).
   CAUTION:
   Do not reuse the gasket.



5. Remove the coolant tube [2 (if necessary)].
CAUTION:
Do not reuse the O-rings (1).

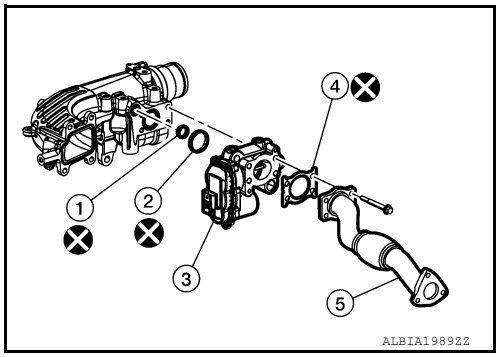


6. Remove the bolts (A) and (B) connecting the EGR bypass tube (1) to the EGR bypass valve after removing the air intake connection.



7. Remove the EGR bypass valve (3).
CAUTION:
Do not reuse the gasket (4) or O-rings (1) and (2).

(5) : EGR bypass tube



INSPECTION AFTER REMOVAL

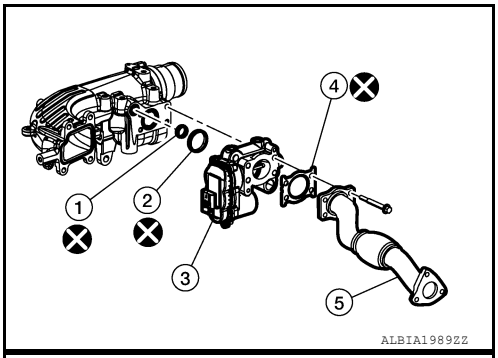
CAUTION:
Cleaning the EGR bypass valve actuator may result in damage to the component. Do not clean the EGR bypass valve.
NOTE:
The EGR bypass valve is not repairable and should not be disassembled.
- Inspect the EGR bypass valve body and sealing surfaces for damage. If damage is found replace the component.
- Inspect the EGR bypass valve sealing surfaces and body for cracks and or other damage.

INSTALLATION

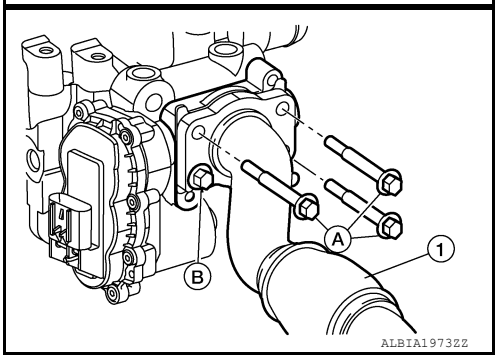
1. Lubricate the O-rings with a suitable water-based lubricant and install the coolant tube into the intake manifold.
CAUTION:
Do not reuse the O-rings.

2. Install the EGR bypass valve (3).
CAUTION:
Do not reuse the O-rings (1) and (2) and gasket (4).

(5) : EGR bypass tube

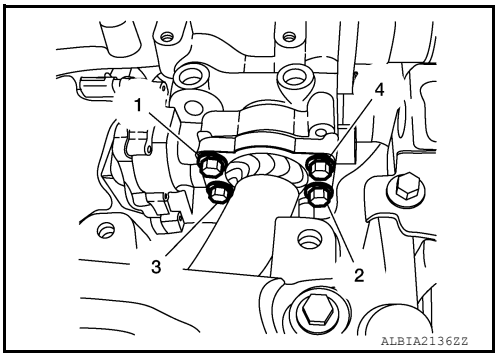


3. Install bolt (B) first and then install bolts (A).
NOTE:
The EGR bypass tube (1) is slotted for this hole to allow for installation of the bolt (B).



4. Tighten the bolts in the sequence shown to the specified torque.

EGR bypass valve bolts : 18 N·m (1.8 kg-m, 13 ft-lb)

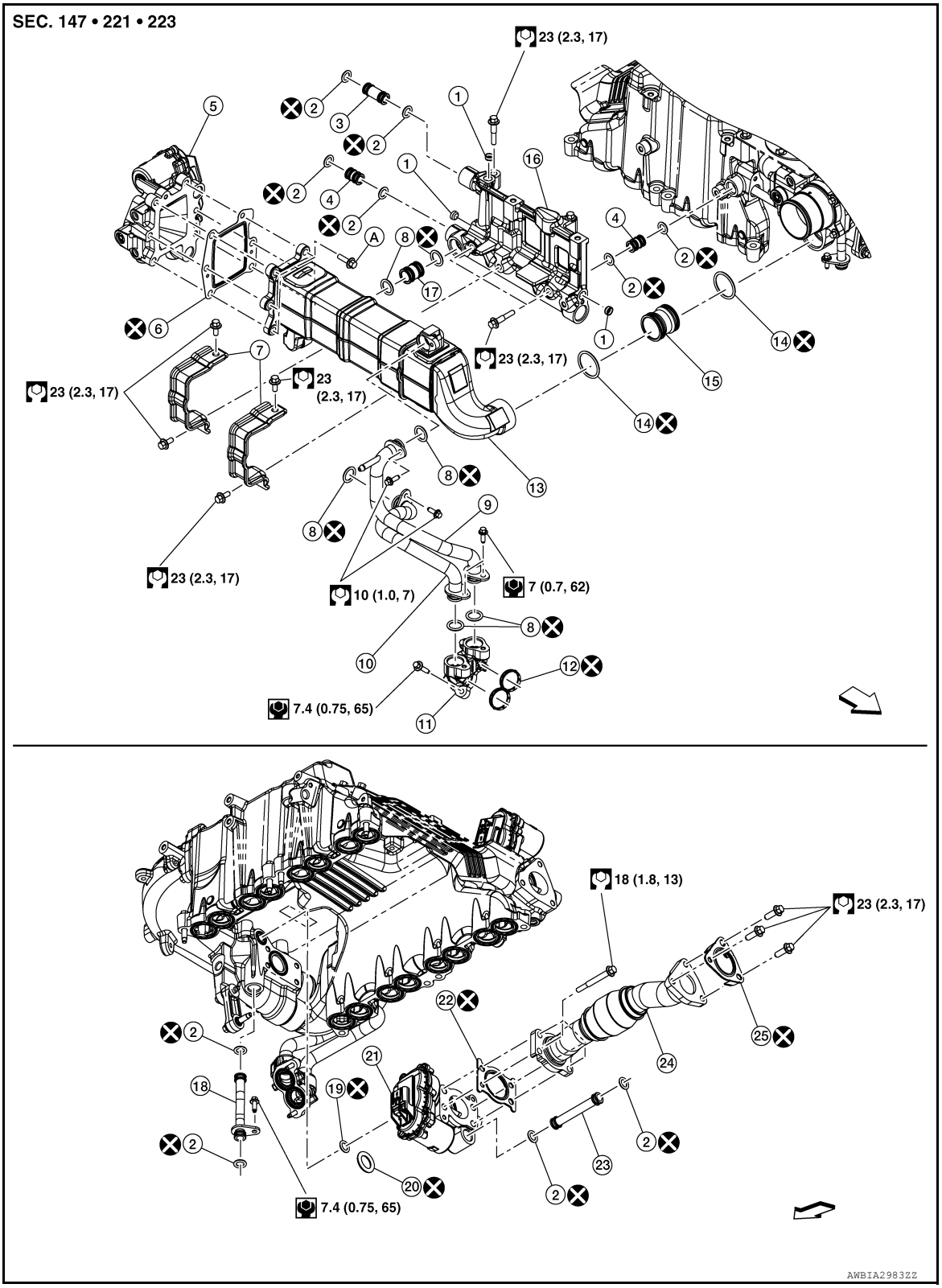


5. Installation of remaining components is in the reverse order of removal.
NOTE:
Operate the engine and check for leaks.

EGR BYPASS TUBE

Exploded View

INFOID:0000000014418637



1. Welch plug
2. O-ring
3. Coolant tube
4. Coolant tube
5. EGR valve
6. EGR valve gasket
7. EGR cooler mounting strap
8. O-ring
9. EGR cooler return line

10. EGR cooler supply line
11. Water transfer connection
12. Water transfer connection gasket
13. EGR cooler
14. O-ring
15. Intake air connection jumper tube
16. EGR mounting bracket
17. Coolant tube
18. EGR bypass valve coolant tube
19. O-ring
20. O-ring
21. EGR bypass valve
22. EGR bypass valve gasket
23. Coolant tube
24. EGR bypass tube
25. EGR bypass tube gasket
A. Refer to INSTALLATION
⇦ Front

CAUTION:
- **EGR cooler is serviced as a kit with EGR valve gasket and O-rings.**
- **EGR valve is serviced as a kit with EGR valve gasket and O-rings.**
- **EGR bypass valve is serviced as a kit with EGR bypass valve gasket and O-rings.**

Removal and Installation

INFOID:0000000014418638

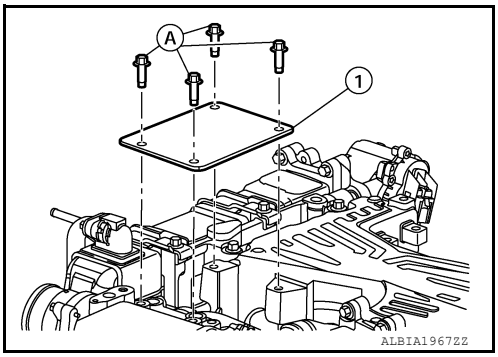
GENERAL INFORMATION

The exhaust gas recirculation (EGR) bypass tube is used to bypass the EGR cooler during initial start-up. EGR bypass tube removal and installation is best accomplished by working it as an EGR bypass subassembly consisting of the EGR bypass valve and the EGR bypass tube.

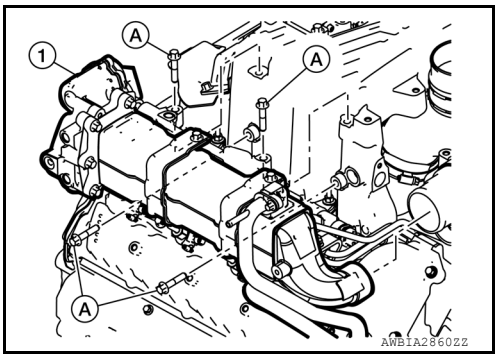
REMOVAL

CAUTION:
- **Brush away any dirt from the area around the air intake connections to avoid contamination of the interior of the engine.**
- **Apply penetration oil to the bolts that mount the EGR bypass tube to the turbocharger housing and to the EGR bypass valve.**

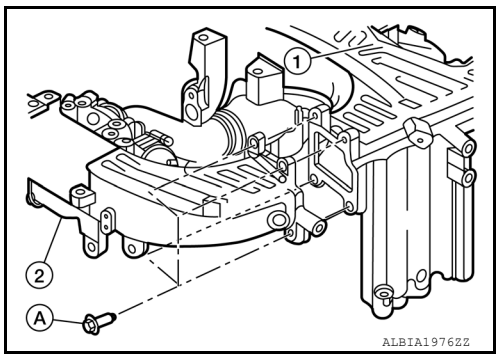
1. Remove the intake manifold. Refer to EM-239, "Removal and Installation".
2. Remove bolts (A) and remove the cover plate (1) from the intake manifold.



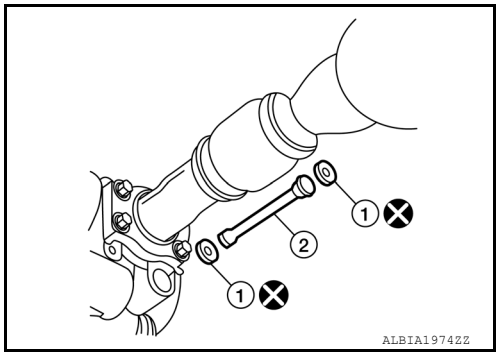
3. Remove the EGR bracket bolts (A), and the EGR cooler assembly (1) from the intake manifold.
   CAUTION:
   Do not reuse the O-rings.



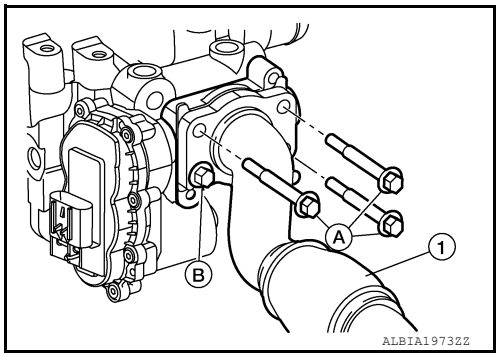
4. Remove the bolts (A) and then remove the air intake connection (2) from the intake manifold (1).
CAUTION:
Do not reuse the gasket.



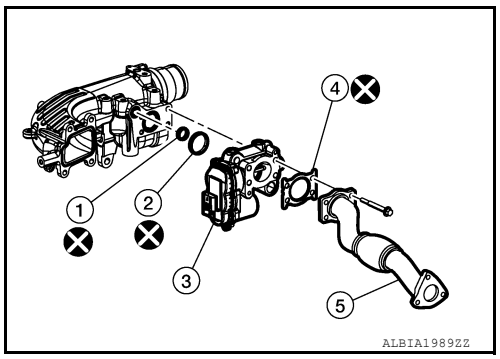
5. Remove the coolant tube (2).
CAUTION:
Do not reuse the O-rings (1).



6. Remove the bolts (A) and (B) connecting the EGR bypass tube (1) to the EGR bypass valve after removing the air intake connection.



7. Remove the EGR bypass valve (3) and EGR bypass tube (5) from the air intake connection.
CAUTION:
Do not reuse the gasket (4) or O-rings (1) and (2).



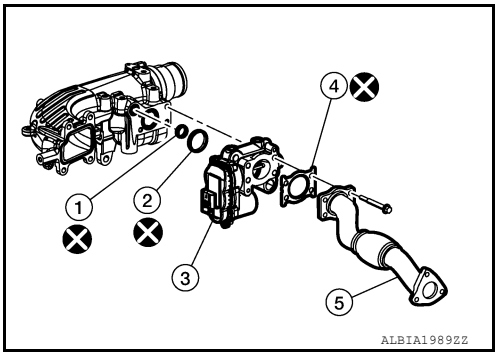
INSPECTION AFTER REMOVAL

- Clean the EGR bypass valve and EGR bypass tube mounting surfaces of gasket material. Do **not** allow debris into the EGR bypass tube or EGR valve.
- Clean the EGR bypass tube and the turbocharger mounting flange mounting surfaces of gasket material.
NOTE:
It is common for the EGR components to have a buildup of carbon on their inside surfaces. This buildup is normal and does not need to be removed.
- Inspect the EGR bypass tube for cracks, distortion, corrosion, and soot streaking on the outside of the connection tube, which would indicate an EGR leak.

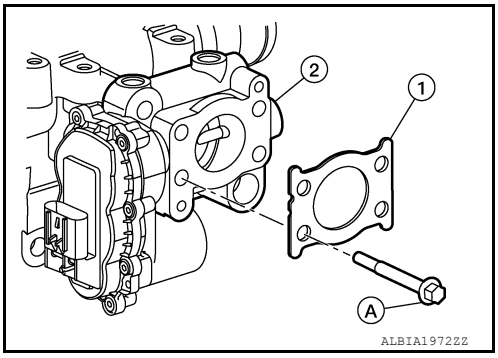
INSTALLATION

1. Before installing EGR bypass valve (3) onto air intake connection, install gaskets (1) and (2).
CAUTION:
Do not reuse the EGR bypass valve gaskets.

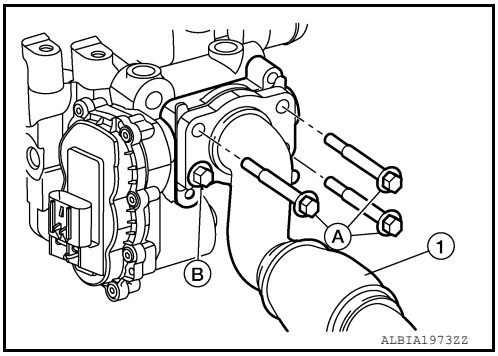
(4) : EGR bypass valve gasket
(5) : EGR bypass tube



2. Install bolt (A) in the lower left hole of the gasket (1) and EGR bypass valve (2), as shown. Do not tighten the bolt and leave a gap to allow the exhaust transfer tube flange to be slid into place.
CAUTION:
Do not reuse the gasket.

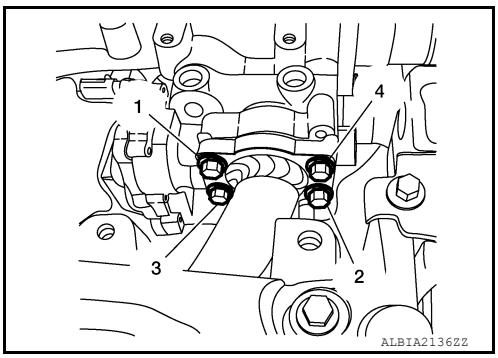


3. Slide the exhaust transfer tube (1) over the installed bolt (B) and install the remaining bolts (A).

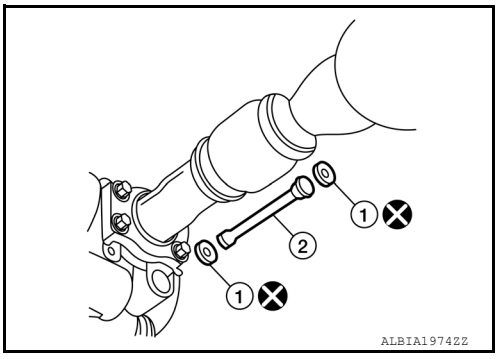


4. Tighten EGR bypass valve bolts in the following sequence.

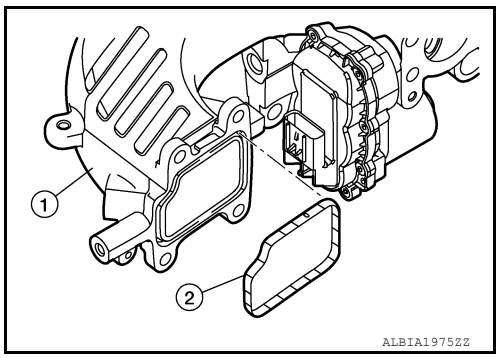
EGR bypass valve bolts : 18 N·m (1.8 kg-m, 13 ft-lb)



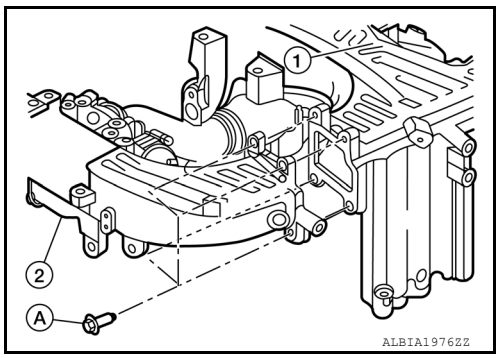
5. Install the coolant tube (2) into the exhaust bypass valve.
CAUTION:
Do not reuse the O-rings (1).
NOTE:
Lubricate the O-ring with a suitable water-based lubricant.



6. Install a new gasket (2) into the air intake connection (1).
CAUTION:
Do not reuse gasket.
NOTE:
Be sure gaskets are in place and properly seated.

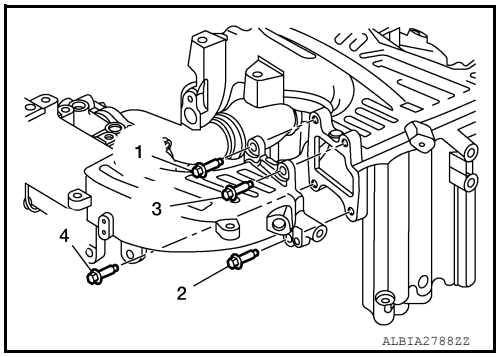


7. Install the air intake connection (2) onto the intake manifold (1) and tighten bolts (A).
NOTE:
Be sure the coolant tube is aligned and installs into the intake manifold.



8. Tighten air intake connection bolts in the sequence shown to the specified torque.

Air intake connection bolts : 18 N·m (1.8 kg-m, 13 ft-lb)

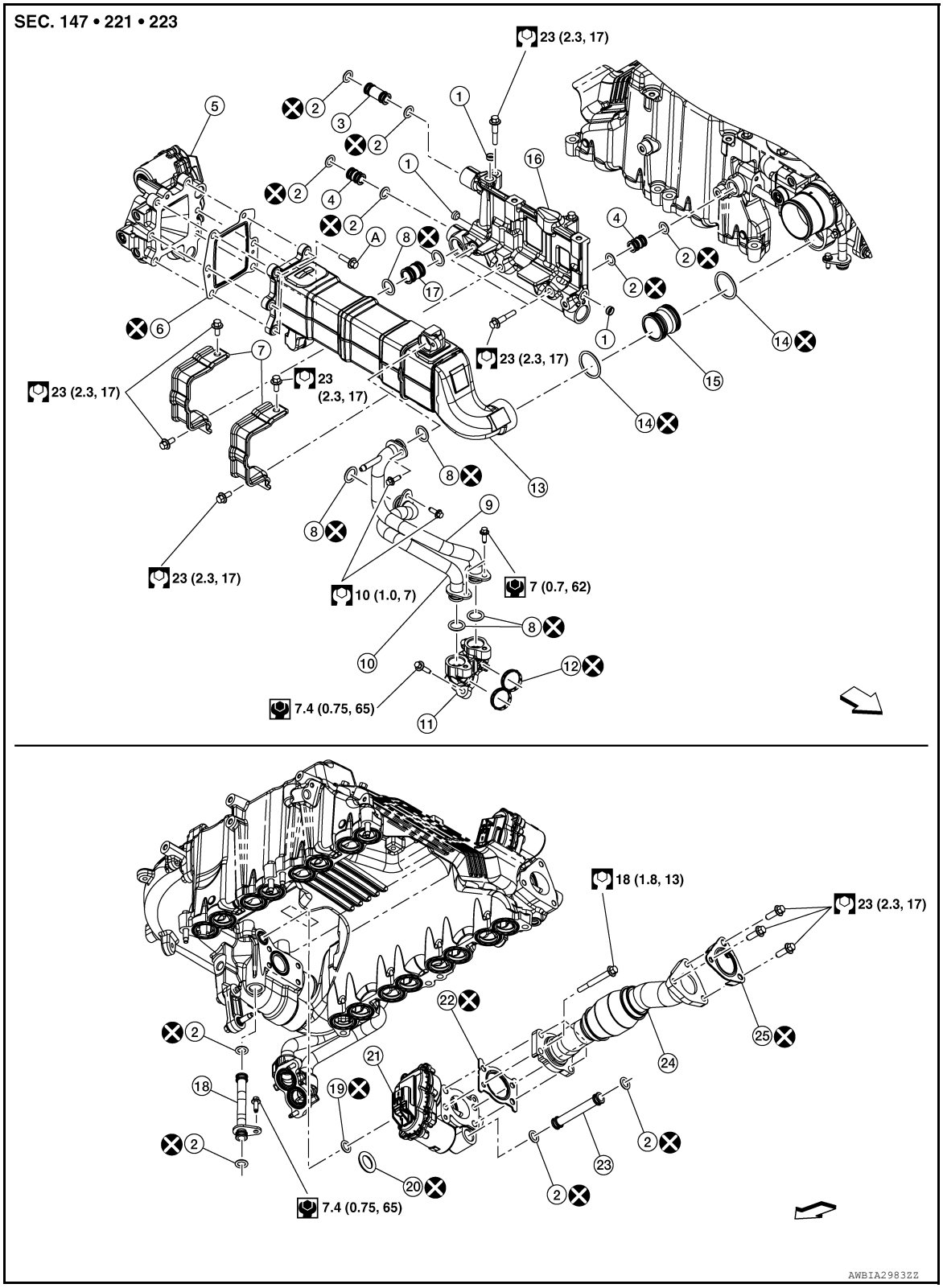


9. Installation of the remaining components is in the reverse order of removal.
NOTE:
Operate the engine and check for leaks.

EGR COOLER MOUNTING BRACKET

Exploded View

INFOID:0000000014418639



1. Welch plug
2. O-ring
3. Coolant tube
4. Coolant tube
5. EGR valve
6. EGR valve gasket
7. EGR cooler mounting strap
8. O-ring
9. EGR cooler return line

10. EGR cooler supply line
11. Water transfer connection
12. Water transfer connection gasket
13. EGR cooler
14. O-ring
15. Intake air connection jumper tube
16. EGR mounting bracket
17. Coolant tube
18. EGR bypass valve coolant tube
19. O-ring
20. O-ring
21. EGR bypass valve
22. EGR bypass valve gasket
23. Coolant tube
24. EGR bypass tube
25. EGR bypass tube gasket
A. Refer to INSTALLATION
⇦ Front

CAUTION:
- **EGR cooler is serviced as a kit with EGR valve gasket and O-rings.**
- **EGR valve is serviced as a kit with EGR valve gasket and O-rings.**
- **EGR bypass valve is serviced as a kit with EGR bypass valve gasket and O-rings.**

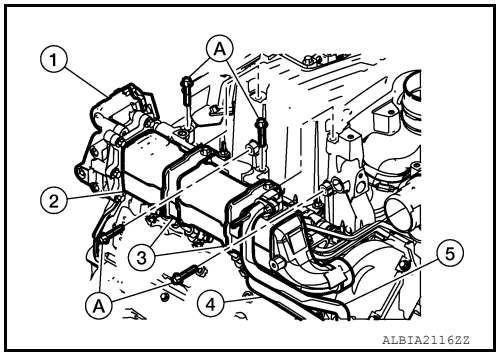
Removal and Installation

INFOID:0000000014418640

GENERAL INFORMATION

- The EGR cooler mounting bracket is best removed and installed as an assembly of the EGR cooler and the bracket.
- The EGR cooler assembly includes the following components:

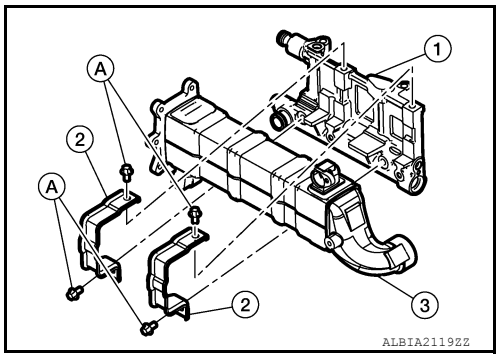
(1) : EGR valve
(2) : EGR cooler
(3) : EGR cooler mounting straps
(4) : EGR cooler supply line
(5) : EGR cooler return line
(A) : Bolts



REMOVAL

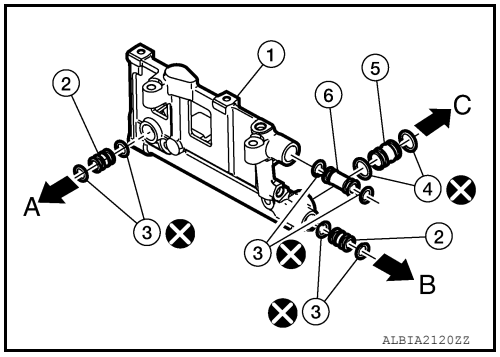
CAUTION:
Brush away any dirt from the area around the air handling connections to reduce the possibility of contaminating the air intake system.

1. Remove the EGR cooler assembly. Refer to EM-276, "Removal and Installation".
2. Remove the bolts (A) connecting the EGR cooler mounting bracket (1) to the EGR cooler (3).
3. Remove the EGR cooler mounting straps (2) and remove the EGR cooler mounting bracket (1).



4. Remove the coolant tubes (2), (5) and (6) from the EGR cooler mounting bracket (1).
CAUTION:
Do not reuse the O-rings.

(3) : O-ring
(4) : O-ring
(A) : To intake manifold
(B) : To EGR valve
(C) : To EGR cooler



INSPECTION AFTER REMOVAL

WARNING:

- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufactures recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- **when using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**

- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**

- Clean the EGR cooler mounting bracket with solvent and dry with compressed air.
- Inspect the EGR cooler mounting bracket for cracks and other damage. Replace the bracket if damage is found.

INSTALLATION

Installation is in the reverse order of removal.

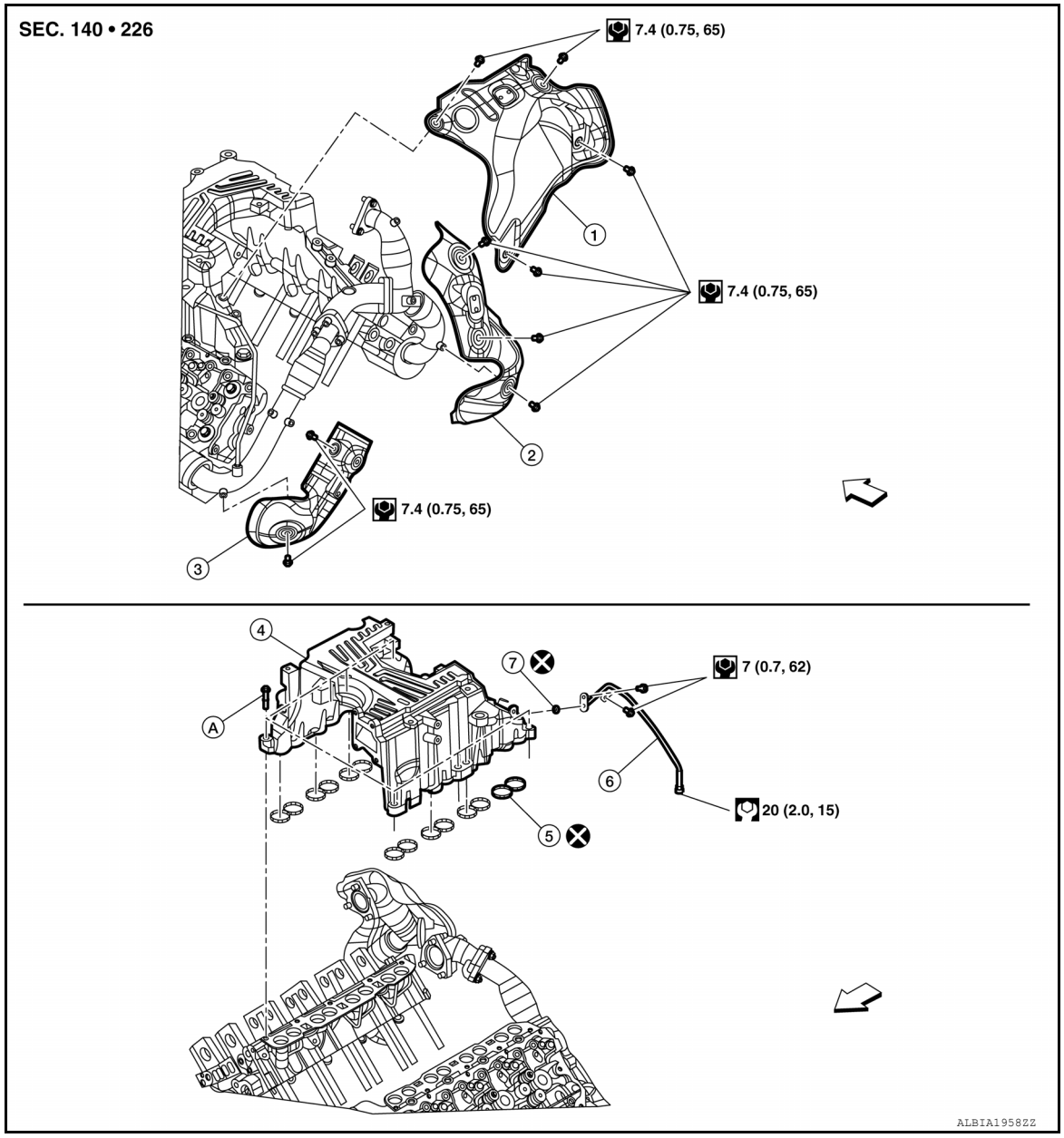
NOTE:

- Lubricate the O-rings with a suitable water-based lubricant before installation.
- Operate the engine and check for leaks.

EXHAUST PRESSURE SENSOR TUBE

Exploded View

INFOID:0000000014418641



1.	Center heat shield	2.	Heat shield (RH)	3.	Heat shield (LH)
4.	Intake manifold	5.	Gasket	6.	Exhaust pressure sensor tube
7.	O-ring	A.	Refer to INSTALLATION	⇦	Front

Removal and Installation

INFOID:0000000014418642

INSPECTION BEFORE REMOVAL

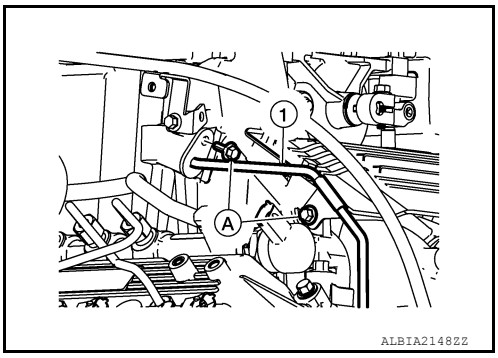
- Inspect the ports on the exhaust manifold and the exhaust pressure sensor for signs of leaks or damage. Leaks can be identified by soot streaks.
- If leaks are found, tighten the fittings again. If the fittings are **not** loose, replace the exhaust gas pressure sensor tube.

REMOVAL

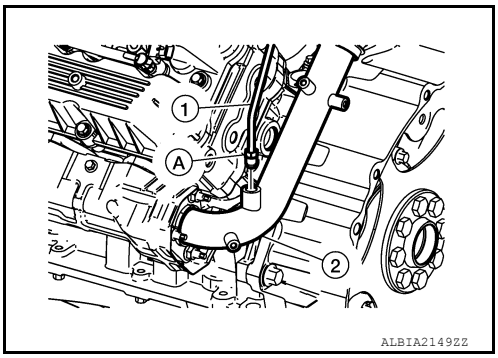
1. Remove the center heat shield. Refer to EX-32, "Removal and Installation".
2. Remove the wheel and tire. Refer to WT-69, "Removal and Installation".
3. Remove the fender protector (LH). Refer to EXT-41, "Removal and Installation - Front Fender Protector".
4. Use compressed air to clean around the fittings where the exhaust pressure sensor tube connects to the intake manifold.

   WARNING:
   - **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
   - **Do not exceed 30 psi (207 kPa).**
   - **Wear appropriate eye protection and protective clothing including gloves.**
   - **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
   - **Wear appropriate eye protection and protective clothing including gloves and a face shield.**

   NOTE:
   Apply a suitable penetrating oil to the exhaust gas pressure sensor tube connection at the exhaust transfer tube.
5. Remove the bolts (A) connecting the exhaust pressure sensor tube (1) to the intake manifold.



6. Loosen nut (A) securing the exhaust pressure sensor tube (1) to the exhaust transfer tube [bank 2 (2)].
7. Remove the exhaust pressure sensor tube (1).



INSPECTION AFTER REMOVAL

WARNING:
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturers recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- Clean the exhaust gas pressure sensor tube with solvent and dry with compressed air.
- Inspect the tube for signs of leakage, damaged sealing areas, or plugging with soot.
- If the tube is plugged with soot, use solvent and a pipe cleaner, or similar device, to remove the soot blockages in the tube.

INSTALLATION

Installation is in the reverse order of removal.

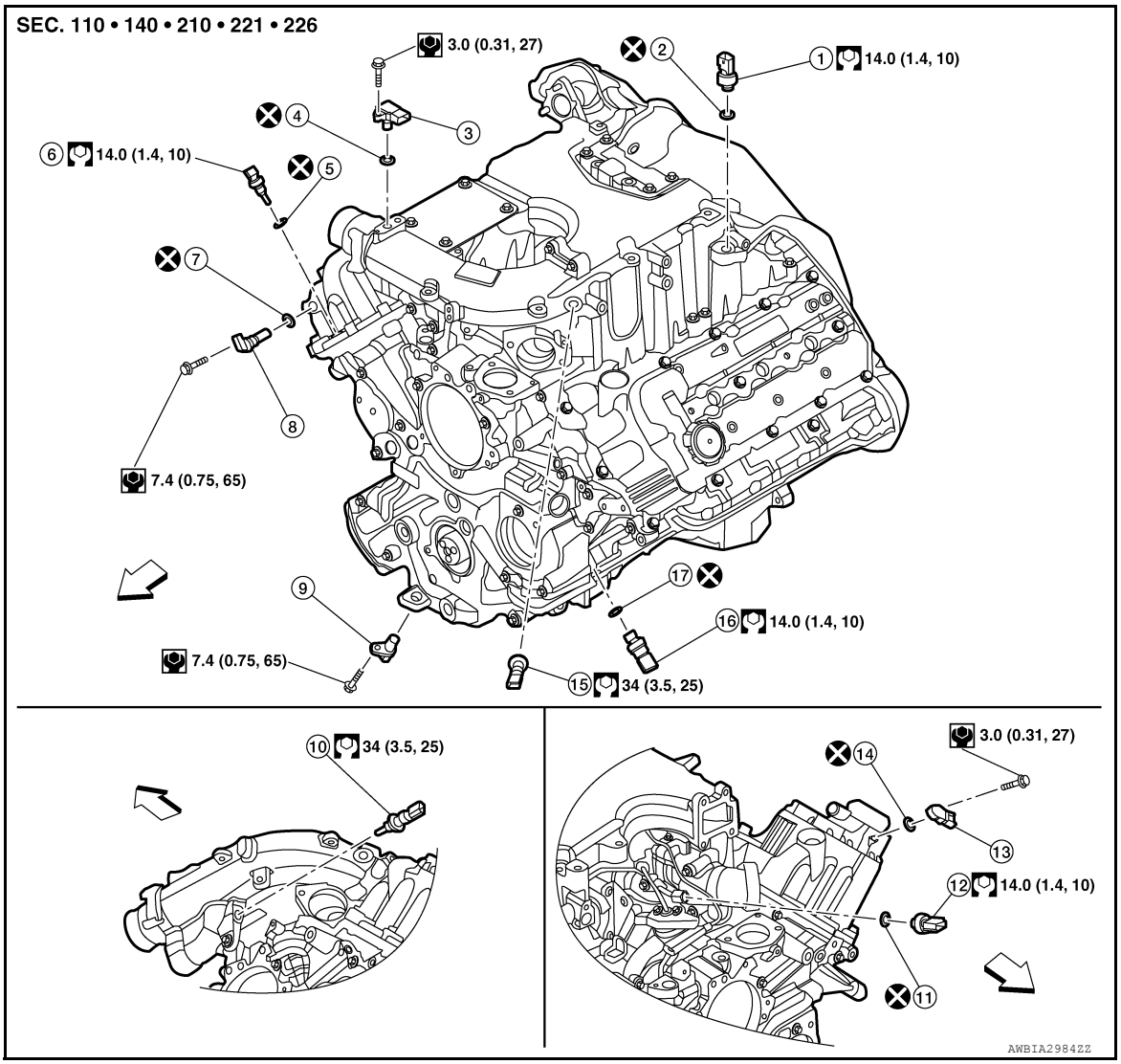
NOTE:

- Lubricate the O-rings with a suitable water based lubricant.
- Operate the engine and check for leaks.

EXHAUST GAS PRESSURE SENSOR

Exploded View

INFOID:0000000014418643



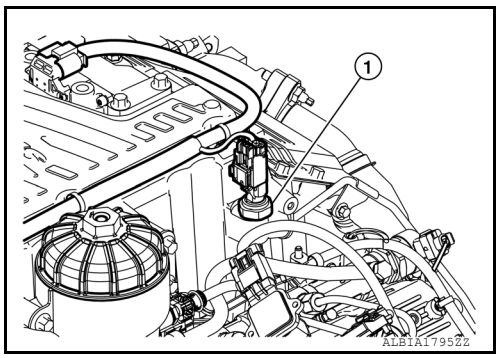
1. Exhaust gas pressure sensor
2. O-ring
3. Engine charge-air cooler outlet pressure/temperature sensor
4. O-ring
5. O-ring
6. Engine coolant temperature sensor
7. O-ring
8. Camshaft position sensor
9. Crankshaft position sensor
10. EGR temperature sensor
11. O-ring
12. Low pressure turbocharger boost pressure sensor
13. Crankcase pressure sensor
14. O-ring
15. Intake manifold air temperature sensor
16. Engine oil pressure switch
17. O-ring
⇦ Front

Removal and Installation

INFOID:0000000014418644

GENERAL INFORMATION

- The exhaust gas pressure sensor (1) monitors the exhaust gas pressure in the exhaust manifold. The sensed pressure is converted to a voltage signal and that information is passed on to the engine control module (ECM) through the engine harness. This information is used by the ECM to control emissions, the exhaust gas recirculation valves and the turbocharger. If the exhaust gas pressure sensor reading becomes too high, it will cause a derate condition.
- The exhaust gas pressure sensor is located on the bank 2 side of the intake manifold.



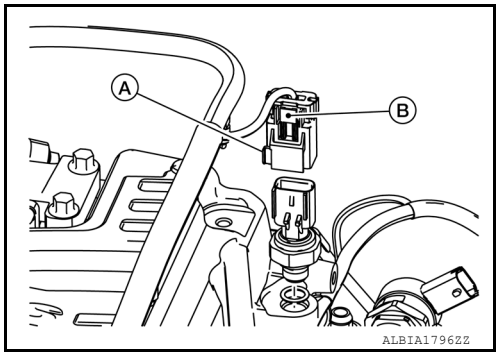
INSPECTION BEFORE REMOVAL

- Use an electronic service tool to monitor the value of the exhaust pressure sensor with the key in the ON position and the engine OFF.
- The value of the exhaust pressure sensor temperature should read within 5 percent of the local barometric air pressure when the local ambient air temperature is between -40°C (-40°F) and 40°C (104°F).
- Replace the exhaust gas pressure sensor if the value is out of specification.

REMOVAL

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".

   WARNING:
   Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:
   - **Wear appropriate goggles and protective clothing.**
   - **Always properly ventilate the area where the service is being performed.**
   - **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
   - **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
   - **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**
2. Clean the area around the sensor.
3. Slide the locking tab (A) on the connector sideways. Push down on the button (B) toward the rear of the connector and disconnect it from the sensor.
4. Remove the exhaust gas pressure sensor from the engine.



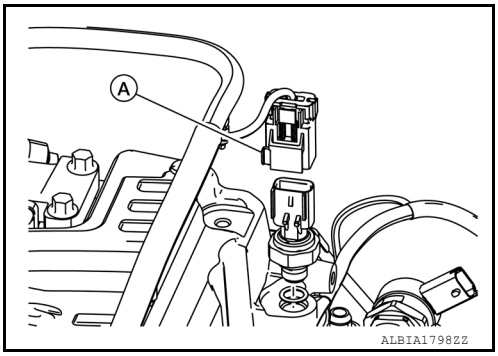
INSPECTION AFTER REMOVAL

- Inspect the engine harness connector and sensor for the following:
- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor.
- Repair or replace parts as necessary.

INSTALLATION

1. Install the exhaust gas pressure sensor.
   CAUTION:
   Do not reuse the O-ring.

2. Connect the exhaust gas pressure harness connector and slide the tab (A) to the lock position.



3. Connect the battery or batteries. Refer to PG-185, "Battery Disconnect".

WARNING:

Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:

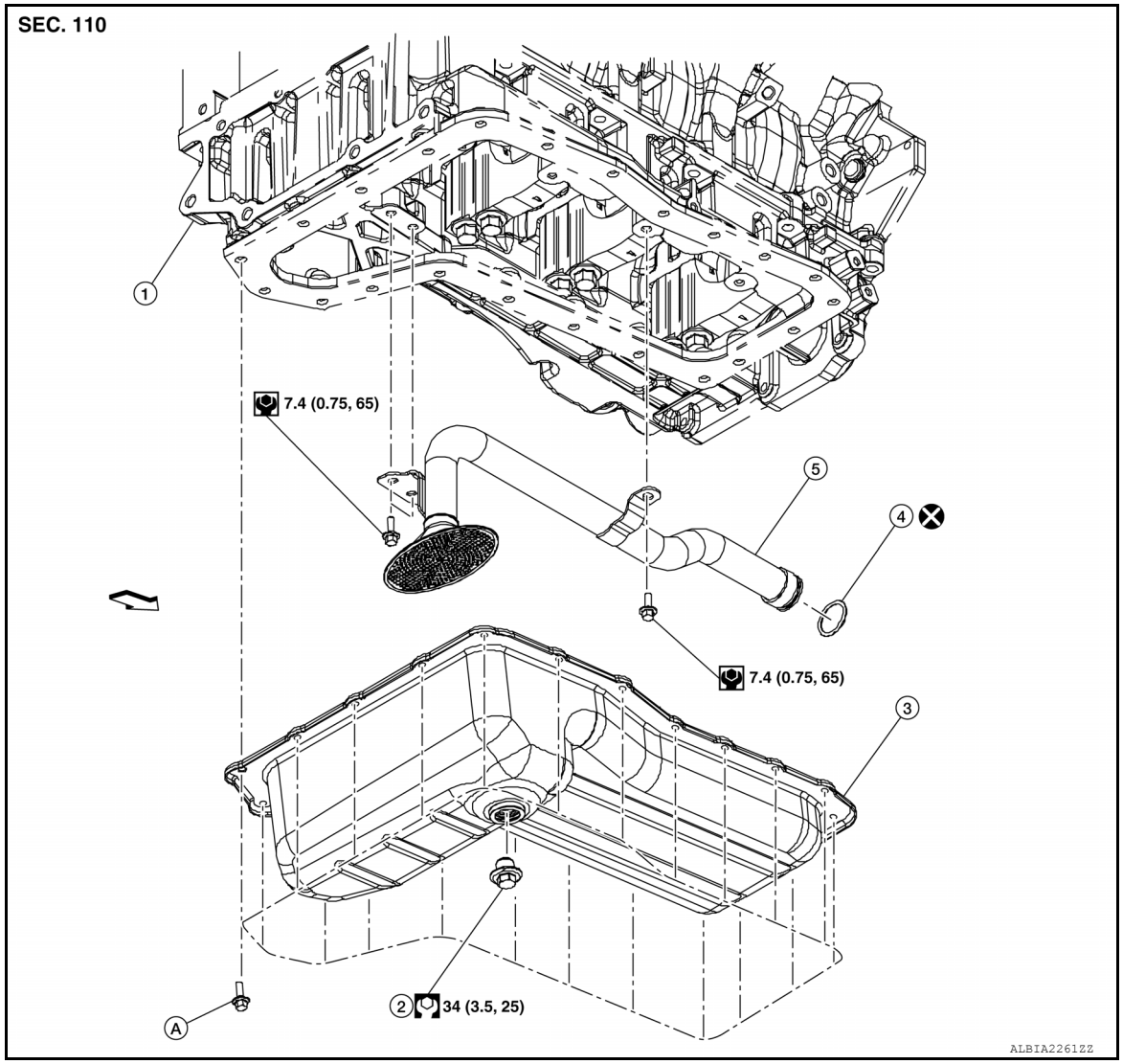
- **Wear appropriate goggles and protective clothing.**
- **Always properly ventilate the area where the service is being performed.**
- **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
- **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
- **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**

4. Operate the engine and check for leaks.

OIL PAN

Exploded View

INFOID:0000000014418645



1. Block stiffening plate
2. Oil pan drain plug
3. Oil pan
4. O-ring
5. Oil suction tube
A. Refer to INSTALLATION

⇦ Front

Removal and Installation

INFOID:0000000014418646

REMOVAL

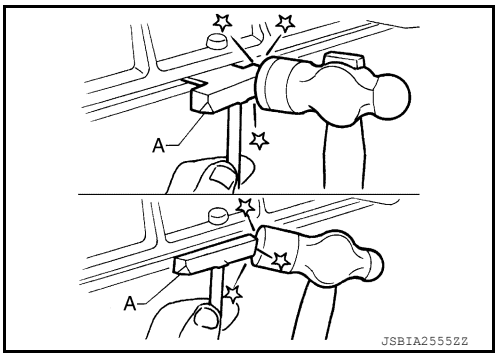
WARNING:

- **To avoid the risk of personal injury:**
- **Be careful not to burn yourself, as engine oil may be hot.**
- **Prolonged and repeated contact with used engine oil may cause skin cancer; try to avoid direct skin contact with used engine oil. If skin contact is made, wash thoroughly with soap or hand cleaner as soon as possible. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.**
- **If not reused, dispose of in accordance with local environmental regulations.**

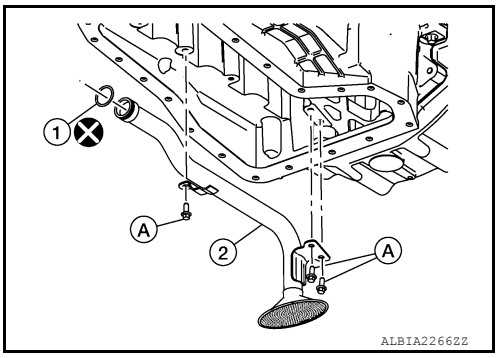
1. Remove the engine undercover. Refer to EXT-39, "ENGINE UNDER COVER : Removal and Installation".
2. Drain the engine oil. Refer to LU-35, "Changing Engine Oil".
3. Remove the front crossmember. Refer to DLN-191, "Exploded View".

4. Remove the oil pan bolts.
5. Insert Tool (A) between oil pan and lower cylinder block, and slide it around the surface of the oil pan by tapping on the side of Tool (A) using a suitable tool.
   CAUTION:
   Do not damage the mating surface.
   NOTE:
   Do not pry on or against the oil pan mounting flange or the block stiffener plate when using the Tool (A) to break the formed-in-place gasket joint.

   Tool : KV10111100 (J-37228)



6. Remove the oil pan.
7. Remove bolts (A) and remove the oil suction tube (2) (if necessary).
   CAUTION:
   Do not reuse O-ring (1).



INSPECTION AFTER REMOVAL

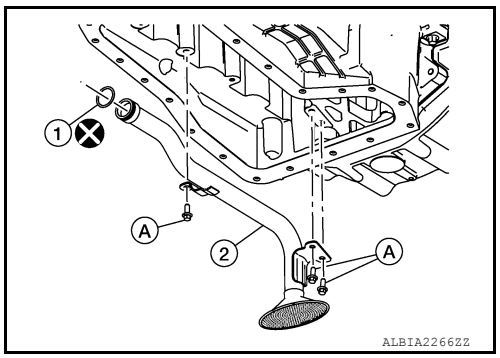
WARNING:
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
- **Wear appropriate eye protection and protective clothing including gloves and a face shield.**

CAUTION:
The use of air or power tools, such as a high speed sander with an abrasive pad, to clean the gasket material can overheat the oil pan and cause damage to the sealing flange.
- Clean gasket residue from the block stiffener plate and oil pan mating surfaces. Do not use abrasive pads or steel scrapers.
- Use solvent to clean the oil pan.
- Dry the oil pan with compressed air.
- Clean the surface of the block stiffener plate of any remaining oil and contaminants.
- Inspect the bottom of the oil pan for debris. If debris is present, perform an oil filter analysis.
- Inspect the oil pan for cracks, scratches, and other damage. If damage is found, replace the oil pan.
- Inspect the oil suction tube and tube braces for damage. If damage is found, replace the oil suction tube.
- Inspect the oil drain plug threads and the sealing surface for damage.
- If damage is present, replace the oil drain plug.

INSTALLATION

1. If removed, install the oil suction tube (2).
CAUTION:
Do not reuse O-ring (1).

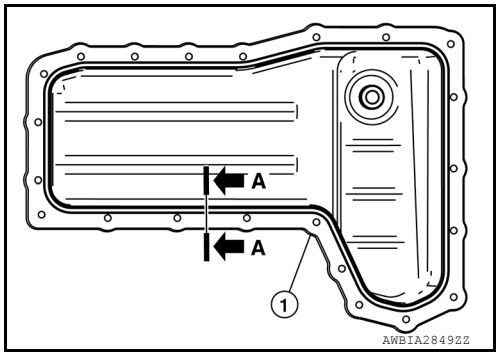
Bolts (A) : 7.4 N·m (0.75 kg-m, 65 in-lb)



2. Verify the oil pan and block stiffening plate are clean and free from oil residue.
NOTE:
Prepare the sealant mating surfaces by wiping them with a lint-free cloth and isopropyl alcohol. After the surface is clean, prepare it with a Bonderite M-NT 5700 wipe or equivalent. wipe. Allow the alodine to dry for a short length of time before applying the sealant to the oil pan.

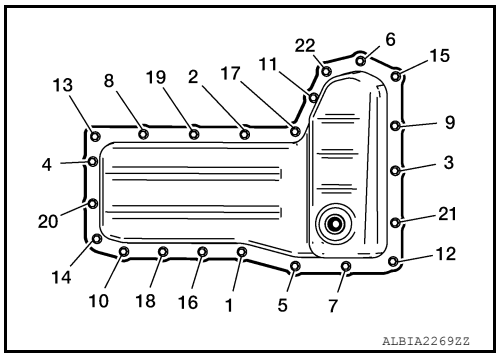
3. Apply the Loctite 5900 RTV sealant or equivalent to the oil pan (1) at the specified sealant bead diameter (A).
NOTE:
The oil pan (1) must be installed within 5 minutes of applying the sealant to be sure the oil pan seals properly. Final torque must be completed within 30 minutes of sealant application.

Sealant bead diameter (A) : 2-3 mm (0.08 - 0.12 in)



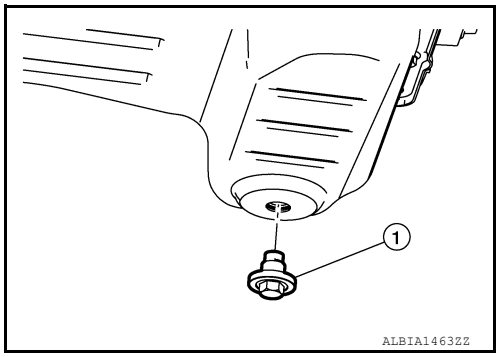
4. Place the oil pan onto its location on the block stiffening plate and tighten the bolts in the sequence shown.
NOTE:
After the pan is installed and the bolts tightened to specified torque, allow the sealant to dry for 30 minutes before running the engine.

Oil pan bolts : 9.4 N·m (0.96 kg-m, 83 in-lb)



5. Install and tighten the oil pan drain plug (1).

Oil pan drain plug : 34 N·m (3.5 kg-m, 25 ft-lb)

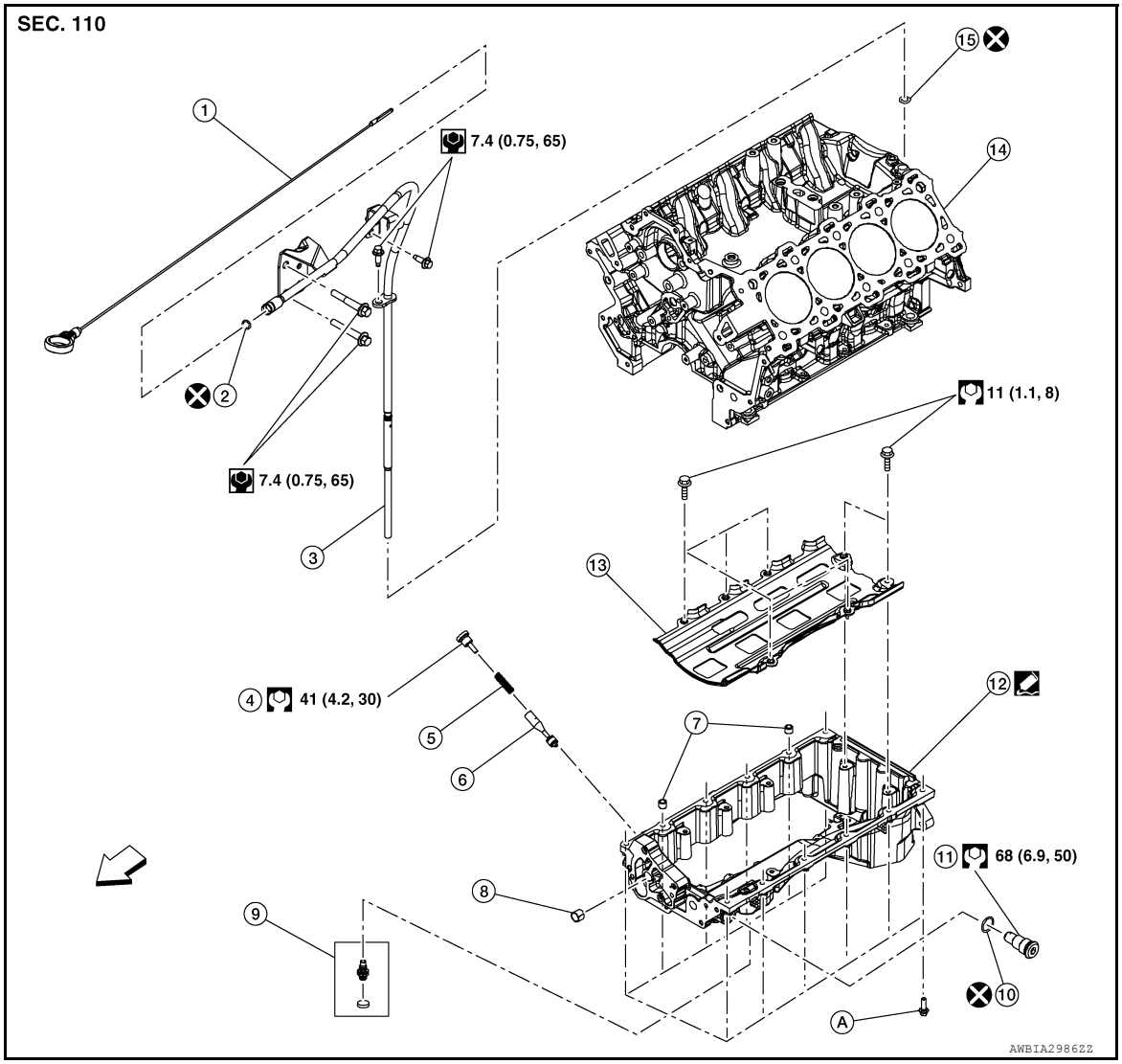


6. Refill the engine oil. Refer to LU-35, "Changing Engine Oil".
7. Operate the engine and check for leaks.

BLOCK STIFFENING PLATE

Exploded View

INFOID:0000000014418647



1. Oil level gauge
2. O-ring
3. Oil level gauge guide
4. Plug
5. Oil pressure regulator spring
6. Oil pressure regulator (main rifle)
7. Dowel pin
8. Bushing
9. Check valve
10. O-ring
11. Oil check valve
12. Block stiffening plate
13. Windage tray
14. Cylinder block
15. O-ring
A. Refer to INSTALLATION
⇦ Front

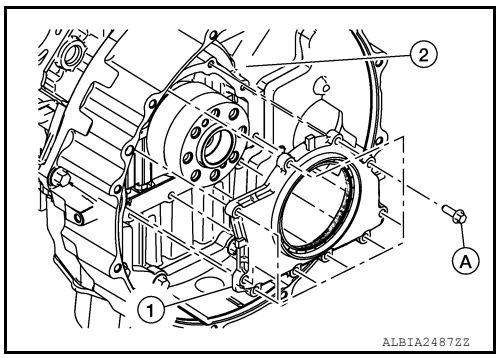
Removal and Installation

INFOID:0000000014418648

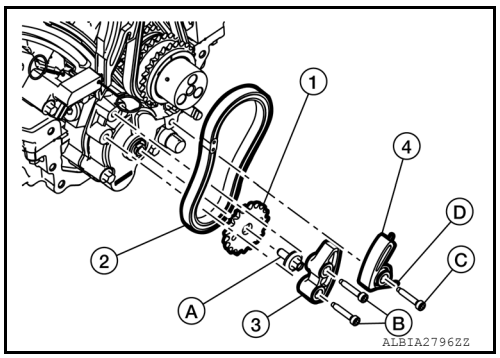
REMOVAL

1. Remove the engine assembly. Refer to EM-493, "Removal and Installation".
2. Remove the front cover. Refer to EM-338, "Removal and Installation".
3. Remove the oil pan. Refer to EM-307, "Exploded View".

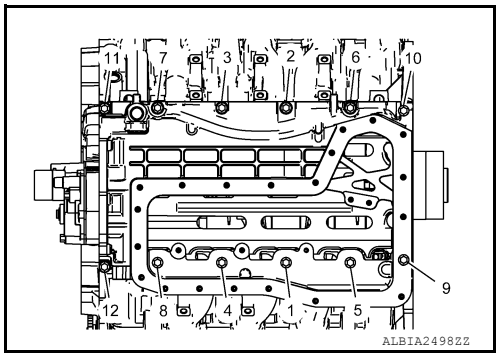
4. Remove the bolts (A) from the rear seal carrier (1) and remove the rear seal carrier from the engine block (2).



5. Release the oil pump slack guide spring (D). Remove the bolt (C) and slack guide (4).
6. Remove bolts (B) and remove the oil pump tension guide (3).
7. Hold the oil pump sprocket with a suitable tool and remove the oil pump sprocket bolt (A).
8. Remove the oil pump sprocket (1) and oil pump drive chain (2).



9. Loosen and remove the block stiffening plate bolts in the reverse sequence as shown.



10. Remove the block stiffening plate from the cylinder block.

INSPECTION AFTER REMOVAL

- **WARNING:**
  To avoid the risk of injury to eyes and skin, when using caustic solutions solvents, acids, or alkaline materials, follow the manufacturer's recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.
- **CAUTION:**
  Do not use abrasive pads to clean the block stiffening plate. Only use pads that do not contain abrasive materials and thoroughly remove all debris after cleaning.
- Use contact cleaner and a lint-free cloth to clean sealant from the mating surfaces on both sides of the block stiffening plate. Check that sealant has **not** plugged the crankcase ventilation check valve.
- Clean the block stiffening plate with isopropyl alcohol and a lint-free cloth.

Block Stiffening Plate

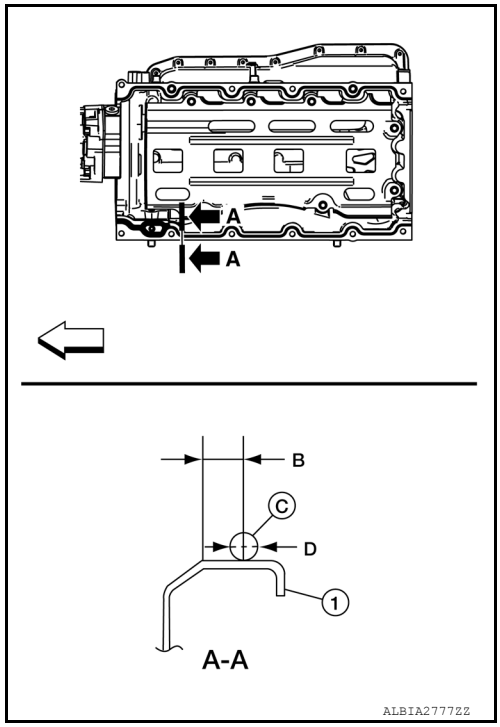
- Inspect the block stiffening plate for cracks, scratches, and other damage.
- Inspect the sealing surfaces for scratches across the flange.
- Inspect the threaded plugs and replace, if necessary.
- Inspect the lubricating oil pump bushing in the block stiffening plate for damage. If the bushing is worn or damaged, the block stiffening plate must be replaced.
- Inspect the oil check valve for damage.
- Inspect the following parts:
- Inspect the windage tray for damage. If damage is found, replace the block stiffening plate.

- Inspect the oil suction tube.
- Inspect the lubricating oil pump.
- Inspect the oil pressure regulator.
- Inspect the closed crankcase ventilation check valve.

INSTALLATION

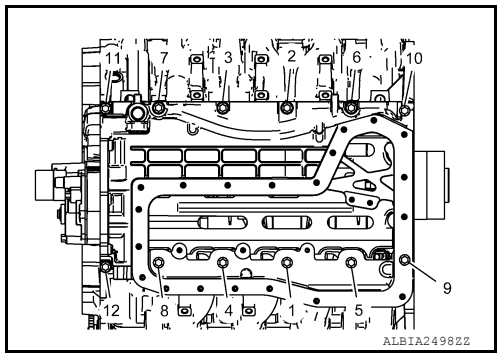
1. Clean the sealant mating surfaces by wiping them with a lint-free cloth and isopropyl alcohol. After the surface is clean, prepare it with a Bonderite M-NT 5700 wipe or equivalent. Allow the Bonderite M-NT 5700 wipe or equivalent to dry before applying sealant.
2. Apply a bead of Loctite 5900 RTV sealant or equivalent (C) to the top of the block stiffening plate (1) in the pattern shown. Apply the bead away from the chamfer (B) on the inside of the block stiffening plate. Do **not** allow the sealant to contact the gasket groove.
   CAUTION:
   Do not apply more than the recommended amount (D) of sealant to the sealing surface. Too much sealant can obstruct oil passages.

   (B) : 1 - 2 mm (0.04 - 0.08 in)
   (D) : 2 - 3 mm (0.08 - 0.12 in)
   ⇦ : Front



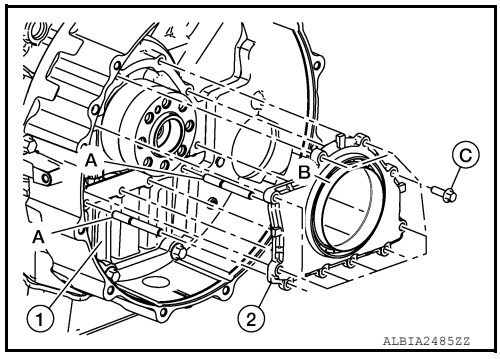
3. Align and install the stiffener plate onto the engine block.
4. Tighten the bolts in the sequence shown.
   NOTE:
   The block stiffening plate **must** be installed within 5 minutes of applying sealant. Final torque **must** be completed within 30 minutes of sealant application.

   ⇦ : Front

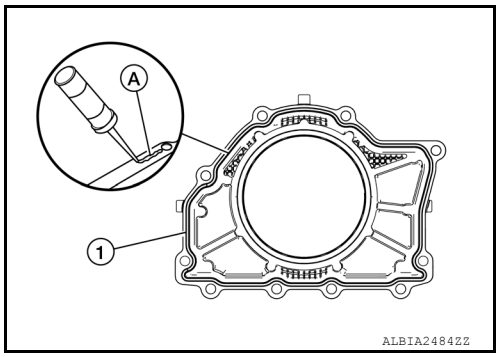


5. Prepare the mating surfaces by wiping them with a lint free cloth and isopropyl alcohol. After the surface is clean, prepare it with Bonderite M-NT 5700 wipe or equivalent. Allow time for the surface to dry.
6. Install suitable tools (A) into the cylinder block (1).

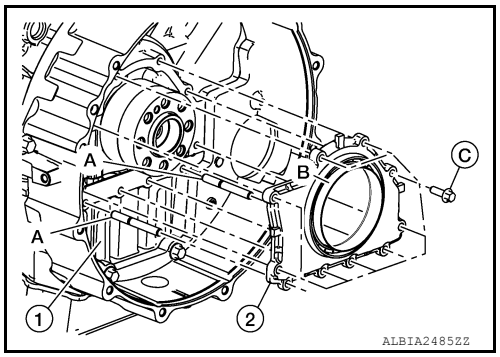
   (2) Rear seal carrier
   (B) Plastic installation sleeve
   (C) Rear seal carrier bolt



7. Apply Loctite 5900 RTV or equivalent sealant (A) to the rear seal carrier (1) in the pattern shown. Apply the bead 1 - 2 mm (0.04 - 0.08 in) away from the chamfer on the inside of the rear seal carrier.
NOTE:
The rear seal carrier **must** be installed within 5 minutes of applying the sealant. The final tightening **must** be completed within 30 minutes of the sealant application.



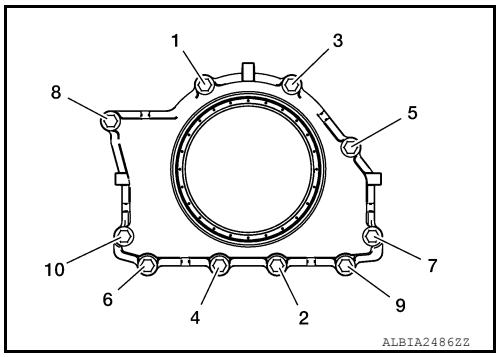
8. Slide the rear seal carrier (2) over the crankshaft and suitable tools (A) until it is seated against the cylinder block (1). Discard the plastic installation sleeve (B).



9. Install and hand tighten bolts (C).
CAUTION:
Be sure to remove the plastic installation sleeve.
NOTE:
Remove suitable tools and install and hand tighten remaining bolts.

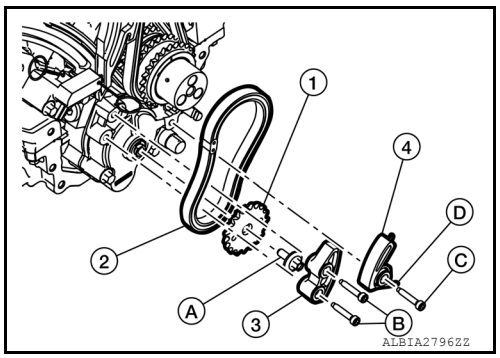
10. Tighten the rear seal carrier bolts in the sequence shown.

Bolts : 23 N·m (2.3 kg-m, 17 ft-lb)



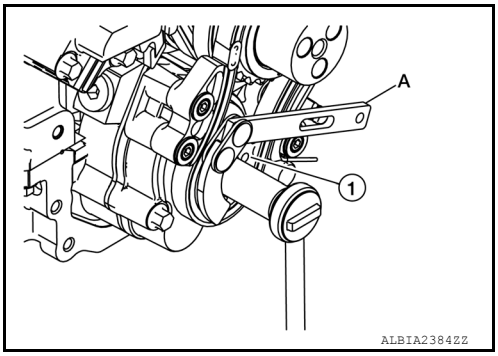
11. Install the oil pump sprocket (1) and finger-tighten bolt (A). Install the oil pump drive chain (2) on the oil pump sprocket and crankshaft sprocket (oil /fuel pump).
12. Install the oil pump tensioner guide (3) and tighten the bolts (B).
13. Install the oil pump tensioner and oil pump slack guide (4) and tighten bolt (C).
14. Install the leg (D) of the tensioner spring in the slot in the arm.
NOTE:
Verify that the oil pump chain runs across the slack guide and tension guide. Check for excessive slack in the oil pump chain.

Bolts (B/C) : 7.4 N·m (0.75, 65)



15. Tighten the bolt for the oil pump sprocket (1) while holding the sprocket with a suitable tool (A).

Bolt : 23 N·m (2.3 kg-m, 17 ft-lb)



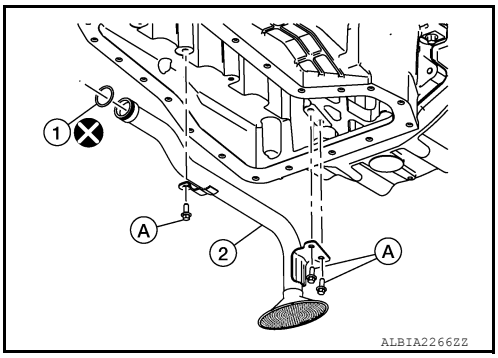
16. Installation of the remaining components is in the reverse order of removal.
    - Run engine and check for leaks.

Disassembly and Assembly

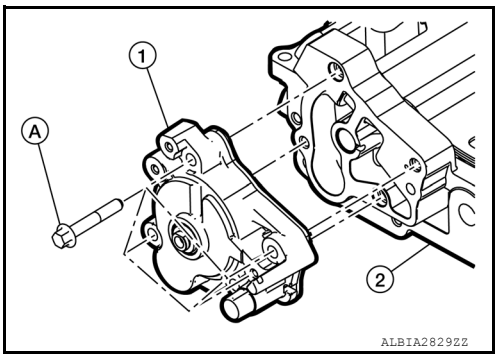
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DISASSEMBLY

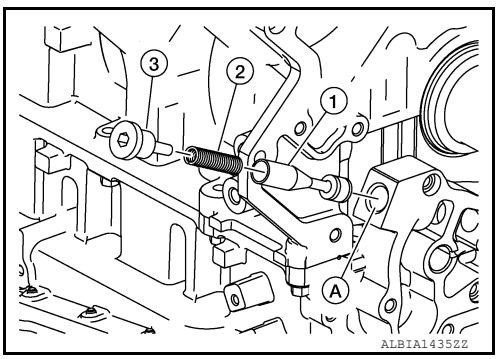
1. Remove the windage tray. Refer to EM-310, "Exploded View".
2. Remove the bolts (A) from the oil pump suction tube (2) and remove the tube.
   CAUTION:
   Do not reuse the O-ring (1).



3. Remove the bolts (A) and remove the lubricating oil pump (1) from the block stiffening plate (2).

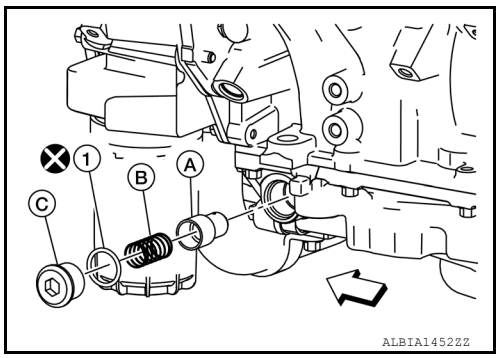


4. Remove the threaded plug (3) from the plunger bore (A).
5. Remove the oil pressure regulator spring (2) and the oil pressure regulator (1).



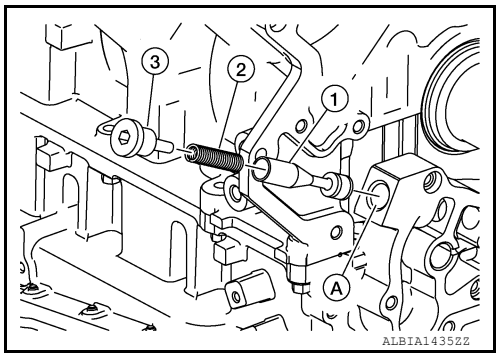
6. Remove the threaded plug (C) and remove the oil check valve spring (B) and oil check valve (A) from the block stiffening plate.
CAUTION:
Do not reuse the O-ring (1).

⇦ : Front



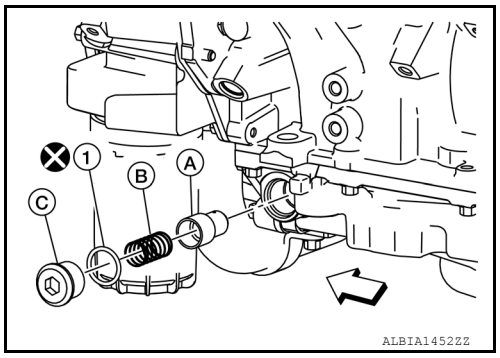
ASSEMBLY

1. Install the oil pressure regulator spring (2) and oil pressure regulator (1).
2. Install the threaded plug (3) into the plunger bore (A).



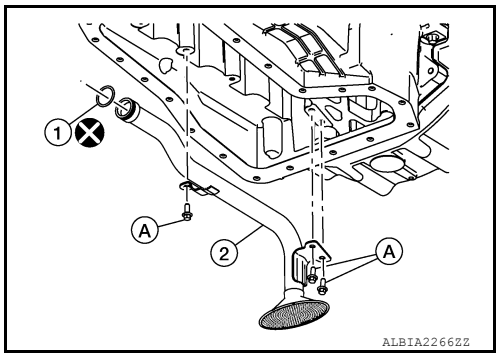
3. Install the oil check valve spring (B) and oil check valve (A) into the block stiffening plate and install the threaded plug (C).
CAUTION:
Do not reuse the O-ring (1).

⇦ : Front



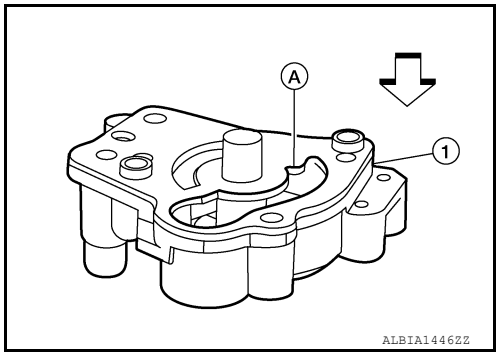
4. Install the oil pump suction tube (2) into the block stiffening plate and tighten bolts (A).
CAUTION:
Do not reuse O-ring (1).

Bolts (A) : 7.4 N·m (0.75 kg-m, 65 in-lb)

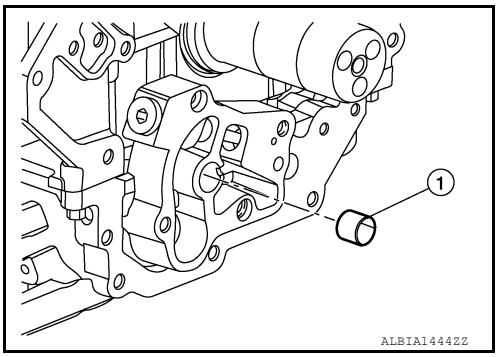


5. Fill the oil pump (1) with clean engine oil through opening (A). Use recommended engine oil or equivalent. Refer to MA-62, "Cummins 5.0L Engine : Fluids and Lubricants".
CAUTION:
Failure to fill the pump with oil during installation can result in a slow prime at initial engine start-up, resulting in severe engine damage.

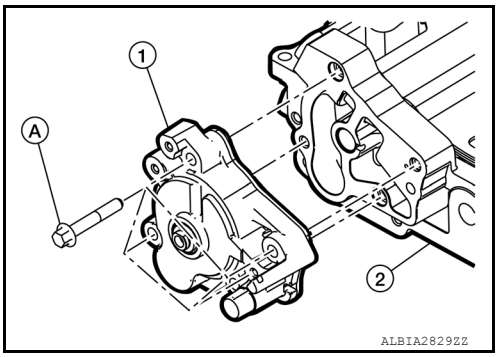
⇦ : Front



6. Make sure the oil pump bushing (1) is installed in the block stiffening plate before installing oil pump.

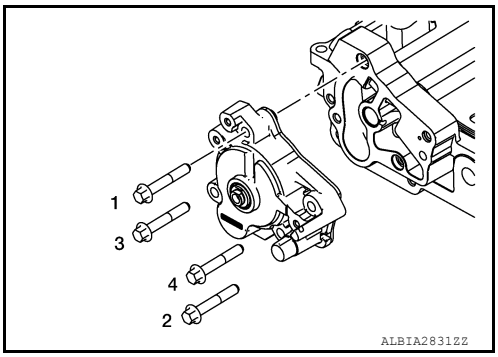


7. Install the oil pump (1) onto the block stiffening plate (2) and hand tighten the bolts (A).
NOTE:
Turn the pump to check for proper rotation using a suitable tool.



8. Tighten the oil pump bolts to specification in the sequence shown.

Oil pump bolts : 20 N·m (2.0 kg-m, 15 ft-lb)

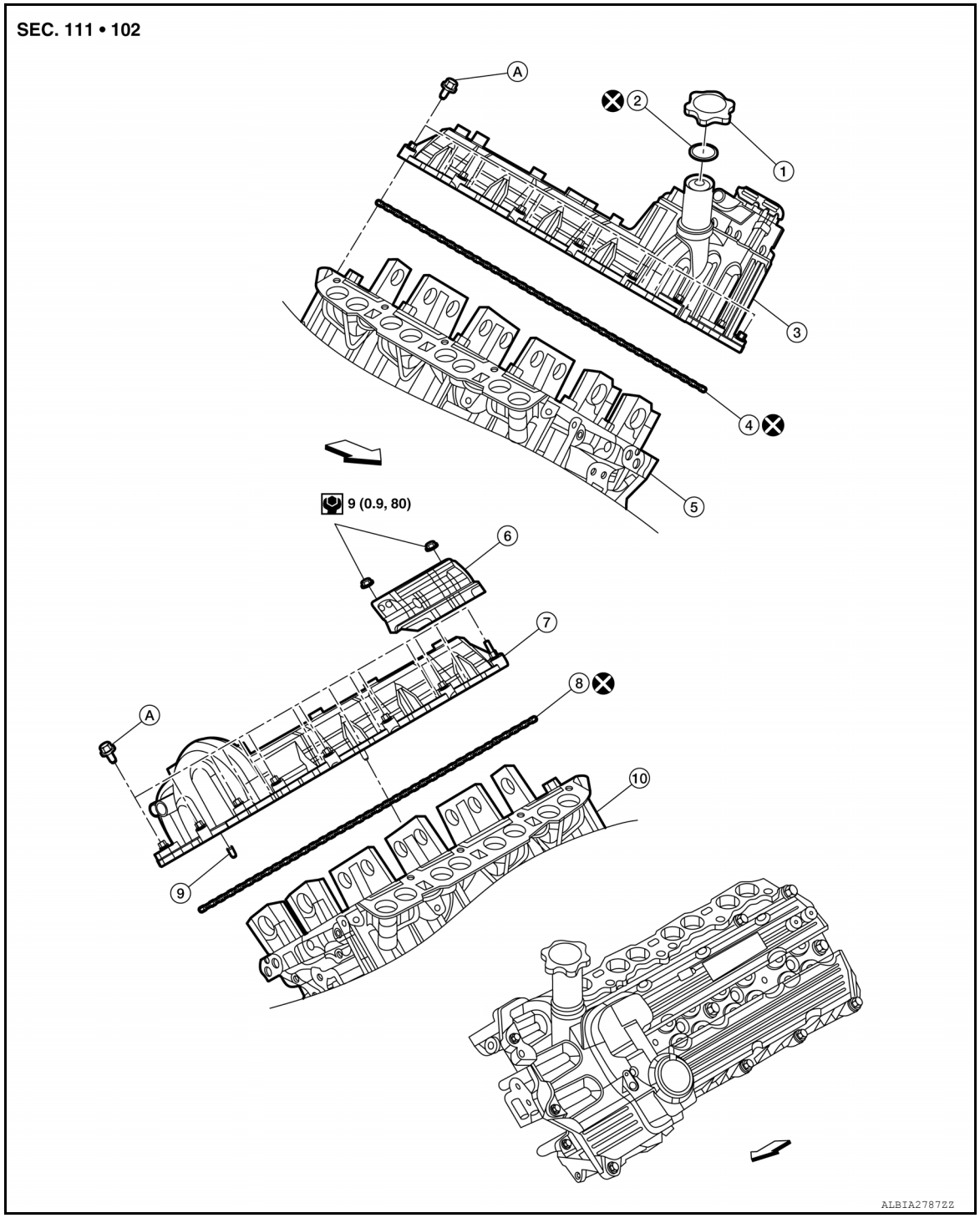


9. Align the windage tray in the stiffening plate and install bolts. Refer to EM-310, "Exploded View".

ROCKER COVER

Exploded View

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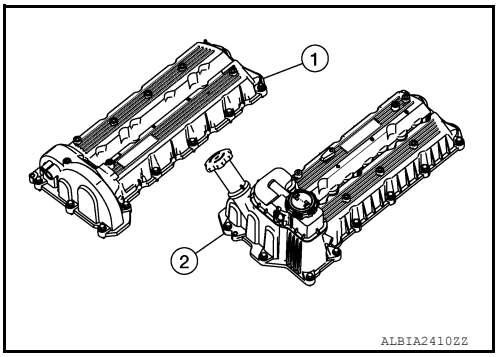
1. Oil filler cap
2. O-ring
3. Rocker cover (bank 2)
4. Rocker cover gasket (bank 2)
5. Cylinder head (bank 2)
6. Rocker cover heat shield
7. Rocker cover (bank 1)
8. Rocker cover gasket (bank 1)
9. Dowel pin
10. Cylinder head (bank 1)
A. Refer to INSTALLATION
⇦ Front

Removal and Installation

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GENERAL INFORMATION

- The rocker cover [bank 1(1)] and rocker cover [bank 2(2)] are **not** interchangeable.
- The rocker covers have captured bolts that are **not** removable from the rocker cover. If a bolt is damaged, the entire rocker cover **must** be replaced.
- The crankcase ventilation valve is integral to the rocker cover (bank 2) and is **not** serviceable. If the crankcase ventilation valve is damaged or malfunctioning, the entire rocker cover **must** be replaced.



ROCKER COVER (BANK 2)

Removal

WARNING:

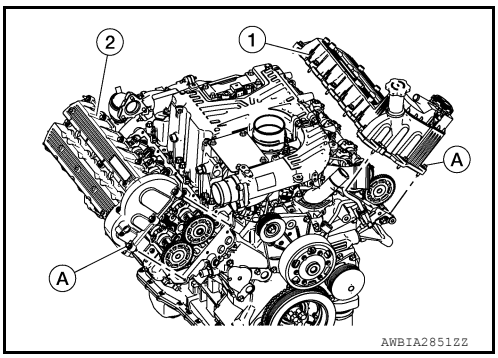
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**

- Do not loosen any fittings while the engine is running.
- Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.
- Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.
- Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.

CAUTION:

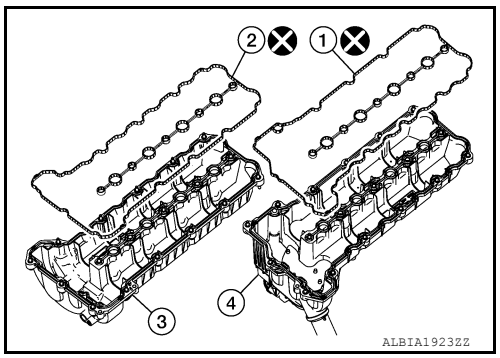
Use appropriate clean care kit caps to protect the engine from contaminants.

1. Remove the intake manifold. Refer to EM-239, "Removal and Installation".
2. Remove the rail to rail high pressure fuel lines. Refer to EM-472, "Removal and Installation".
3. Remove the fuel injectors. Refer to EM-436, "Removal and Installation (CYLINDER 1 and CYLINDER 3)", EM-439, "Removal and Installation (CYLINDER 2 and CYLINDER 4)", EM-442, "Removal and Installation (CYLINDER 5 and CYLINDER 7)" and EM-446, "Removal and Installation (CYLINDER 6 and CYLINDER 8)".
4. Remove the fuel rail. Refer to EM-451, "Removal and Installation".
5. Disconnect the harness connector from the crankcase pressure sensor (bank 2).
6. Loosen the rocker cover bolts (A) and remove the rocker cover [bank 2 (1)].
   NOTE:
   - Place the rocker cover on a clean surface to reduce the possibility of contaminating the gasket groove with debris or oil.
   - Rocker cover bolts are captured bolts and should not be removed.



(2) : Rocker cover (bank 1)

7. Remove and discard the rocker cover gasket (1) from the rocker cover [bank 2 (4)].
CAUTION:
Do not reuse rocker cover gaskets.



(2) : Rocker cover gasket (bank 1)
(3) : Rocker cover (bank 1)

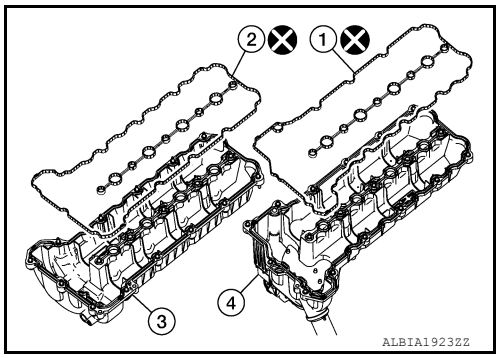
Inspection After Removal

WARNING:
- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturers recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- **Some solvents are flammable and toxic. Read and follow the manufacturer's instructions before using.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- Clean the rocker cover with solvent. Dry with compressed air.
- Remove any gasket residue from the rocker cover.
- Inspect the rocker cover for cracks or other damage. Replace the rocker cover if any damage is found.
- Use a suitable tool to remove any gasket residue from the sealing surfaces on the cylinder heads and front cover. Use care to **not** scratch the sealing surfaces of the cylinder heads or front cover.
- Inspect the following for damage:
- Cylinder head (bank 2)
- Front cover
- Crankcase breather tube (bank 2).
- Crankcase pressure sensor in (bank 2) rocker cover.
- Inspect the bank 2 oil fill neck and oil fill cap.
- If the oil fill cap is damaged, replace the cap. If the oil fill neck is damaged, replace the rocker cover (bank 2).

NOTE:
The bank 2 oil fill cap O-ring has a pink coating that can leave marks around the edge of the oil fill neck.

Installation

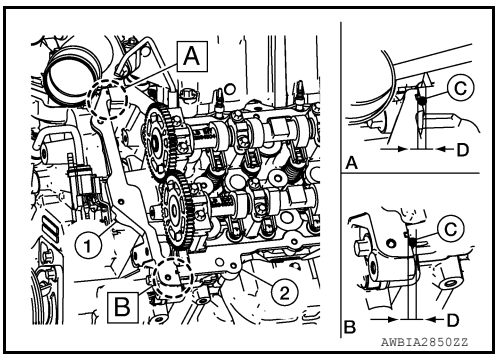
1. Install a new rocker cover gasket (2) into the rocker cover (3) grooves.
CAUTION:
- **Do note reuse rocker cover gasket.**
- **Do not lubricate the gasket.**



(1) : Rocker cover gasket (bank 2)
(4) : Rocker cover (bank 2)

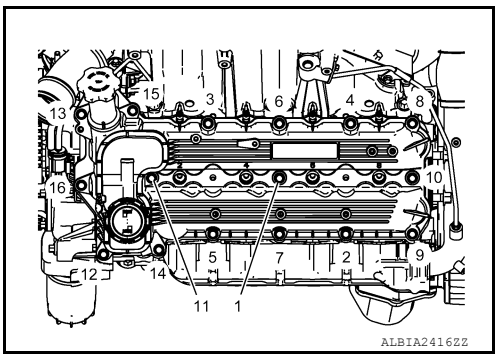
2. Clean the joint sealing surfaces with isopropyl alcohol and a lint-free towel. After surface is clean, prepare it with Bonderite M-NT 5700 or equivalent wipe. Allow surface to dry before applying sealant.

3. Apply a 9 mm (0.35 in) diameter (D) drop of Loctite 5900 RTV or equivalent sealant (C) to the joints (A) and (B) at the cylinder head (2) and front cover (1).
NOTE:
- Bank 2 shown, bank 1 similar.
- The rocker cover **must** be installed within 5 minutes of applying sealant. Final torque **must** be completed within 30 minutes of sealant application.
- The mating surface for the rocker cover **must** be clean and free of oil and debris.



4. Install the rocker cover (bank 2) and hand-tighten the bolts and then tighten the bolts in the sequence shown.
NOTE:
Bank 2 shown, Bank 1 similar.

Step 1 : 9 N·m (0.9 kg-m, 80 in-lb)
Step 2 : 9 N·m (0.9 kg-m, 80 in-lb)



5. Installation of the remaining components is in the reverse order of removal.
NOTE:
- Perform CONSULT High-Pressure Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
- Operate the engine and check for leaks.

ROCKER COVER (BANK 1)

Removal

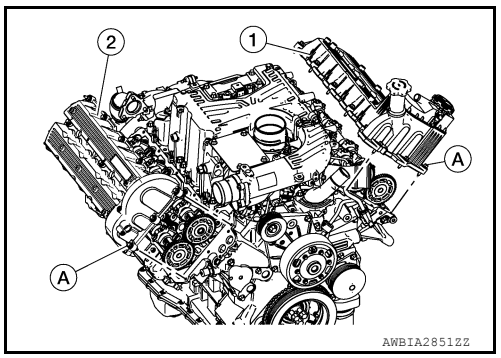
WARNING:
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

CAUTION:
Use appropriate clean care kit caps to protect the engine from contaminants.

1. Remove the intake manifold. Refer to EM-239, "Removal and Installation".
2. Remove the rail to rail and pump to rail high pressure fuel lines. Refer to EM-472, "Removal and Installation" and EM-468, "Removal and Installation".
3. Remove the fuel injectors. Refer to EM-436, "Removal and Installation (CYLINDER 1 and CYLINDER 3)", EM-439, "Removal and Installation (CYLINDER 2 and CYLINDER 4)", EM-442, "Removal and Installation (CYLINDER 5 and CYLINDER 7)" and EM-446, "Removal and Installation (CYLINDER 6 and CYLINDER 8)".
4. Remove the fuel rail. Refer to EM-451, "Removal and Installation".
5. Disconnect the harness connector from the camshaft position sensor (bank 1). Refer to EM-323, "Exploded View".

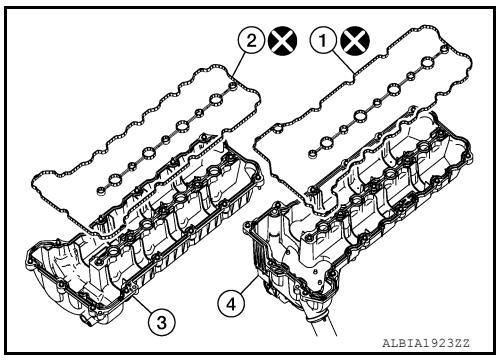
6. Loosen the rocker cover bolts (A) and remove the rocker cover [bank 1 (2)].
NOTE:
- Rocker cover bolts are captured bolts and should not be removed.
- Place the rocker cover on a clean surface to reduce the possibility of contaminating the gasket groove with debris or oil.

(1) : Rocker cover (bank 2)



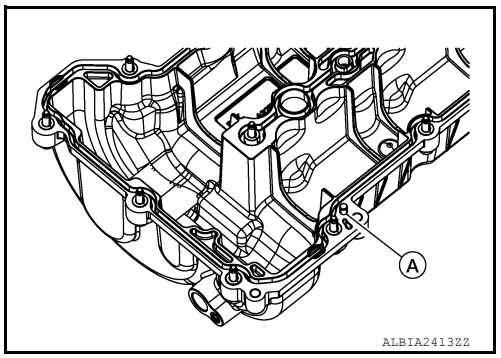
7. Remove and discard the rocker cover gasket (2) from the rocker cover [bank 1 (3)].
CAUTION:
Do not reuse rocker cover gaskets.

(1) : Rocker cover gasket (bank 2)
(4) : Rocker cover (bank 2)



Inspection After Removal

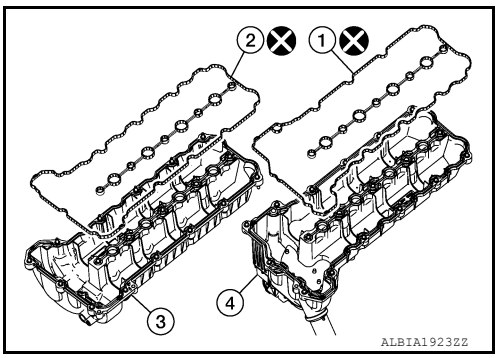
WARNING:
- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturers recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- **Some solvents are flammable and toxic. Read and follow the manufacturer's instructions before using.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- Clean the rocker cover with solvent. Dry with compressed air.
- Remove any gasket residue from the rocker cover.
- Inspect the rocker cover for cracks or other damage. Replace the rocker cover if any damage is found.
- Inspect the heat shield on the rocker cover (bank 1). Replace the heat shield if damage is found.
- Use a suitable tool to remove any gasket residue from the sealing surfaces on the cylinder heads and front cover. Use care to **not** scratch the sealing surfaces of the cylinder heads or front cover.
- Inspect the following for damage:
- Cylinder heads (bank 1)
- Front cover
- Camshaft position sensor in (bank 1) rocker cover.
- Check that the dowel (A) in the rocker cover (bank 1) is installed in the cover and has **not** stuck in the cylinder head (bank 1).



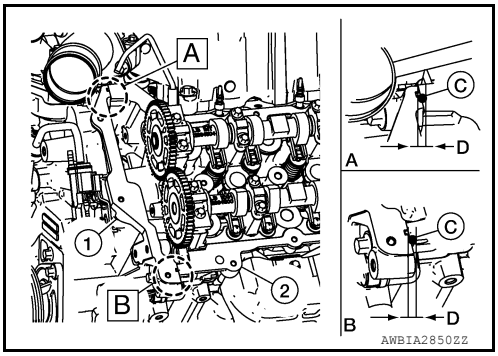
Installation

1. Install a new rocker cover gasket (2) or into the rocker cover (3) grooves.
   CAUTION:
   - **Do note reuse rocker cover gasket.**
   - **Do not lubricate the gasket.**

   (1) : Rocker cover gasket (bank 2)
   (4) : Rocker cover (bank 2)

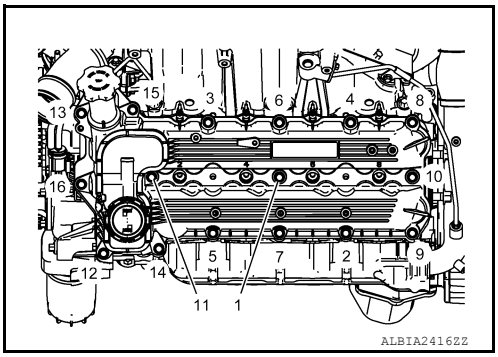


2. Clean the joint sealing surfaces with isopropyl alcohol and a lint-free towel. After surface is clean, prepare it with Bonderite M-NT 5700 or equivalent wipe. Allow surface to dry before applying sealant.
3. Apply a 9 mm (0.35 in) diameter (D) drop of Loctite 5900 RTV or equivalent sealant (C) to the joints (A) and (B) at the cylinder head (2) and front cover (1).
   NOTE:
   - The rocker cover **must** be installed within 5 minutes of applying sealant. Final torque **must** be completed within 30 minutes of sealant application.
   - The mating surface for the rocker cover **must** be clean and free of oil and debris.



4. Install the rocker cover (bank 1) and hand-tighten the bolts and then tighten the bolts in the sequence shown.

   Step 1 : 9 N·m (0.9 kg-m, 80 in-lb)
   Step 2 : 9 N·m (0.9 kg-m, 80 in-lb)

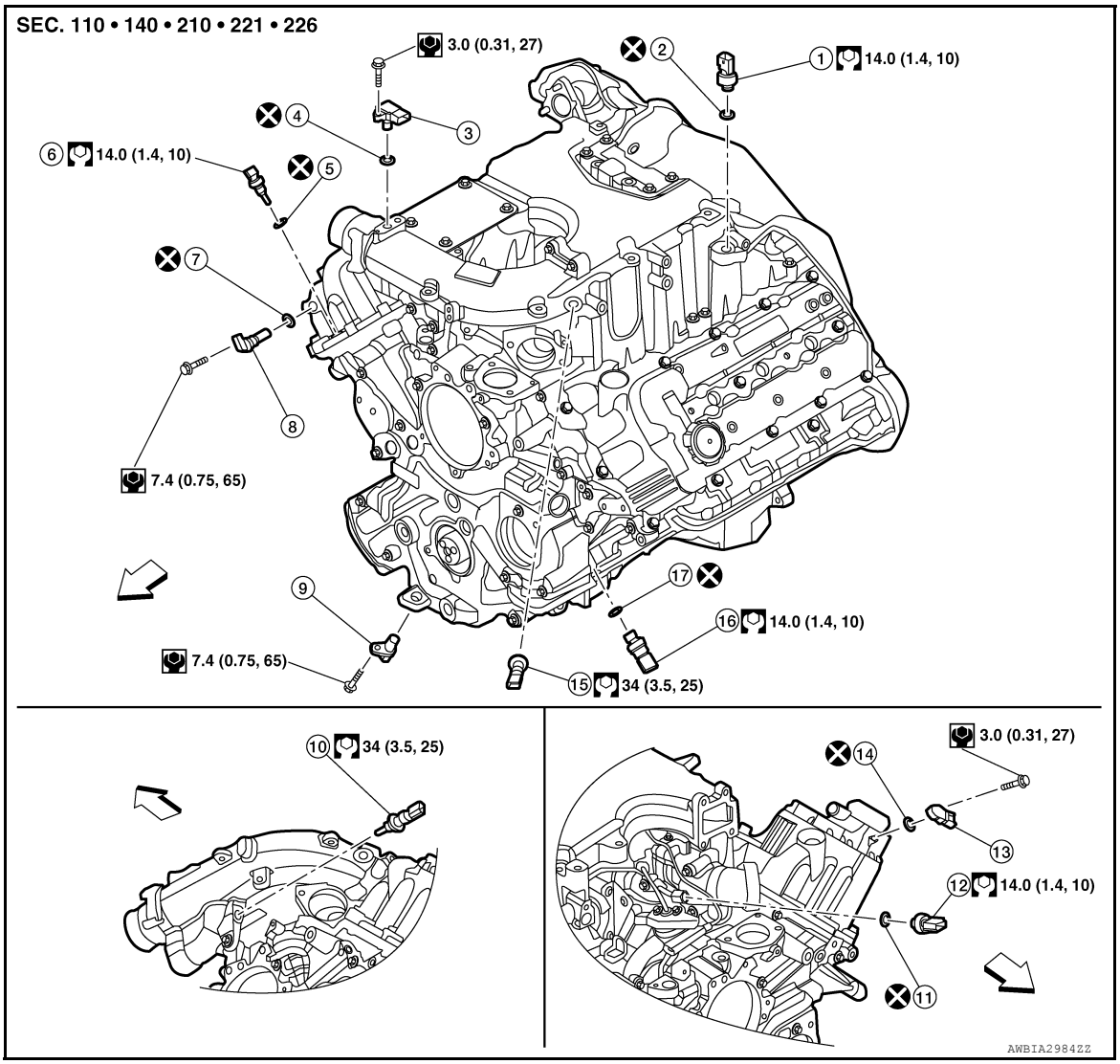


5. Installation of the remaining components is in the reverse order of removal.
   NOTE:
   - Perform CONSULT High-Pressure Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
   - Operate the engine and check for leaks.

CAMSHAFT POSITION SENSOR

Exploded View

INFOID:0000000014418652



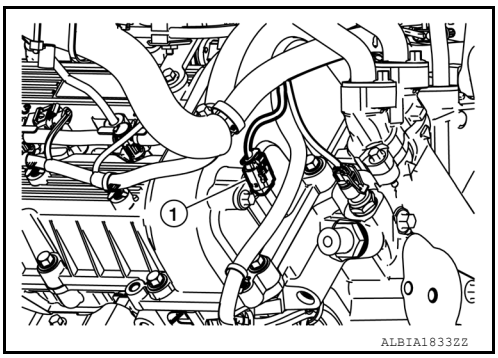
1. Exhaust gas pressure sensor
2. O-ring
3. Engine charge-air cooler outlet pressure/temperature sensor
4. O-ring
5. O-ring
6. Engine coolant temperature sensor
7. O-ring
8. Camshaft position sensor
9. Crankshaft position sensor
10. EGR temperature sensor
11. O-ring
12. Low pressure turbocharger boost pressure sensor
13. Crankcase pressure sensor
14. O-ring
15. Intake manifold air temperature sensor
16. Engine oil pressure switch
17. O-ring
⇦ Front

Removal and Installation

INFOID:0000000014418653

GENERAL INFORMATION

- The camshaft position sensor is a Hall effect sensor (1) that reports the speed and position of the engine by axially detecting the camshaft gear metal webbings. The camshaft position sensor signal outputs a Pulse Width Modulated signal which changes in frequency with engine speed. The signal is then sent to the engine control module (ECM) via the engine harness. The camshaft position sensor is used for synchronization between the camshaft and the crankshaft and is also a backup sensor in the case of a crankshaft sensor failure. The camshaft position sensor is mounted on the right bank valve cover and can be seen from the front of the engine.



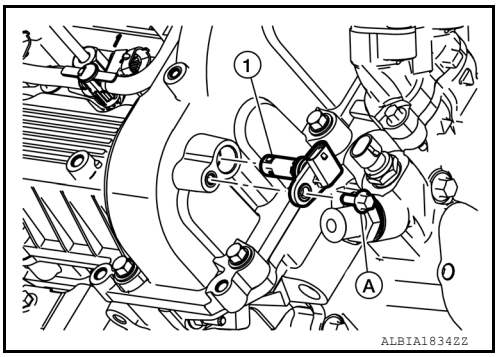
REMOVAL

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".

   WARNING:
   Battery acid and battery acid fumes are extremely dangerous and can cause severe burns and explosion. To help reduce the risk of personal injury;
   - **Wear appropriate goggles and protective clothing.**
   - **Always properly ventilate the area where the service is being performed.**
   - **Never allow battery fluid to come in contact with skin, eyes, fabrics or painted surfaces.**
   - **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
   - **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**

2. Disconnect the harness connector from the camshaft position sensor (1).
3. Remove the bolt (A).
4. Remove the camshaft position sensor (1).

   CAUTION:
   Do not reuse the O-ring.

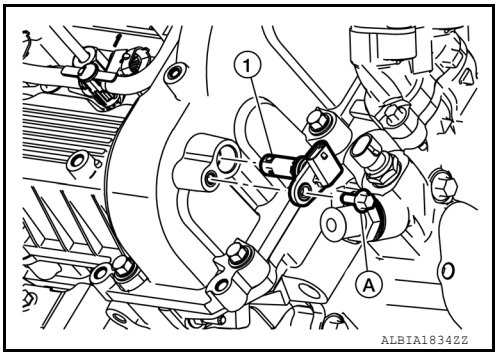


INSPECTION AFTER REMOVAL

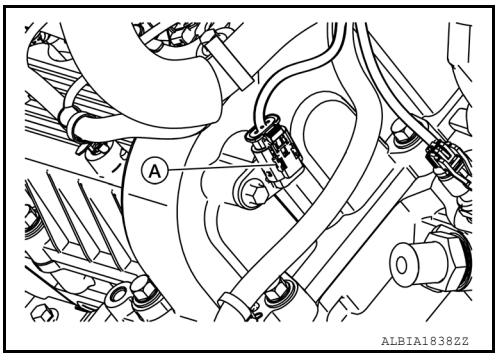
- Inspect the camshaft position sensor for debris, cracks, or damage from contact with the tone wheel.
- If there is debris on the camshaft position sensor, clean the sensor.
- Inspect the engine harness connector and sensor for the following:
- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor.
- Repair or replace parts as necessary.

INSTALLATION

1. Install the camshaft position sensor (1) by pressing firmly on the top of the sensor until the o-ring is fully seated.
2. Install and tighten the bolt (A).



3. Connect the harness connector to the camshaft position sensor.
4. Push the connectors together until they lock.
5. Slide the locking tab to the lock position (A).



6. Connect the battery or batteries. Refer to PG-185, "Battery Disconnect".

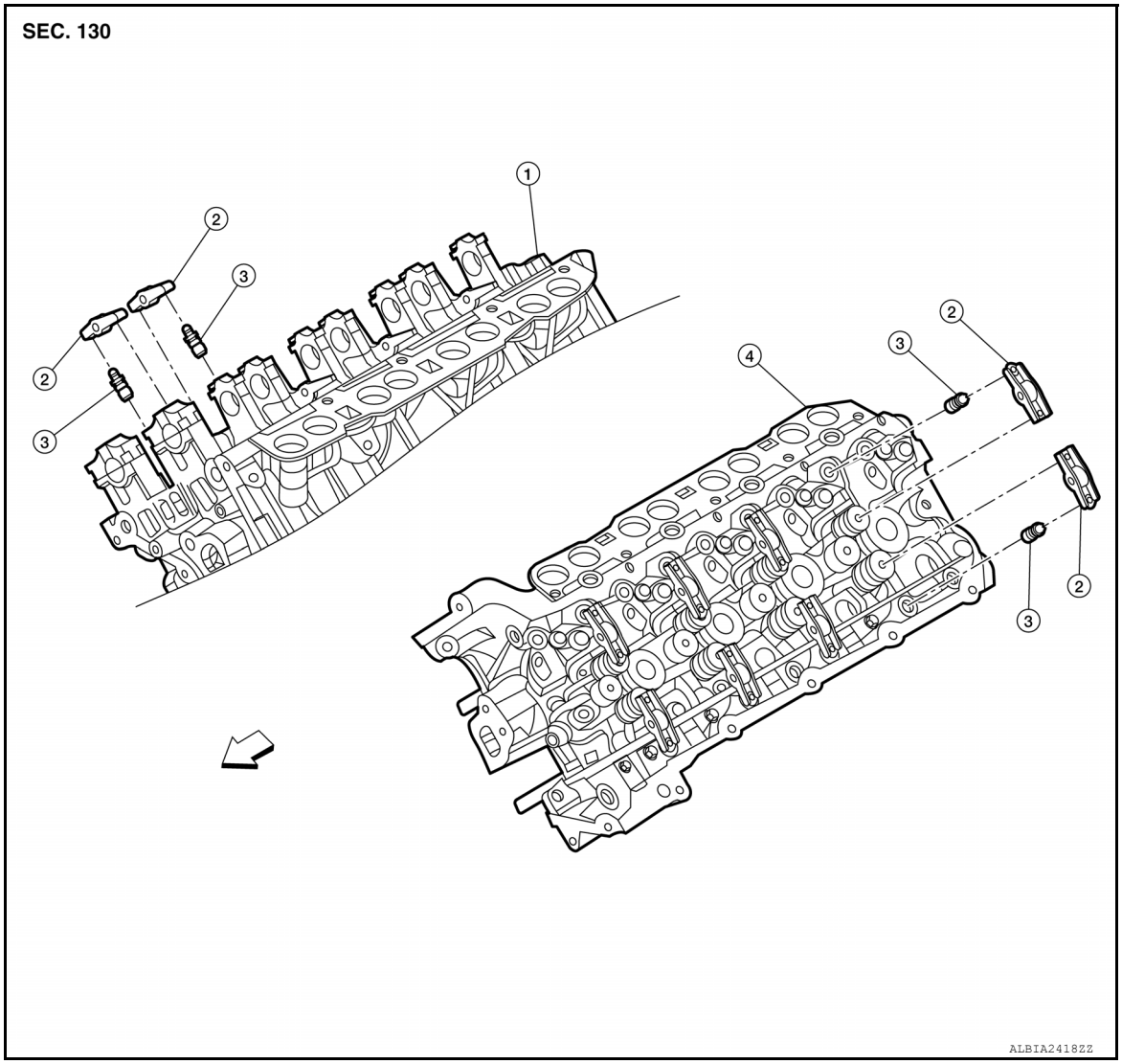
WARNING:
Battery acid and battery acid fumes are extremely dangerous and can cause severe burns and explosion. To help reduce the risk of personal injury;
- **Wear appropriate goggles and protective clothing.**
- **Always properly ventilate the area where the service is being performed.**
- **Never allow battery fluid to come in contact with skin, eyes, fabrics or painted surfaces.**
- **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
- **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**

7. If the camshaft position sensor was replaced, in CONSULT click the Timing button on the Fuel or Timing System Table Reset screen in Work Support. Refer to EC-806, "CONSULT Function".
8. Operate the engine and check for leaks.

ROCKER ARM

Exploded View

INFOID:0000000014418654



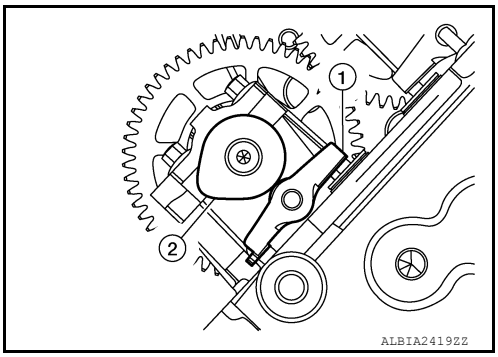
1. Cylinder head (bank 1)
2. Rocker arm
3. Hydraulic lash adjuster
4. Cylinder head (bank 2)
⇦ Front

Removal and Installation

INFOID:0000000014418655

GENERAL INFORMATION

- The rocker arms (1) are located under the camshafts (2) and are directly responsible for transferring the camshaft lobe position to the valves. The rocker arm lash is not adjustable and is controlled by oil pressure.
- This procedure is written to remove, inspect, and install the rocker arms one cylinder at a time. The procedure is then repeated for other cylinders.
- If all rocker arms must be removed for inspection, remove the camshafts first. Refer to EM-350, "Removal and Installation".



REMOVAL

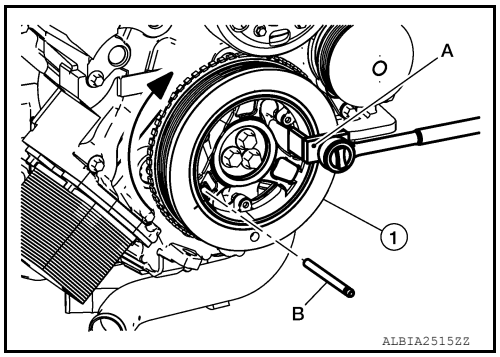
WARNING:

The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:

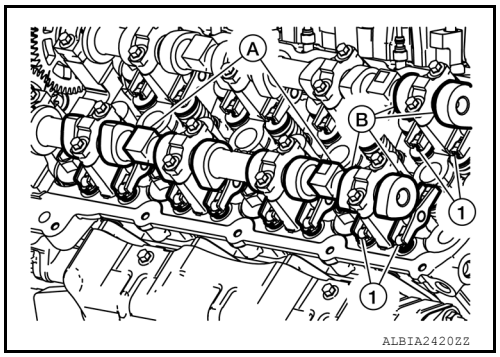
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

1. Remove the rocker covers. Refer to EM-318, "Removal and Installation".
2. Use Tool (A) on the vibration damper (1), rotate the engine clockwise until cylinder number 1 top dead center (TDC) has been located.
   - Locate cylinder number 1 TDC by rotating the engine clockwise until the timing mark on the vibration damper and front cover are aligned. After TDC is located, insert Tool (B).

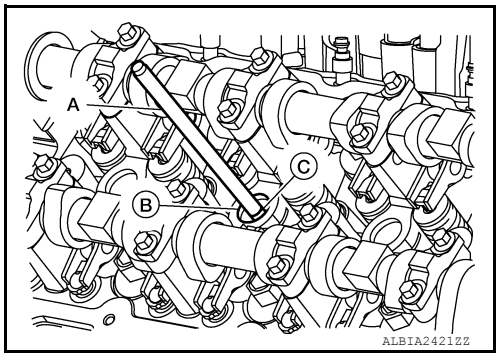
   Tool (A) : — (J-54424)
   Tool (B) : — (J-54404)



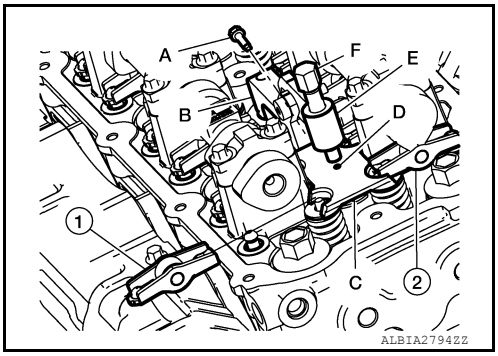
3. Verify that the flats (A) on the camshaft are facing upward. If they are not, rotate the crankshaft clockwise 360 degrees until the flats are facing upward.
   NOTE:
   - The low portion of the camshaft lobes (B) are located over all four of the rocker arms (1) for cylinder number 1 (intake and exhaust valves).
   - Mark the location of all the rocker arms. It is important for the rocker arms to be installed in their original locations.



4. Obtain a 6.4 mm (0.25 in) wooden or plastic dowel rod (A) that is, at least, 305 mm (12 in) long.
5. Insert the rod into the injector bore (B) of cylinder number 1 until the dowel rod contacts the piston. With a permanent marker, place a mark (C) on the dowel rod that is level with the top of the cylinder head injector bore. This will help identify TDC for all the other cylinders.
6. Remove the rod and place a second mark 13 mm (0.5 in) above the TDC mark.
7. Rotate the crankshaft clockwise until the second mark aligns with the top of the cylinder head injector bore.
   NOTE:
   Rotating the crankshaft clockwise past TDC gives the valves clearance with the piston when the valve springs are being compressed to remove the rocker arms. This reduces the possibility of disengaging the valve retainers.



8. Use the following steps for compressing the valve springs:



a. Install the compression plate (C) of the suitable tool with the proper orientation for the intake and exhaust valves (etched on the suitable tool).

b. There is a provision on the suitable tool which uses the adjacent injector for support and location. Slide the compression arm (E) of the suitable all the way forward to allow access to the bolt (A). Tighten the bolt.

Bolt (A) : 24 N·m (2.4 kg-m, 18 ft-lb)

c. Slide the compression arm (E) of the suitable tool backward until the marks align. Turn the forcing screw (F) of the suitable tool until it makes contact with the compression plate. Be sure the tip of the threaded bar engages the hole (D) in the compression plate.

d. Slowly turn the forcing screw until the bottom face of the hex head meets the compression arm.
NOTE:
Bank 1 shown, Bank 2 similar.

9. Remove the rocker arms (1) and (2) for both intake valves and exhaust valves on cylinder number 1.
NOTE:
Remember to label the location of the rocker arms during removal.

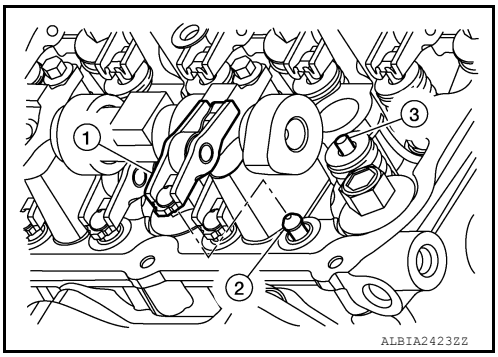
INSPECTION AFTER REMOVAL

- **WARNING:**
  - **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
  - **Do not exceed 30 psi (207 kPa).**
  - **Wear appropriate eye protection and protective clothing including gloves.**
  - **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturers recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- Clean the rocker arms with solvent.
  CAUTION:
  Do not submerge the rocker arms in water or solvent.
- Dry with compressed air.
- Inspect the rocker arms for cracks and excessive wear on contact points, such as the hydraulic lash adjuster cup, roller, and valve stem contact area.
- Check that the roller spins freely and does not bind.
- If the roller does not spin freely or there is damage or excessive wear to the rocker arm, the rocker arm must be replaced.
- Lubricate the rocker arm contact points and roller with clean engine oil.

INSTALLATION

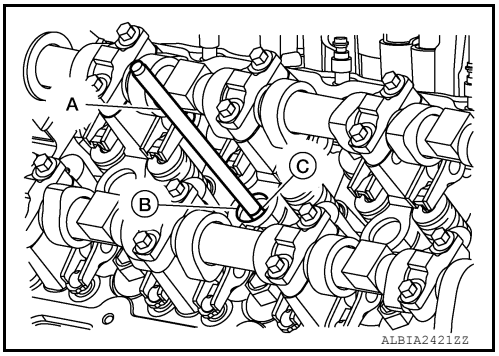
1. Install the intake and exhaust rocker arms on cylinder number 1.
NOTE:
Be sure the rocker arm is installed on the original location.

2. Verify the proper orientating of the rocker arm (1). The spherical cup end of the rocker arm mates with the hydraulic lash adjuster (2). The flat end installs over the valve stem (3).



3. Remove the valve spring compressor service tool.

4. If other rocker arms **must** be removed for inspection or replacement, insert the marked dowel rod (A) in the injector hole (B) for the next cylinder in the firing order.
5. Rotate the crankshaft clockwise until the dowel rod mark (C) indicates that cylinder is at TDC. Then rotate the crankshaft clockwise again slightly until the second mark on the dowel rod is aligned with the injector bore surface on the top of the cylinder head surface.
6. Repeat these steps to remove rocker arms for all subsequent cylinders.

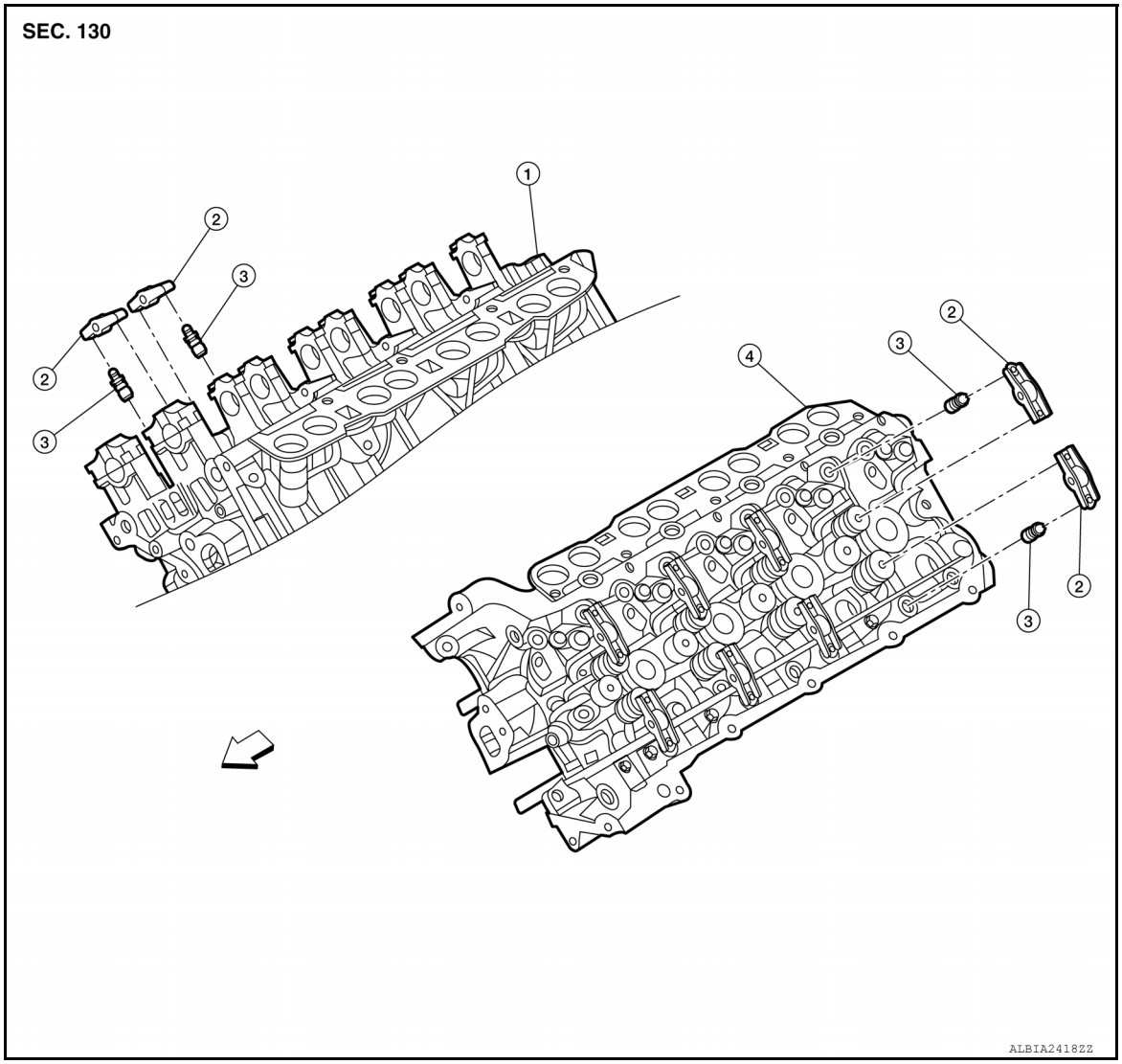


7. Installation of the remaining components is in the reverse order of removal.
   - Run CONSULT High-Pressure Fuel Sysyem Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
   - Operate the engine and check for leaks.

HYDRAULIC LASH ADJUSTER

Exploded View

INFOID:0000000014418656



1. Cylinder head (bank 1)
2. Rocker arm
3. Hydraulic lash adjuster
4. Cylinder head (bank 2)
⇦ Front

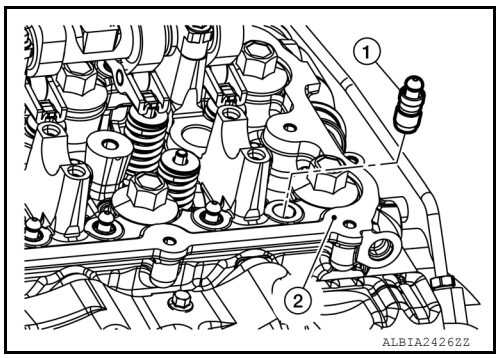
Removal and Installation

INFOID:0000000014418657

REMOVAL

1. Remove the rocker arm. Refer to EM-326, "Removal and Installation".

2. Remove the hydraulic lash adjusters (1) from the cylinder head (2).
NOTE:
Label the hydraulic lash adjusters with their location in the cylinder head.

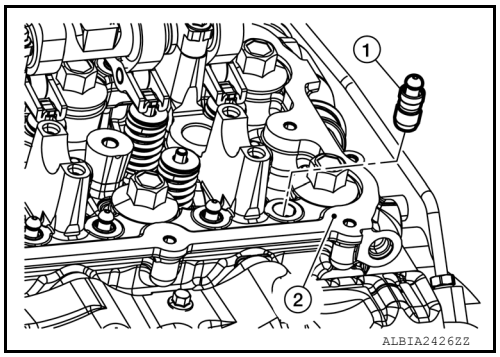


INSPECTION AFTER REMOVAL

- Inspect the hydraulic lash adjuster body for signs of wear, cracking, and other damage.
- Replace the hydraulic lash adjuster if it is damaged.
- Check the hydraulic lash adjuster bores for debris. Remove any debris, if found.
NOTE:
Replace all of the hydraulic lash adjusters if debris is found in the lubricating oil system.

INSTALLATION

1. Apply a coat of clean engine oil to the hydraulic lash adjuster (1).
2. Install the hydraulic lash adjuster into the original locations in the cylinder head (2).
NOTE:
- The hydraulic lash adjuster **must** be installed with the round end facing upward.
- Be sure the hydraulic lash adjuster is fully inserted into the bores.

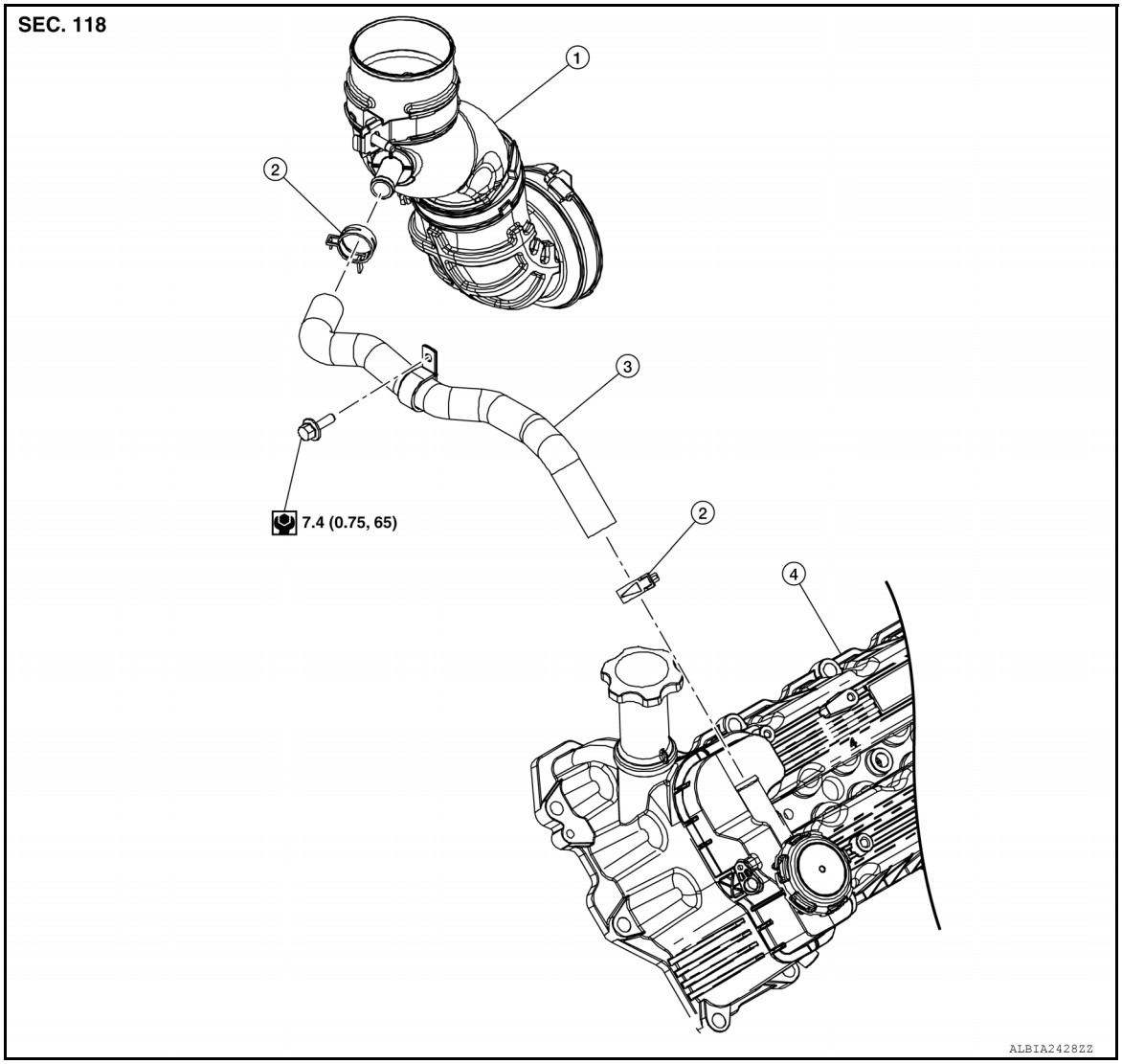


3. Installation of the remaining components is in the reverse order of removal.
NOTE:
- Perform CONSULT High-Pressure Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
- Operate the engine and check for leaks.

CRANKCASE BREATHER TUBE

Exploded View

INFOID:0000000014418658



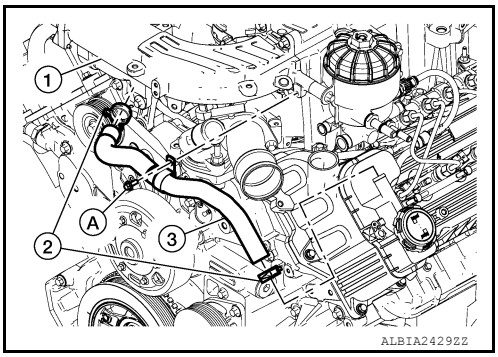
1. Air inlet connection
2. Clamp
3. Crankcase breather tube
4. Rocker cover (bank 2)

Removal and Installation

INFOID:0000000014418659

REMOVAL

1. Remove bolt (A) that secures the crankcase breather tube (3) to the air intake connection (1).
2. Release clamps (2) and disconnect the crankcase breather tube from air inlet connection assembly and rocker cover (bank 2).
3. Pull crankcase breather tube forward to remove it from underneath the intake manifold.



INSPECTION AFTER REMOVAL

- **WARNING:**
  When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:
  - **Do not exceed 30 psi (207 kPa).**
  - **Wear appropriate eye protection and protective clothing including gloves.**
- Inspect all crankcase breather tubes internally for obstructions or sludge buildup.
- If a tube is blocked, it **must** be cleaned with a strong solution of detergent or replaced to prevent excess crankcase pressure buildup.
- Dry the crankcase breather tube with compressed air.
- Check the crankcase breather tubes for cracks. Replace any damaged crankcase breather tubes.

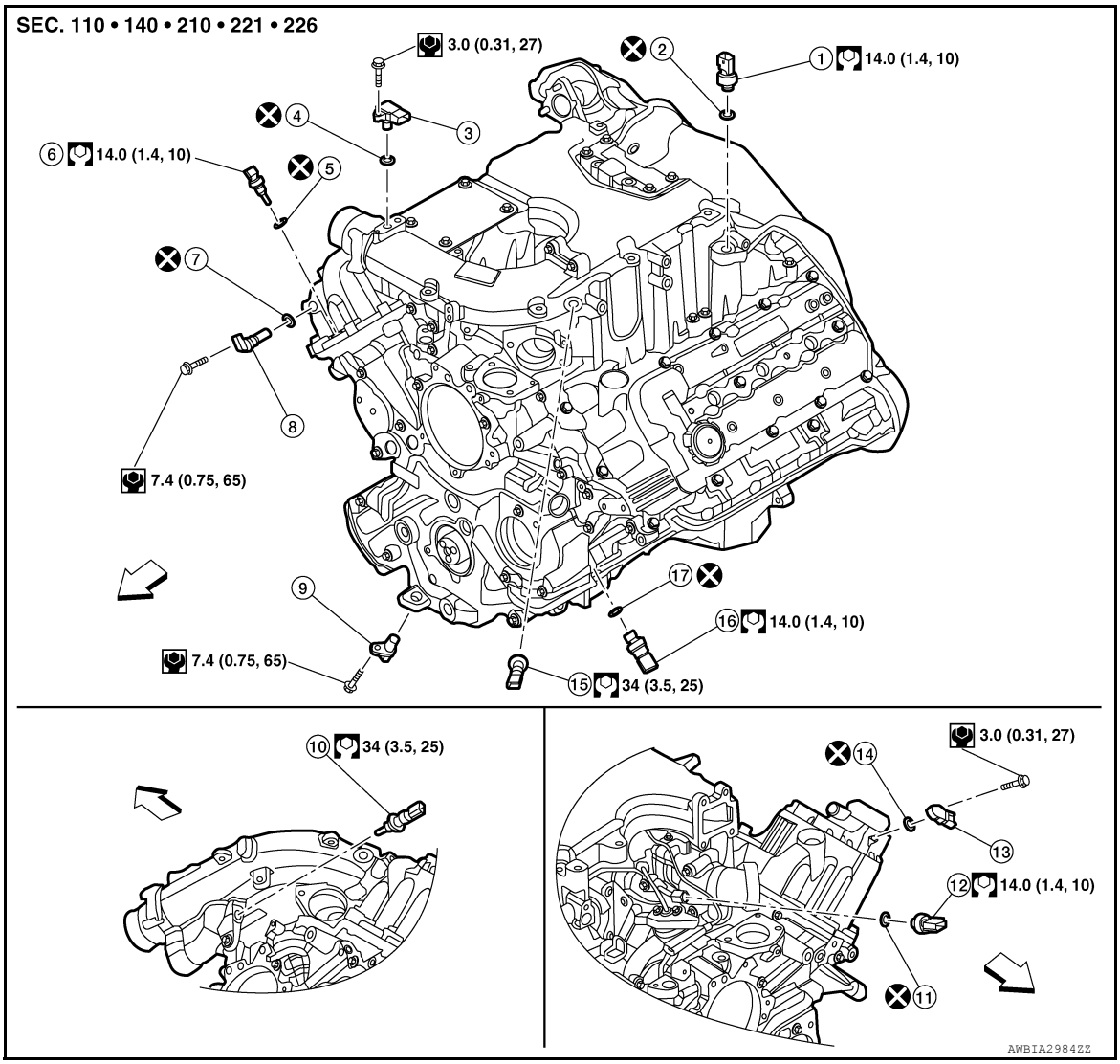
INSTALLATION

Installation is in the reverse order of removal.

CRANKCASE PRESSURE SENSOR

Exploded View

INFOID:0000000014418660



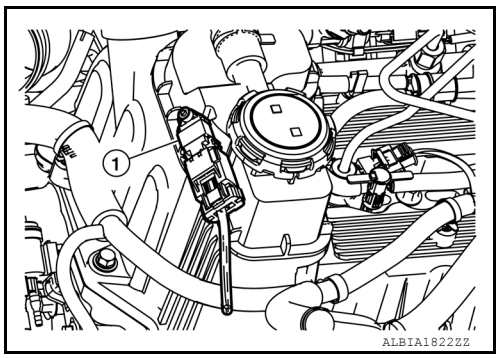
1. Exhaust gas pressure sensor
2. O-ring
3. Engine charge-air cooler outlet pressure/temperature sensor
4. O-ring
5. O-ring
6. Engine coolant temperature sensor
7. O-ring
8. Camshaft position sensor
9. Crankshaft position sensor
10. EGR temperature sensor
11. O-ring
12. Low pressure turbocharger boost pressure sensor
13. Crankcase pressure sensor
14. O-ring
15. Intake manifold air temperature sensor
16. Engine oil pressure switch
17. O-ring
⇦ Front

Removal and Installation

INFOID:0000000014418661

GENERAL INFORMATION

- The crankcase pressure sensor (1) is used to monitor the pressure in the crankcase.
- The crankcase pressure sensor is located on the rocker cover (bank 2).



INSPECTION BEFORE REMOVAL

- Use CONSULT tool to monitor the value of the crankcase pressure sensor with the key in the ON position and the engine off.
- The crankcase pressure sensor value should meet the following specification.

Crankcase Pressure (Nominal) : 0 ± 0.61 kPa (0 ± 0.0062 kg/cm^2, 0 ± 0.09 psi)

- If the crankcase pressure value is out of specification, replace the crankcase pressure sensor.

REMOVAL

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".
   WARNING:
   Battery acid and battery acid fumes are extremely dangerous and can cause severe burns and explosion. To help reduce the risk of personal injury;
   - **Wear appropriate goggles and protective clothing.**
   - **Always properly ventilate the area where the service is being performed.**
   - **Never allow battery fluid to come in contact with skin, eyes, fabrics or painted surfaces.**
   - **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
   - **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**
2. Clean the area around the crankcase pressure sensor.
3. Remove the bolt.
4. Disconnect the harness connector from the crankcase pressure sensor.
5. Remove the crankcase pressure sensor from the engine by pulling straight up on the crankcase pressure sensor.
   CAUTION:
   Do not reuse the O-ring.

INSPECTION AFTER REMOVAL

- Inspect the engine harness connector and the crankcase pressure sensor for the following:
- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor
- Connector base between the sensor body and the connector shell.
- Repair or replace parts as necessary.
- Inspect the crankcase pressure sensor for the following:

INSTALLATION

1. Lubricate the boss on the valve cover behind the breather with P80 lubricant, or equivalent, before installing the sensor.
   CAUTION:
   Failing to add P80 lubricant, or equivalent, could result in o-ring damage and a crankcase ventilation leak.
2. Install the crankcase pressure sensor by pressing firmly on the top of the sensor until the o-ring is fully seated.

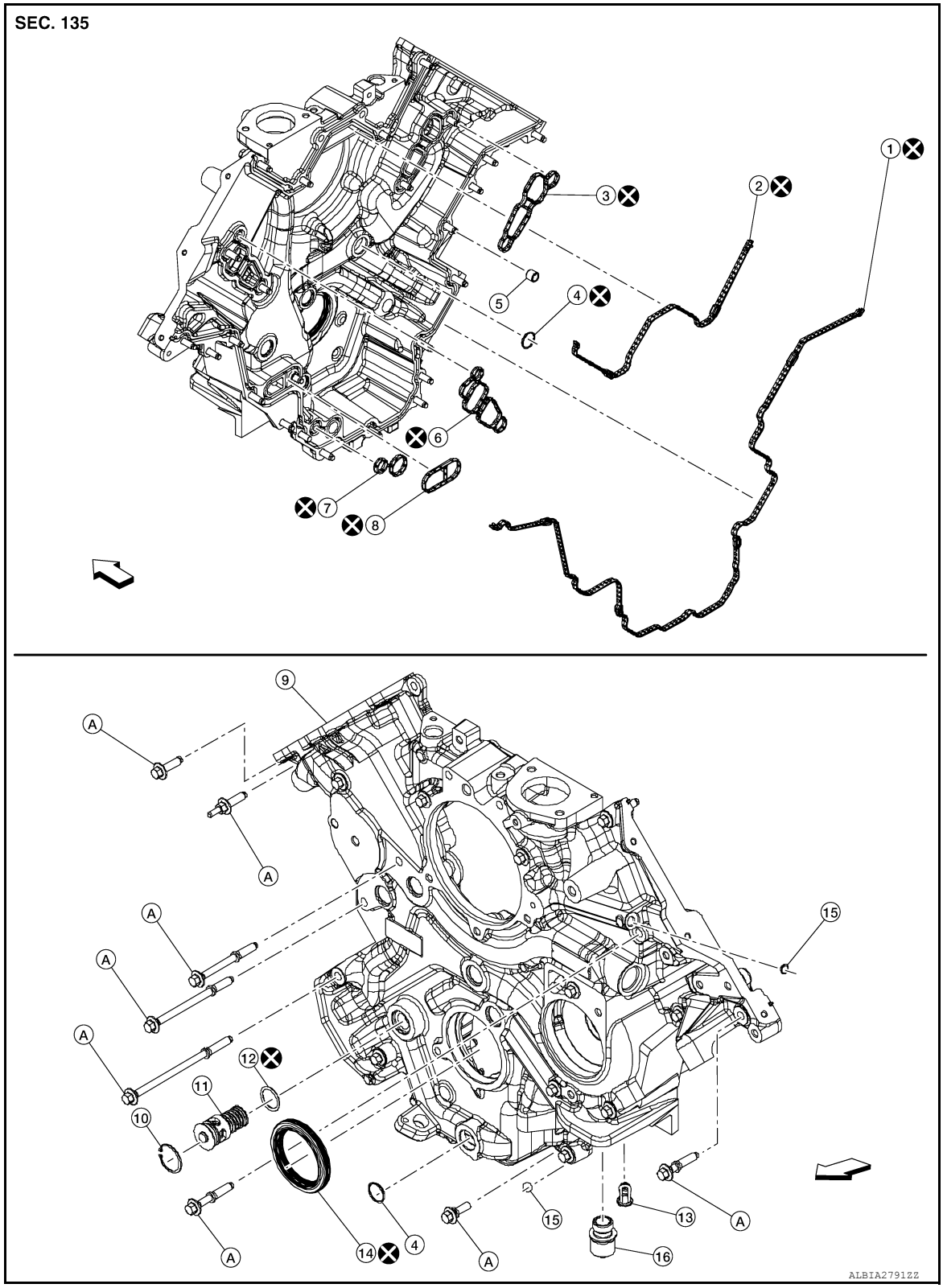
3. Install and tighten the bolt.
4. Connect the engine harness to the crankcase pressure sensor.
5. Connect the battery or batteries. Refer to PG-185, "Battery Disconnect".

   WARNING:
   Battery acid and battery acid fumes are extremely dangerous and can cause severe burns and explosion. To help reduce the risk of personal injury;
   - **Wear appropriate goggles and protective clothing.**
   - **Always properly ventilate the area where the service is being performed.**
   - **Never allow battery fluid to come in contact with skin, eyes, fabrics or painted surfaces.**
   - **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
   - **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**
6. Operate the engine and check for leaks.

FRONT COVER

Exploded View

INFOID:0000000014418662



1. Front cover gasket A
2. Front cover gasket B
3. Front cover gasket C
4. Welch plug
5. Dowel
6. Front cover gasket D
7. Front cover gasket E
8. Front cover gasket F
9. Front cover

10. Snap ring
11. Oil thermostat
12. O-ring
13. Oil check valve
14. Front oil seal
15. Welch plug
16. Oil filter head adapter
A. Refer to INSTALLATION
⇦ Front

Removal and Installation

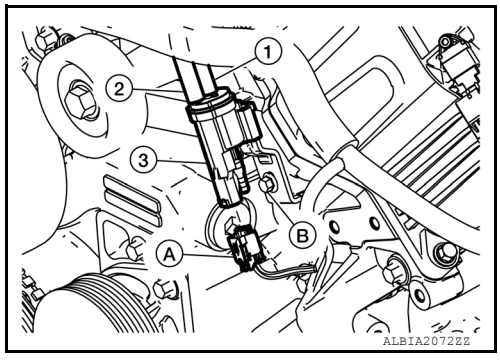
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REMOVAL

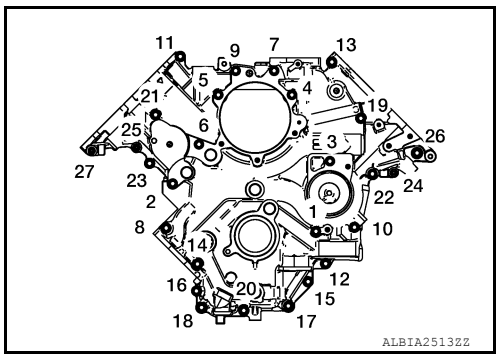
WARNING:

- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **The fuel system (fuel pump, high-pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Never loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

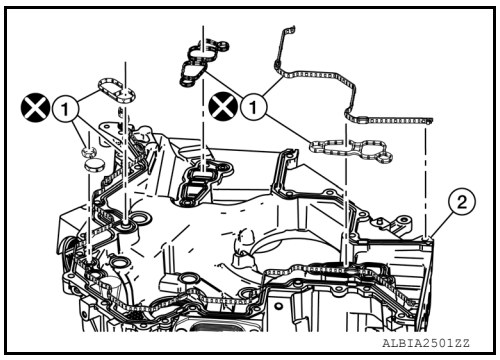
1. Remove the power steering pump and pump mounting bracket. Refer to ST-67, "Removal and Installation - Cummins 5.0".
2. Remove the A/C compressor. Refer to HA-31, "Removal and Installation".
3. Remove the generator and generator mounting bracket. Refer to CHG-48, "Removal and Installation: Cummins 5.0L".
4. Remove the charge-air cooler inlet hose and tube. Refer to EM-256, "Exploded View".
5. Remove the charge-air cooler outlet hose and tube. Refer to EM-256, "Exploded View".
6. Remove the oil filter. Refer to LU-36, "Removal and Installation".
7. Remove the rocker cover (bank 1) and rocker cover (bank 2). Refer to EM-318, "Removal and Installation".
8. Remove the radiator shroud. Refer to CO-49, "Removal and Installation".
9. Remove the vibration damper. Refer to EM-489, "Removal and Installation".
10. Remove the drive belt auto tensioner. Refer to CO-73, "Exploded View".
11. Disconnect the radiator hose (upper) and radiator hose (lower) from the engine. Refer to CO-71, "Exploded View".
12. Disconnect the harness connector from the crankshaft position sensor. Refer to EM-344, "Exploded View".
13. Disconnect the harness connector from the engine coolant temperature sensor. Refer to EM-347, "Exploded View".
14. Disconnect the harness connector from the coolant heater (if equipped). Refer to CO-63, "Exploded View".
15. Disconnect the harness connector (A) from the turbocharger compressor bypass solenoid (3).
16. Remove the vacuum hoses (1) and (2) from the turbocharger compressor bypass solenoid.
17. Remove bolt (B) and remove the turbocharger compressor bypass solenoid.



18. Loosen and remove the front cover bolts in the reverse order as shown.
NOTE:
Use the illustration to keep track of bolt locations.



19. Remove the front cover, taking care not to spill oil or coolant into the engine.
20. Remove and discard the front cover gaskets (1) from the grooves in the front cover (2).
CAUTION:
Do not reuse the front cover gaskets.
NOTE:
- Check for gasket material on the cylinder block or heads.
- If there is a lack of tension on the fuel pump or camshaft timing chains after removing the front cover, this does not indicate chain tensioner failure. The chain tensioners are fed oil pressure to keep tension on the chains. During removal, the chains may not be under full tension, this does not warrant replacement.



21. Drain all engine coolant and oil from front cover and clean after removal.

INSPECTION AFTER REMOVAL

WARNING:
When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**

CAUTION:
- **Do not use abrasive pads such to clean the front cover, block stiffener plate, cylinder heads, or cylinder block surfaces. Only use pads that do not contain abrasive materials and thoroughly remove all debris after cleaning.**
- **Cap all oil, coolant, and fuel components to prevent fluids from contaminating the sealing surfaces on the front cover, block stiffener plate, cylinder heads, and cylinder block.**

Inspection
- Inspect the front cover for cracks, leaks, or other damage. Inspect the oil and coolant passages for contamination or blockage.
- Damaged bolt holes in the front cover can be repaired or replace component as required.
- Replace the front cover if any damage is found that can **not** be repaired.
- Inspect the coolant heater fitting in the front cover. If damaged, replace the fitting.
- Inspect the cylinder block.
- Inspect the cylinder heads.

Cleaning the Front Cover
- Use a brush to clean thread locking sealant from the bolt hole threads in the block stiffening plate, cylinder heads, and block.
- Use a brass or nylon brush to clean thread locking sealant from the front cover bolts.
- Drain all of the oil and coolant passages in the front cover.
- Use a nylon or brass brush and isopropyl alcohol to clean gasket residue from the sealing surfaces on the front cover.
- Be sure to clean the grooves and chamfers on the front cover. Do **not** submerge the front cover in a wash tank unless all plugs, valves, and gaskets have been removed.
- Dry with compressed air.

CAUTION:
- **Do not brush in the same direction as the joints. This will remove critical form in place gasket material from the joint and can result in oil leaks.**
- **Use care on aluminum parts, such as the block stiffener plate and the cylinder heads, if removing form in place gasket material with a scraper. Failure to do so will result in component damage and oil leaks.**

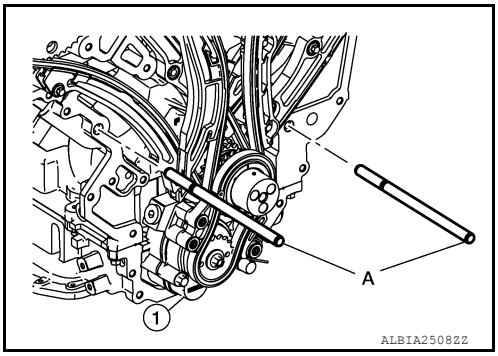
Cleaning the Block Stiffening Plate, Cylinder Head and Block.
- Clean the mating surface of the block stiffener plate, cylinder head, and block.
- Allow the block and block stiffener plate to drain excess oil. Use a dull tool to engage the anti-drain back valve in the block stiffener and drain the excess oil.
- Use a nylon or brass brush and contact cleaner to clean the gasket residue from the T-joint sealing surfaces on the block stiffener plate, cylinder heads, and block. **Only** brush across (perpendicular) the T-joint.
- A gasket scraper can be used instead of a brush to remove form in place gasket material. However, additional care **must** be used with aluminum surfaces so they are **not** damaged by the scraper.
- Dry the components with compressed air.

INSTALLATION

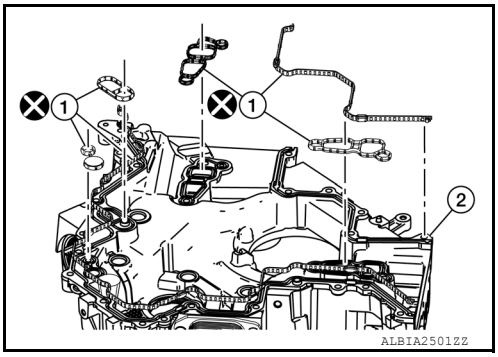
1. Install Tool (A) in the locations shown.

Tool : — (J-54403)

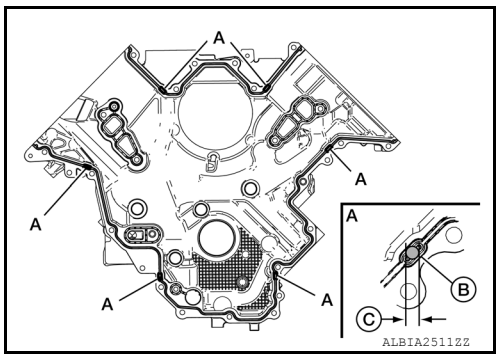
(1) : Oil pump



2. Immediately before installing the front cover, clean all sealing surfaces and chamfers with isopropyl alcohol and a lint-free cloth. After the surface is clean, prepare it with Bonderite M-NT 5700 ir equivalent wipe. Allow the surfaces to dry before applying sealant.
   NOTE:
   - The cylinder block, cylinder heads, block stiffening plate, and front cover sealing surfaces **must** be clean and dry before installing the front cover.
   - Be sure that tools and hands are free of oil before installing the front cover.
   - The cleaning and surface preparation procedures **must** be followed to reduce the possibility of oil leaks from the front cover.
3. Install the front cover gaskets (1) into the grooves of the front cover (2).
   CAUTION:
   Do not reuse the front cover gaskets.
   NOTE:
   Install the pads on the front cover gaskets first. Continue to press the seal between the pads, then press in the remaining seal. Make sure the seal is pressed firmly inside the groove. Make sure the seal is pressed firmly inside the groove.



4. Apply a drop of Loctite 5900 RTV or equivalant sealant (B) to the front cover in the six locations (A), as shown.



CAUTION:
Do not apply more than the recommended amount (C) of sealant to the sealing surface. Too much sealant can obstruct oil passages.

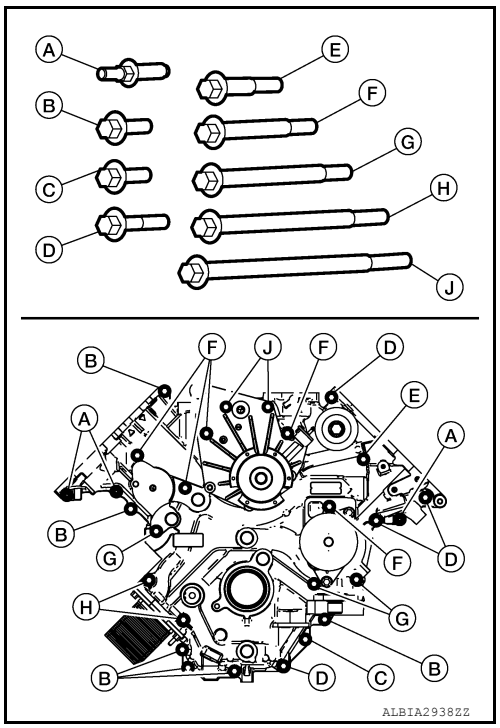
(C) : 9 mm (0.35 in)

NOTE:
The front cover **must** be installed and hand-tightened within 5 minutes of applying the sealant. Final application of torque **must** be completed within 30 minutes of the application of the form in place gasket.

5. Install the front cover over the Tool and install the bolts.
NOTE:
Before installing the bolts, apply Loctite 242 or equivalent thread locking sealant to the bolt threads.

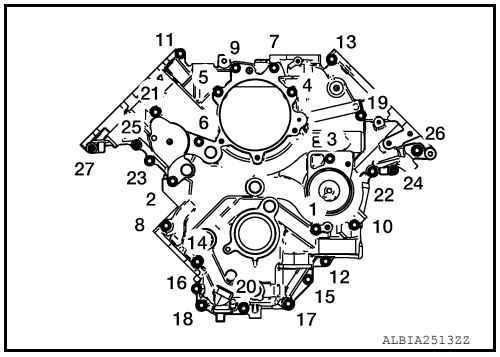
Tool : — (J-54403)

a. Make sure the bolts are installed in the correct location.
NOTE:
Bolt (C) does not have a tapered point.



(A) : 25 mm (0.98 in)
(B) : 25 mm (0.98 in)
(C) : 25 mm (0.98 in)
(D) : 40 mm (1.57 in)
(E) : 50 mm (1.97 in)
(F) : 80 mm (3.15 in)
(G) : 110 mm (4.33 in)
(H) : 140 mm (5.51 in)
(J) : 90 mm (3.54 in)

6. Torque the bolts to specification in the sequence shown.



Step 1 : 10 N·m (1.0 kg-m, 7 ft-lb)
Step 2 : 15 N·m (1.5 kg-m, 11 ft-lb)
Step 3 : 18 N·m (1.8 kg-m, 13 ft-lb)

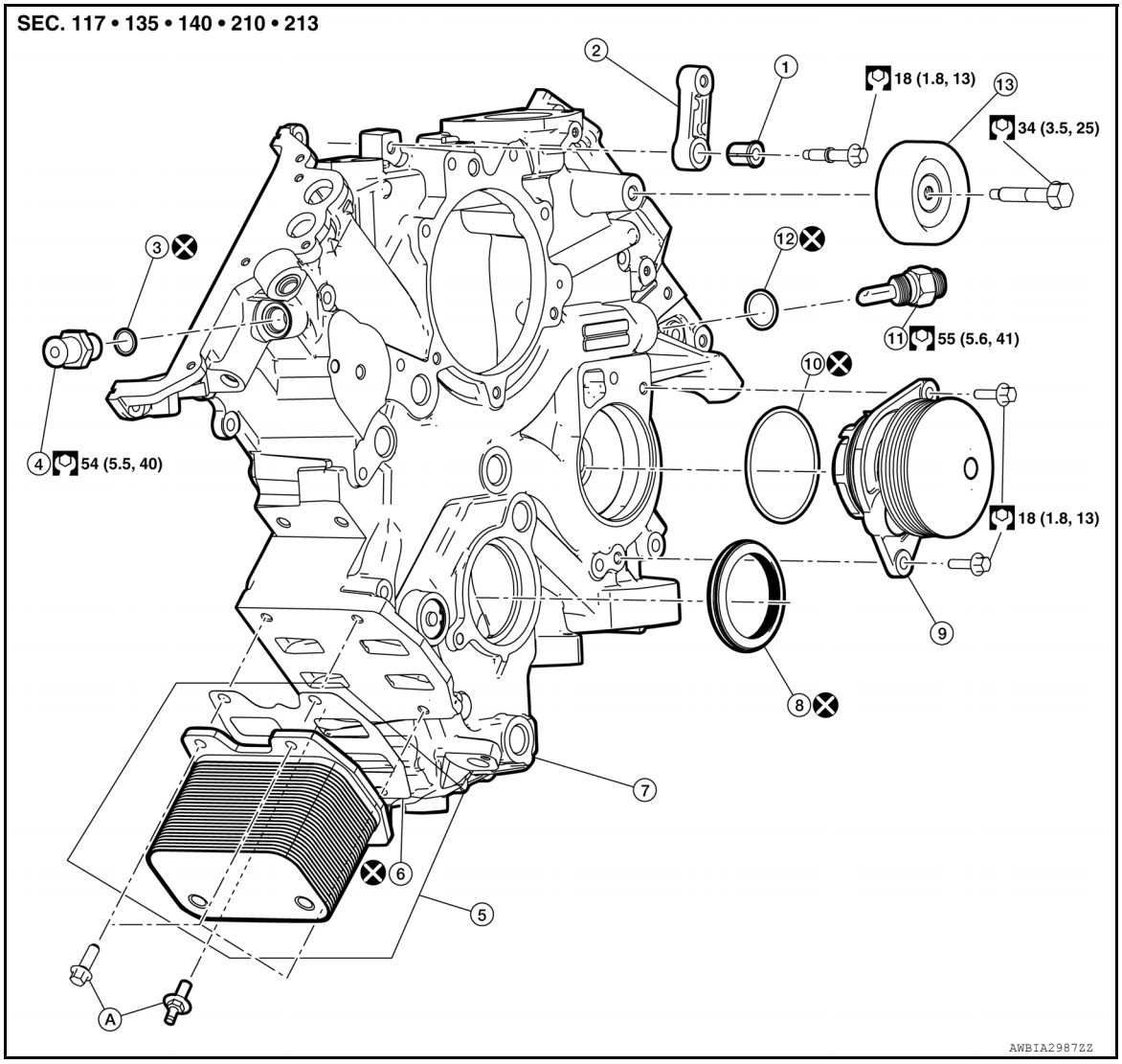
NOTE:
There are 25 bolts used in the front cover and an additional two bolts to mount the vacuum pump. Check that all bolts have been installed and tightened.

7. Installation of the remaining components is in the reverse order of removal.
NOTE:
Operate the engine and check for leaks.

Disassembly and Assembly

INFOID:0000000014418664

EXPLODED VIEW



1. Spacer
2. Air intake connection bracket
3. O-ring
4. Coolant plumbing fitting
5. Oil cooler
6. Oil cooler gasket
7. Front cover
8. Front oil seal
9. Water pump
10. O-ring
11. Coolant heater
12. O-ring
13. Idler pulley
A. Refer to LU-38, "Exploded View"

DISASSEMBLY

1. Remove the bolts and remove the water pump.
   CAUTION:
   Do not reuse the O-ring.
2. Remove the vacuum pump assembly from the front cover. Refer to EM-486, "Exploded View".
3. Remove the water transfer connection. Refer to CO-78, "Exploded View".
4. Remove the coolant heater.
   CAUTION:
   Do not reuse the O-ring.
5. Remove the idler pulley.
6. Remove the air intake connection bracket and spacer.

7. Remove the coolant plumbing fitting.
CAUTION:
Do not reuse the O-ring.
8. Remove the bolts and remove the oil cooler.
CAUTION:
Do not reuse the gasket.
9. Remove the front oil seal.
CAUTION:
Do not reuse the front oil seal.
10. Remove the following sensors:
    - Engine coolant temperature sensor. Refer to EM-347, "Exploded View".
    - Crankshaft position sensor. Refer to EM-344, "Exploded View".
11. Remove the oil cooler thermostat. Refer to LU-55, "Exploded View".
CAUTION:
Do not reuse the O-ring.
12. Remove the oil filter bypass valve. Refer to LU-44, "Exploded View".
13. Remove welch plugs from front cover. Refer to EM-337, "Exploded View".

INSPECTION AFTER DISASSEMBLY

- Inspect the front cover for cracks, leaks, or other damage. Inspect the oil and coolant passages for contamination or blockage.
- Damaged bolt holes in the front cover can be repaired or replace component as required.
- If the oil bypass valves are damaged or inoperable, they **must** be replaced.
- Replace the front cover if any damage is found that can **not** be repaired.
- Install the bypass valves.

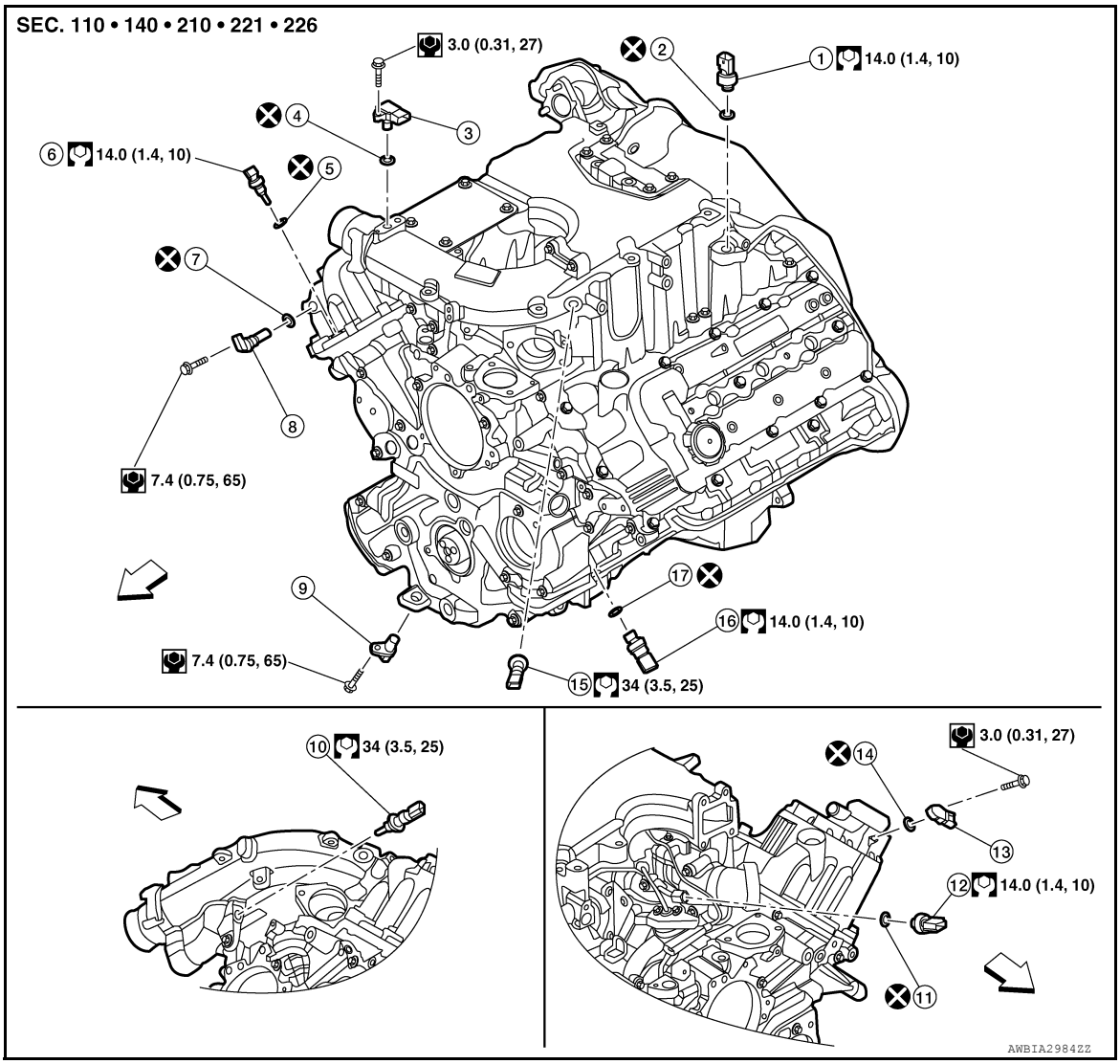
ASSEMBLY

Assembly is in the reverse order of disassembly.
NOTE:
Lubricate new O-rings with clean engine oil.

CRANKSHAFT POSITION SENSOR

Exploded View

INFOID:0000000014418665



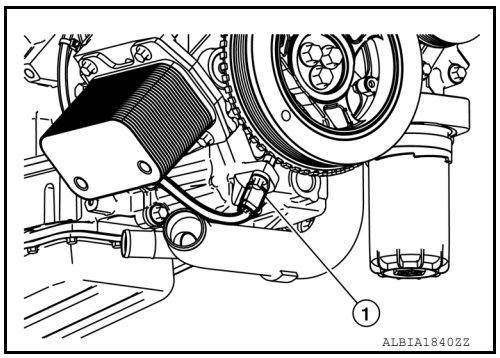
1. Exhaust gas pressure sensor	2. O-ring	3. Engine charge-air cooler outlet pressure/temperature sensor
4. O-ring	5. O-ring	6. Engine coolant temperature sensor
7. O-ring	8. Camshaft position sensor	9. Crankshaft position sensor
10. EGR temperature sensor	11. O-ring	12. Low pressure turbocharger boost pressure sensor
13. Crankcase pressure sensor	14. O-ring	15. Intake manifold air temperature sensor
16. Engine oil pressure switch	17. O-ring	⇦ Front

Removal and Installation

INFOID:0000000014418666

GENERAL INFORMATION

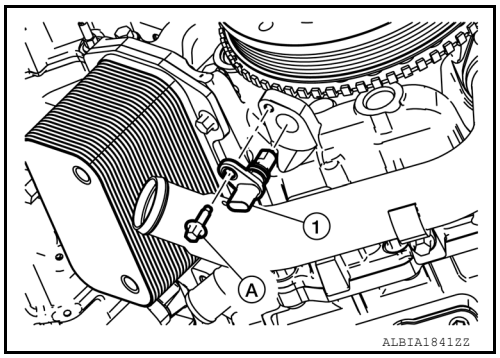
- The crankshaft position sensor (1) is a Hall effect sensor that reports the speed and position of the engine by radially detecting the gaps between the tone wheel teeth as it passes through the sensor. The sensor signal outputs a Pulse Width Modulated signal which changes in frequency depending on engine speed. The signal is then sent to the engine control module (ECM) via the engine harness. The crankshaft signal is used for controlling the timing at which injections need to occur.



REMOVAL

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".

   WARNING:
   Battery acid and battery acid fumes are extremely dangerous and can cause severe burns and explosion. To help reduce the risk of personal injury;
   - **Wear appropriate goggles and protective clothing.**
   - **Always properly ventilate the area where the service is being performed.**
   - **Never allow battery fluid to come in contact with skin, eyes, fabrics or painted surfaces.**
   - **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
   - **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**
2. Remove engine under cover. Refer to EXT-39, "ENGINE UNDER COVER : Removal and Installation".
3. Disconnect the harness connector from the crankshaft position sensor (1).
4. Remove bolt (A) and crankshaft position sensor (1).

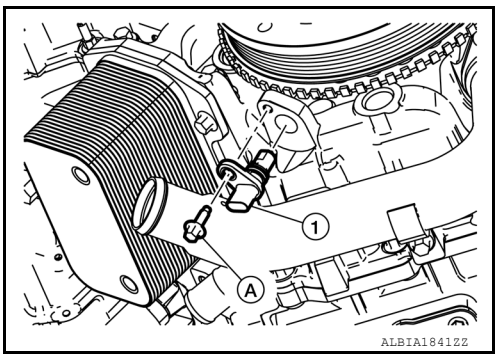


INSPECTION AFTER REMOVAL

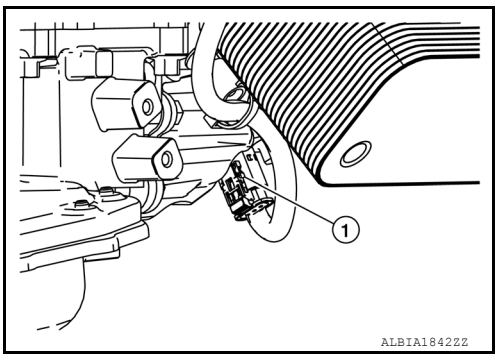
- Inspect the crankshaft position sensor for debris, cracks, or damage from contact with the tone wheel.
- If there is debris on the crankshaft position sensor, clean the sensor.
- Inspect the engine harness connector and sensor for the following:
- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor.
- Repair or replace parts as necessary.
- Inspect the crankshaft position sensor o-ring for the following:
- Swollen o-ring
- Nicks or cuts in or on the o-ring.

INSTALLATION

1. Install the crankshaft position sensor (1) by pressing firmly on the top of the sensor until the o-ring is fully seated.
2. Install and tighten the bolt (A).



3. Push the connectors together until they lock.
4. Slide the locking tab to the lock position (A).



5. Connect the battery or batteries. Refer to PG-185, "Battery Disconnect".

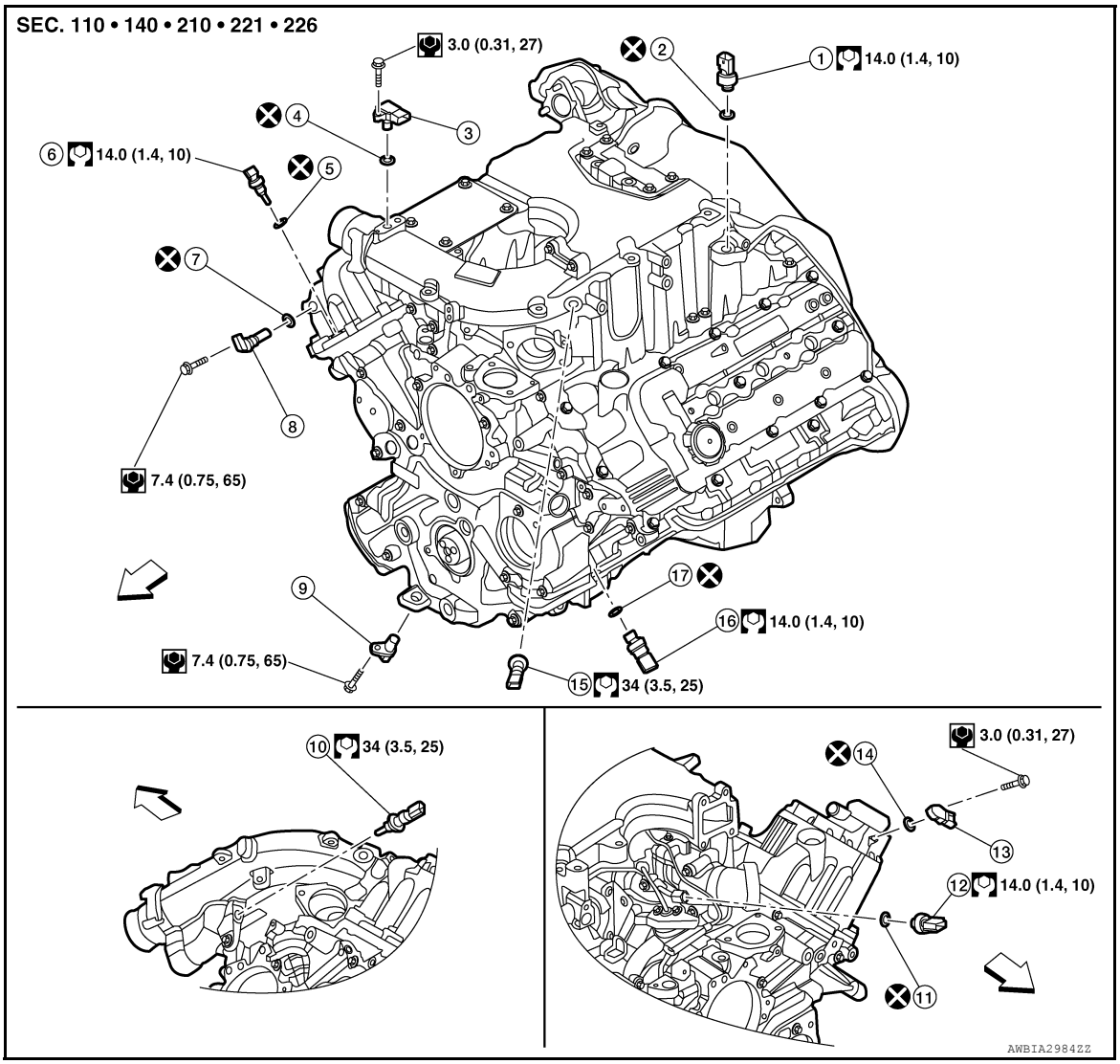
   WARNING:

   Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.
6. If crankshaft position sensor was replaced, in CONSULT click the Crank and the Timing buttons on the Fuel or Timing System Table Reset screen in Work Support. Refer to EC-806, "CONSULT Function".
7. Operate the engine and check for leaks.

ENGINE COOLANT TEMPERATURE SENSOR

Exploded View

INFOID:0000000014418667



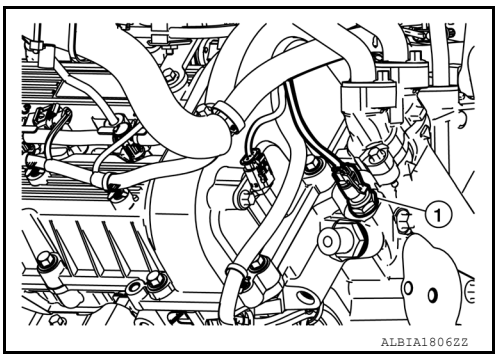
1. Exhaust gas pressure sensor
2. O-ring
3. Engine charge-air cooler outlet pressure/temperature sensor
4. O-ring
5. O-ring
6. Engine coolant temperature sensor
7. O-ring
8. Camshaft position sensor
9. Crankshaft position sensor
10. EGR temperature sensor
11. O-ring
12. Low pressure turbocharger boost pressure sensor
13. Crankcase pressure sensor
14. O-ring
15. Intake manifold air temperature sensor
16. Engine oil pressure switch
17. O-ring
⇦ Front

Removal and Installation

INFOID:0000000014418668

GENERAL INFORMATION

- The coolant temperature sensor (1) is threaded to the engine front cover.



- The coolant temperature sensor is a thermistor and decreases in resistance as the temperature of the coolant increases. The coolant temperature sensor measures the coolant temperature after the coolant has passed through the radiator and before it enters the right bank cylinder head.

INSPECTION BEFORE REMOVAL

- Use CONSULT to monitor the value of the coolant temperature sensor with the key in the ON position and the engine off.
- The engine **must** be off long enough for the coolant temperature to be equal to the local ambient air temperature. The coolant temperature sensor should read within 5.5°C (10°F) of the local ambient air temperature on a cold engine.
- Replace the coolant temperature sensor if the ambient temperature value is out of specification.

REMOVAL

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".

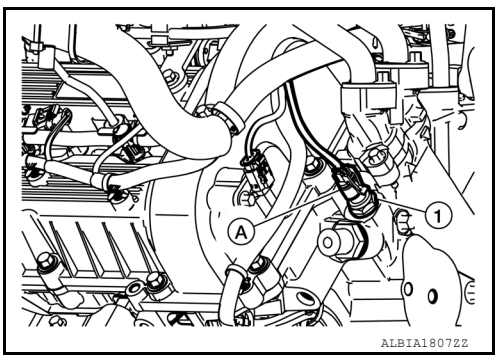
   WARNING:

   Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:
   - **Wear appropriate goggles and protective clothing.**
   - **Always properly ventilate the area where the service is being performed.**
   - **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
   - **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
   - **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**

2. Drain the coolant. Refer to CO-47, "Changing Engine Coolant".

   WARNING:
   - **To avoid the risk of personal injury, do not remove the radiator cap when the engine is hot. Serious burns could occur from high-pressure engine coolant escaping from the radiator. Wrap a thick cloth around the cap. Slowly turn it a quarter of a turn to release built-up pressure. Carefully remove the radiator cap by turning it all the way.**
   - **Coolant is toxic and can be fatal if swallowed. Keep away from pets and children. If not reused, dispose of in accordance with local environmental regulations.**

3. Clean the area around the coolant temperature sensor.
4. Disconnect the engine coolant temperature sensor harness connector (A) and remove the engine coolant temperature sensor (1).



INSPECTION AFTER REMOVAL

Inspect the engine harness connector and coolant temperature sensor for the following:
- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor.

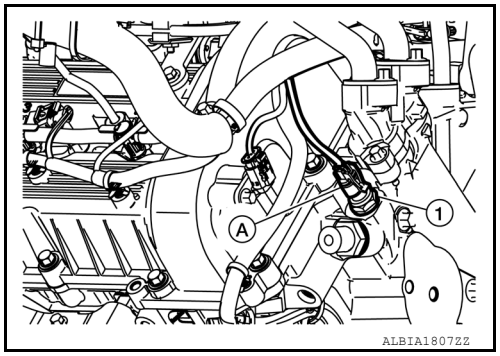
Repair or replace parts as necessary.

Measure the resistance across the sensor signal and return terminals to be sure they agree with the table shown below. If the sensor ambient conditions change, the resistance values should be measured **only** after 2.5 minutes of the ambient change.

Temperature (°C)	Temperature (°F)	Resistance (ohms)
0	32	30k to 37k
25	77	9.3k to 10.7k
50	122	3.2k to 3.8k
80	176	1.1k to 1.3k
100	212	605 to 669

INSTALLATION

1. Install the engine coolant temperature sensor (1) and connect the engine coolant temperature sensor harness connector (A).
   CAUTION:
   Do not reuse O-ring.

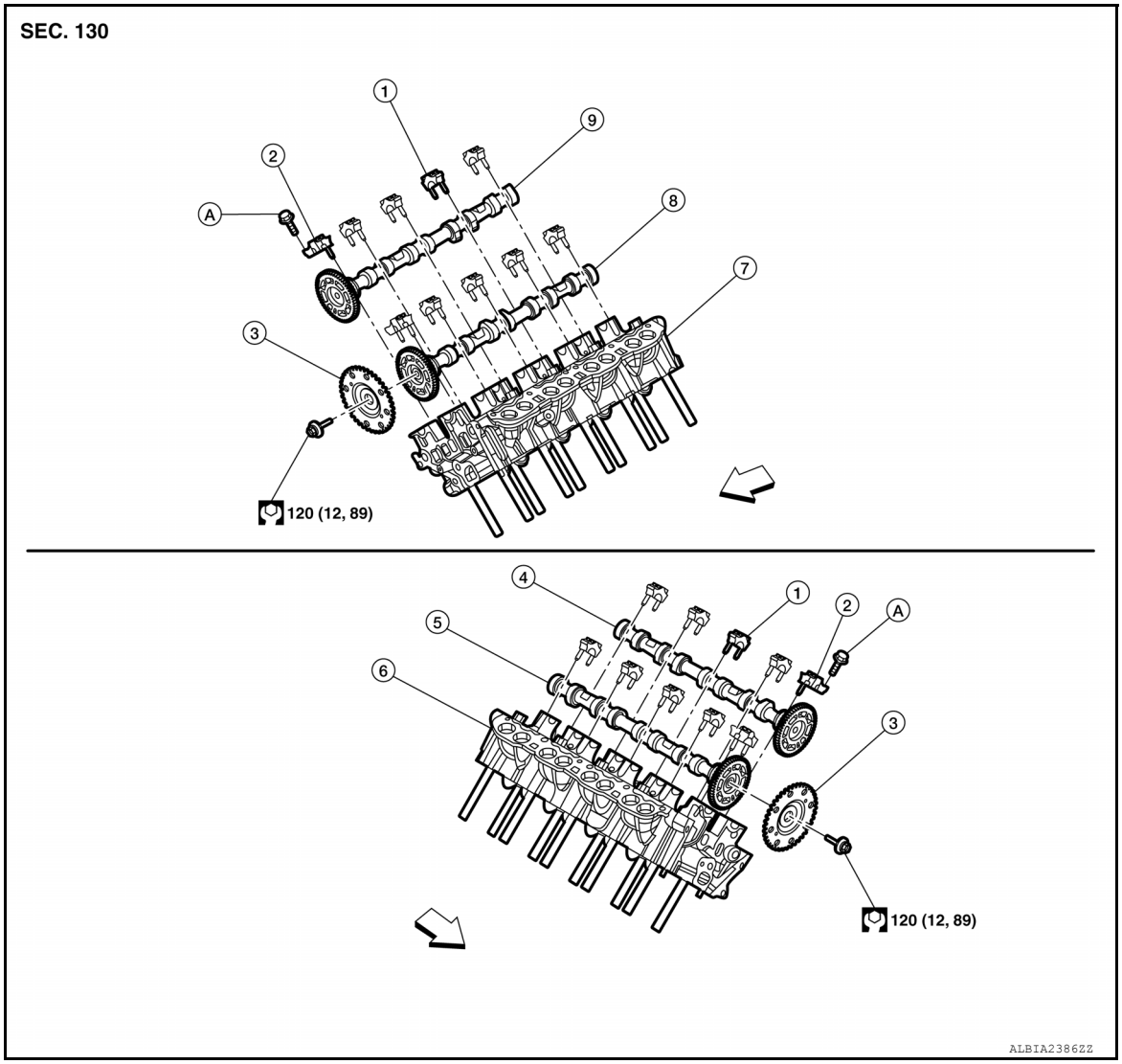


2. Refill the engine cooling system. Refer to CO-47, "Changing Engine Coolant".
3. Connect the battery or batteries. Refer to PG-185, "Battery Disconnect".
   WARNING:
   Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:
   - **Wear appropriate goggles and protective clothing.**
   - **Always properly ventilate the area where the service is being performed.**
   - **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
   - **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
   - **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**
4. Operate the engine and check for leaks.

CAMSHAFT

Exploded View

INFOID:0000000014418669



1. Camshaft cap
2. Camshaft cap
3. Camshaft sprocket
4. Exhaust camshaft (bank 2)
5. Intake camshaft (bank 2)
6. Cylinder head (bank 2)
7. Cylinder head (bank 1)
8. Intake camshaft (bank 1)
9. Exhaust camshaft (bank 1)
A. Refer to INSTALLATION
⇦ Front

CAUTION:
The camshaft caps are machined with the cylinder head and must be replaced as an assembly.

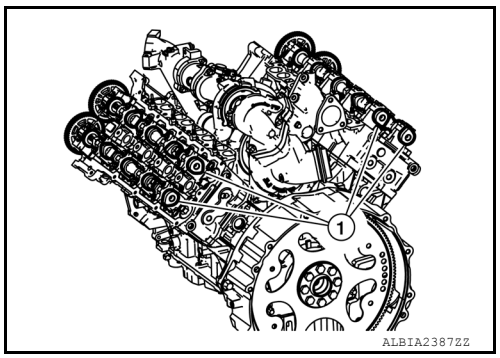
Removal and Installation

INFOID:0000000014418670

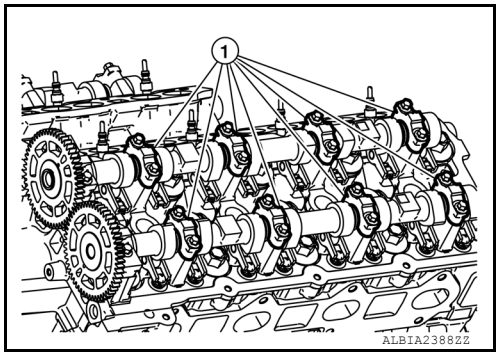
GENERAL INFORMATION

- Each of the camshafts (1) are marked for bank 1 or bank 2 and the intake or exhaust side.

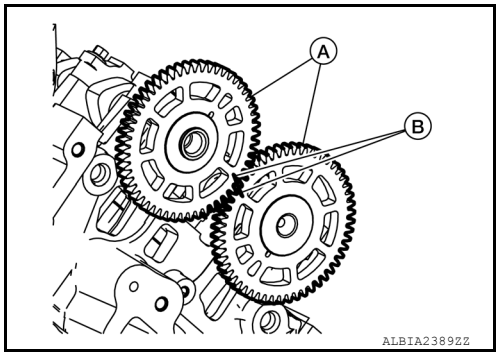
CAUTION:
Camshafts must be installed in their specified location.



- The camshaft caps (1) are marked by position and have an arrow pointing toward the front of the engine.
- The camshaft caps **must** be installed in their specified location.
- The inner diameter of the camshaft cap is manufactured together with the cylinder head. If a camshaft cap is damaged, the cylinder head **must** be replaced.



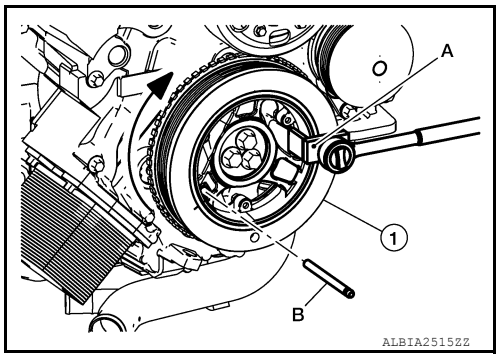
- Camshaft gears (A) are **not** serviceable.
- If the camshaft or camshaft gear is damaged, the camshaft and gear assembly **must** be replaced.
- The gears have timing marks (B) on them. When the timing marks are lined up and in contact, as shown, the engine is at Top Dead Center (TDC) for the number 1 piston.



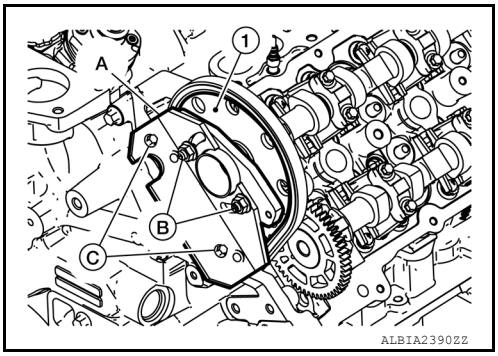
REMOVAL

1. Remove the rocker cover. Refer to EM-318, "Removal and Installation".
2. Using Tool A, rotate the engine so that cylinder 1 is at TDC. Insert Tool B into the vibration damper (1). TDC for cylinder 1 is identified by aligning the matching marks on the camshaft gears.

Tool A : — (J-54424)
Tool B : — (J-54404)



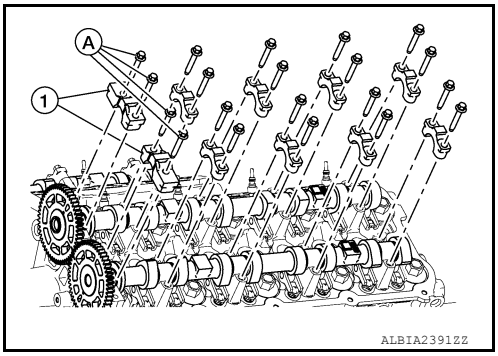
3. Install Tool A on the intake cam sprocket (1).



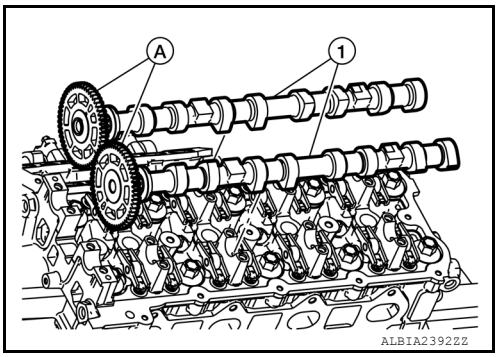
Tool A : — (J-54408)
Bolts (C) : 9.0 N·m (0.9 kg-m, 80 in-lb)
Nuts (B) : 23 N·m (2.3 kg-m, 17 ft-lb)

NOTE:
Tighten bolts (C) first and then tighten nuts (B).
If removing all camshafts on both heads simultaneously, two tools will be required.

4. Loosen and remove the camshaft sprocket bolt.
NOTE:
When the camshaft sprocket bolt is loosened, the valve springs will move the camshafts slightly. This is acceptable.
5. Slide the camshaft sprocket away from the camshaft slightly.
6. Loosen and remove the camshaft cap bolts (A) and remove the camshaft caps (1).
NOTE:
Camshaft caps must be installed in their specific location.

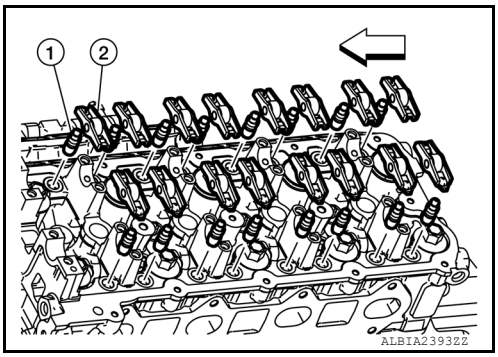


7. Remove the camshafts (1).
NOTE:
Do **not** attempt to remove the camshaft gear (A) from the camshaft.



8. Remove the rocker arms (2) and hydraulic lash adjusters (1) (if necessary).

⇦ : Front



INSPECTION AFTER REMOVAL

WARNING:
- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufactures recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns,**

never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- Clean the camshafts and camshaft caps with a detergent solution or solvent.
- Dry the camshafts with compressed air.

Camshaft
- Inspect the camshaft lobes and bearing journals for cracks, scratches, and other damage.
- Inspect the camshaft gear teeth for excessive wear, fretting, and cracked or broken teeth.
- If the camshaft or camshaft gear is damaged, the entire camshaft assembly **must** be replaced.
- If camshaft damage is found, inspect the chain drive, crankshaft, and lubricating oil system for progressive damage.

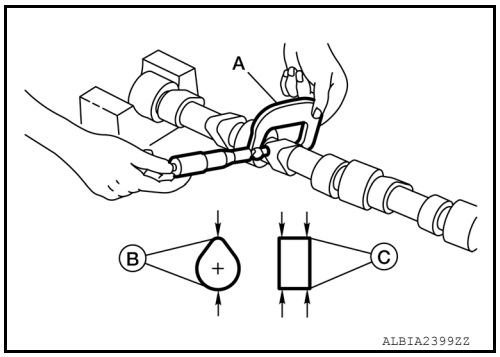
Cylinder Head
- Inspect the camshaft caps and cam towers for cracks or other damage.
- If the camshaft bore has corresponding damage on the camshaft, the cylinder head and camshaft **must** be replaced.
- If any camshaft cap is damaged, the cylinder head **must** be replaced.

Rocker Arm and Hydraulic Lash Adjuster
- Inspect the rocker arms. Replace if damaged.
- Inspect the hydraulic lash adjusters. Replace if damaged.

Measurement

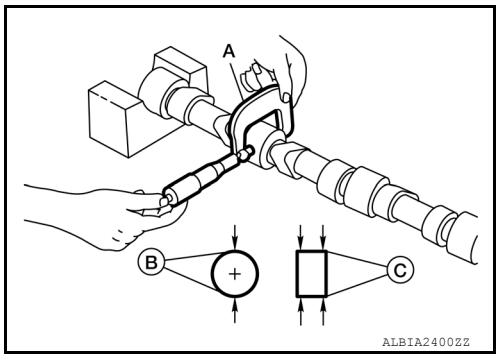
1. Measure the peak of the camshaft lobes (B) and (C) using a suitable tool (A).

Camshaft lobe height **: Refer to EM-529, "CAMSHAFT".**



2. Measure the camshaft bearing journals (B) and (C) using a suitable tool (A). If the camshaft lobes or journals are out of specification, the camshaft and gear assembly must be replaced.

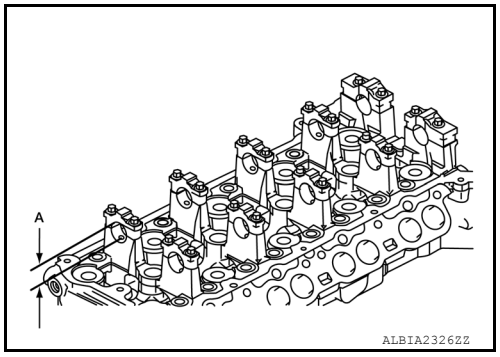
Camshaft journal **: Refer to EM-529, "CAMSHAFT".**



3. Install the front and rear camshaft caps and measure the camshaft bores (A). If the camshaft bores are out of specification, the cylinder head must be replaced.

Camshaft bore **: Refer to EM-530, "CYLINDER HEAD".**

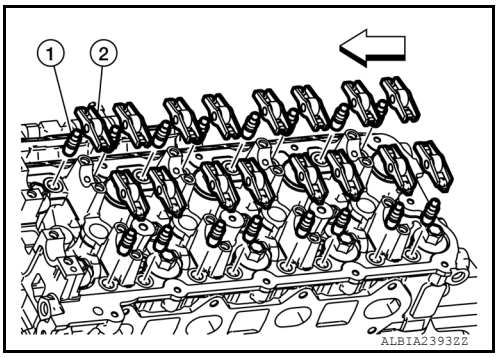
Camshaft cap bolts **: 11 N·m (1.1 kg-m, 8 ft-lb)**



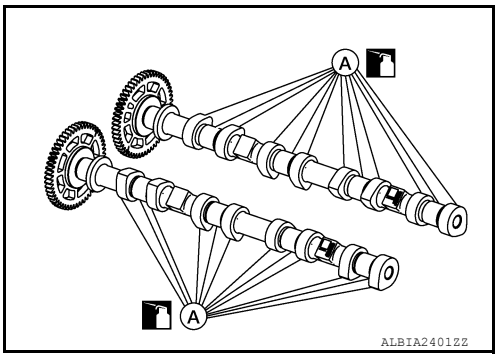
INSTALLATION

1. Install the rocker arms (2) and hydraulic lash adjusters (1) if removed.

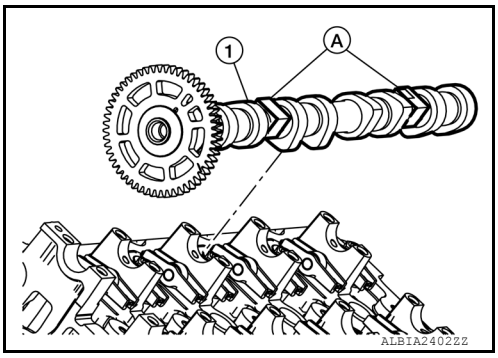
⇦ : Front



2. Lubricate all camshaft lobes and journals (A) with clean engine oil or assembly lubricant.



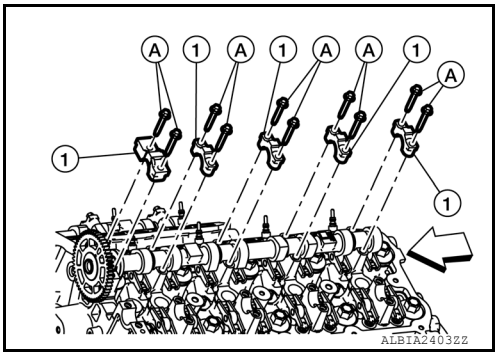
3. Install the intake camshaft (1) first with the camshaft flats (A) facing upward in plane with the rocker cover sealing surface.
NOTE:
The valve springs will prevent the flats from being perfectly horizontal. This is acceptable. The camshaft orientation should be approximately the same as when it was removed.



4. Install the camshaft caps (1) and finger-tighten the bolts (A).

⇦ : Front

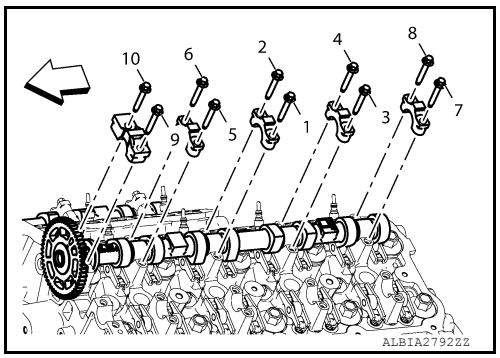
NOTE:
The camshaft caps are labeled with their position and have an arrow that points toward the front.



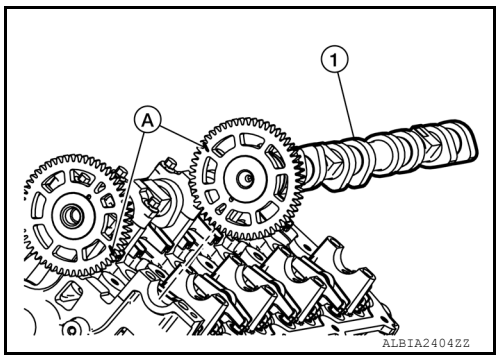
5. Tighten bolts to specification in the sequence shown.
NOTE:
Make sure the rockers are seated correctly.

Camshaft cap bolts : 11 N·m (1.1 kg-m, 8 ft-lb)

⇦ : Front

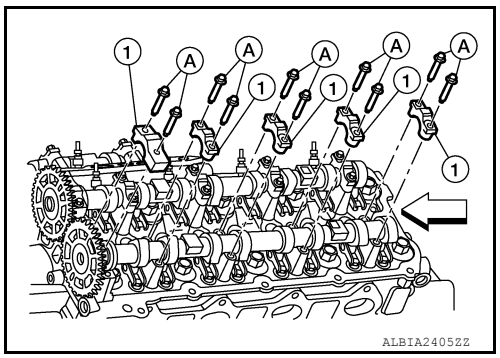


6. Install the exhaust camshaft (1). While holding the exhaust camshaft, engage the camshaft gears so that the timing marks (A) will align once the camshaft is placed in the camshaft towers. Carefully roll the exhaust camshaft in place while maintaining gear contact.



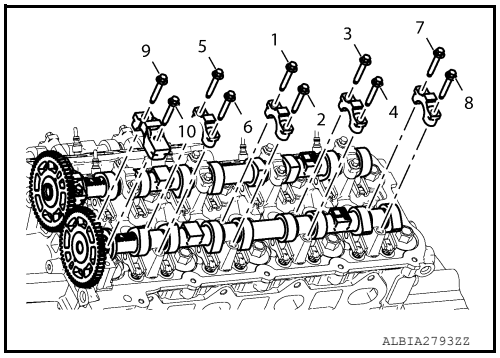
7. Install the camshaft caps (1) and finger-tighten the bolts (A).
NOTE:
The camshaft caps are labeled with their position and have an arrow that points toward the front.

⇦ : Front



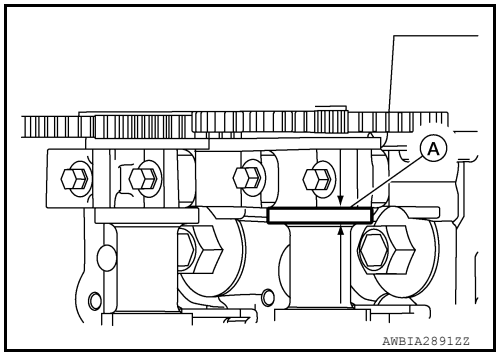
8. Tighten bolts to specification in the sequence shown.

Camshaft cap bolts : 11 N·m (1.1 kg-m, 8 ft-lb)

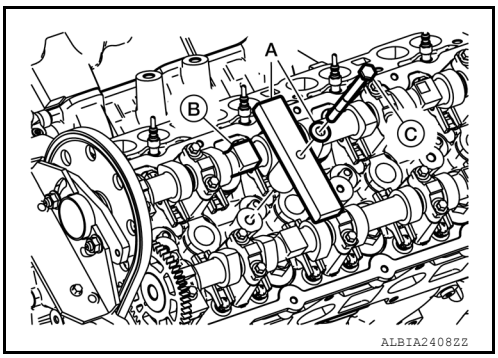


9. Measure camshaft end clearance (A) on each camshaft.

Camshaft end play : Refer to EM-529, "CAMSHAFT".



10. Install Tool (A) on the front flats (B) of the intake and exhaust camshafts.Tighten bolt (C) to secure tool in position.



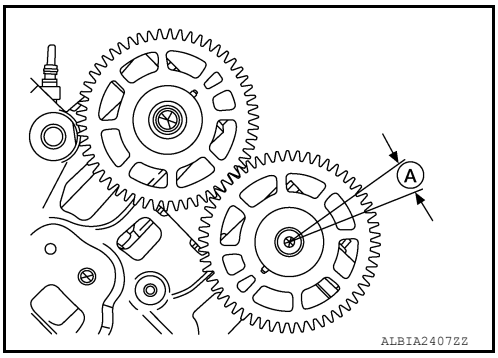
CAUTION:
Make sure the camshaft and camshaft sprocket are properly seated before tightening the camshaft sprocket bolts or the camshaft will be damaged.
NOTE:
- It may be necessary to rotate the camshafts slightly with a suitable tool on the rear camshaft flats to get the front camshaft flats to align with the Tool.
- Verify that the timing marks on the camshaft gears are still aligned.

Tool : — (J-54409)
Bolt (C) : 25 N·m (2.6 kg-m, 18 ft-lb)

11. Install and tighten the camshaft sprocket bolt and remove the Tools.
NOTE:
Rotate the engine clockwise two full revolutions to make sure the valve train and camshaft sprocket are operating properly.

Camshaft sprocket bolt : 120 N·m (12 kg-m, 89 ft-lb)

12. Measure gear backlash (A) using a suitable tool on each camshaft gear.



Camshaft gear backlash : Refer to EM-529, "CAMSHAFT".

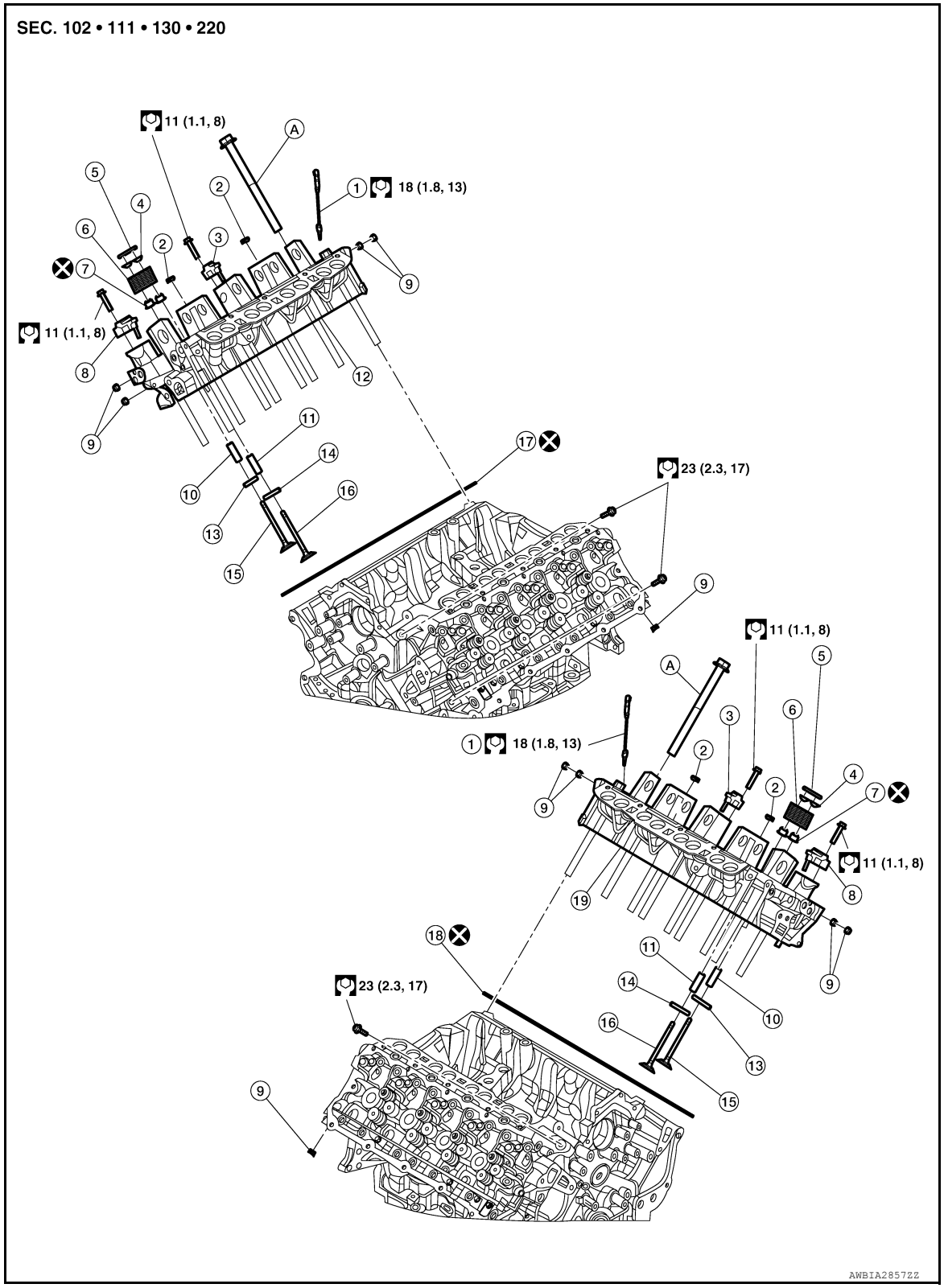
NOTE:
- Camshaft gear backlash should be measured with the camshaft sprocket torqued to the camshaft. This will allow the intake camshaft to be held in place while backlash is measured on the exhaust camshaft gear.
- The camshaft sprocket retaining tool base is made of steel and is a suitable location for attaching the suitable tool.

13. Installation of the remaining components is in the reverse order of removal.
NOTE:
- If the Camshaft was removed or replaced, in CONSULT click the Timing button on the Fuel or Timing System Table Reset in Work Support. Refer to EC-806, "CONSULT Function".
- Operate the engine and check for leaks.

CYLINDER HEAD

Exploded View

INFOID:0000000014418671



1. Glow plug
2. Welch plug
3. Camshaft cap
4. Valve spring retainer
5. Valve collet
6. Valve spring
7. Valve guide seal
8. Camshaft cap
9. Welch plug

10. Exhaust valve stem guide
11. Intake valve stem guide
12. Cylinder head (bank 1)
13. Exhaust valve insert
14. Intake valve insert
15. Exhaust valve
16. Intake valve
17. Cylinder head gasket (bank 1)
18. Cylinder head gasket (bank 2)
19. Cylinder head (bank 2)
A. Refer to INSTALLATION

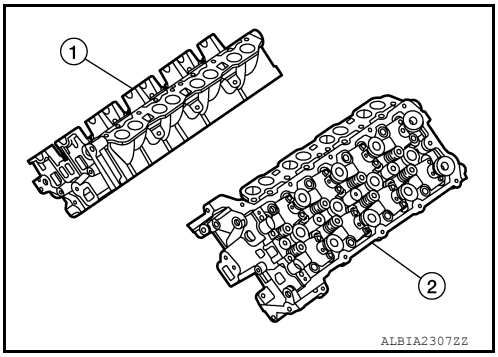
CAUTION:
Valve collet and valve (intake or exhaust) are serviced as an assembly.

Removal and Installation

INFOID:0000000014418672

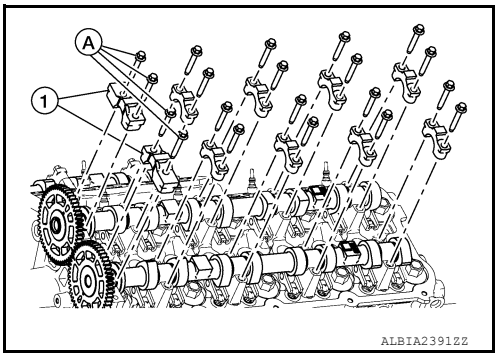
GENERAL NFORMATION

- The cylinder heads [bank 1 (1)] and [bank 2 (2)] are not interchangeable.
- Use extreme caution when setting the cylinder heads down. Set the head upside down or on a soft, clean surface to prevent damage to the combustion face.
- Always use new sealing washers when installing the injectors.

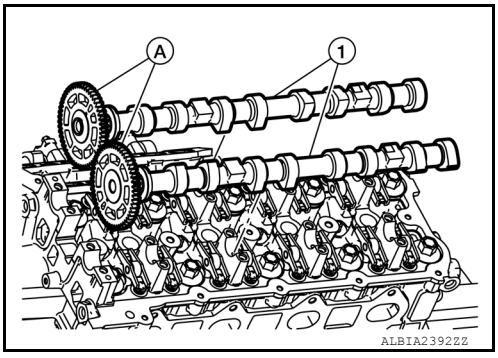


REMOVAL

1. Remove the camshaft timing chains from cylinder head (bank 1) and cylinder head (bank 2). Refer to EM-374, "Removal and Installation".
2. Remove the exhaust manifolds from cylinder head (bank 1) or cylinder head (bank 2). Refer to EM-265, "Removal and Installation - Bank 1".
3. Loosen and remove the camshaft cap bolts (A) and remove the camshaft caps (1).
   NOTE:
   - Bank 2 shown, Bank 1 similar.
   - Camshaft caps must be installed in their specific location.

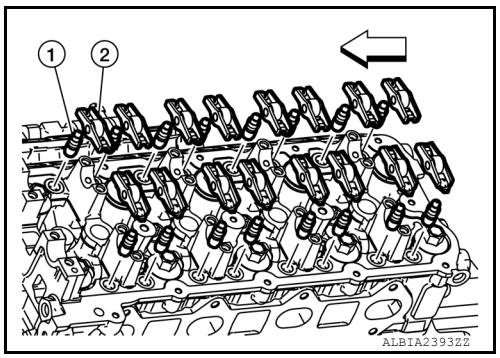


4. Remove the camshafts (1).
   NOTE:
   - Bank 2 shown, Bank 1 similar.
   - Do **not** attempt to remove the camshaft gear (A) from the camshaft.



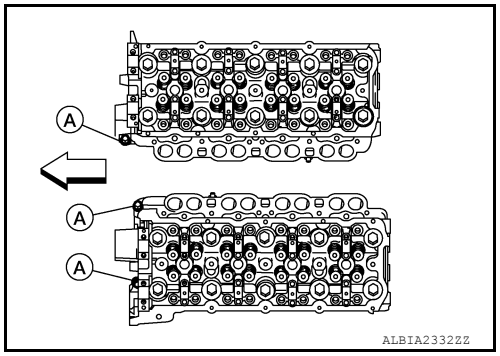
5. Remove the rocker arms (2) and hydraulic lash adjusters (1).
NOTE:
- Bank 2 shown, Bank 1 similar.
- Remember to label the location of the rocker arms during removal.

⇦ : Front

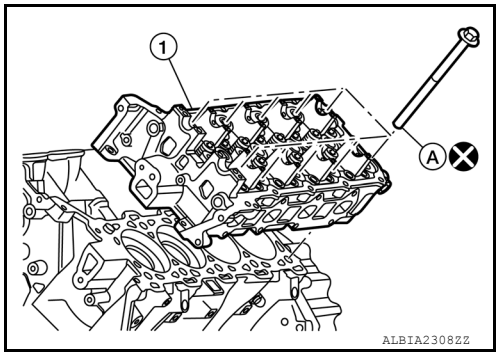


6. Disconnect the harness connector from the glow plugs and remove the glow plugs. Refer to EM-259, "Exploded View".
7. Remove bolts (A).

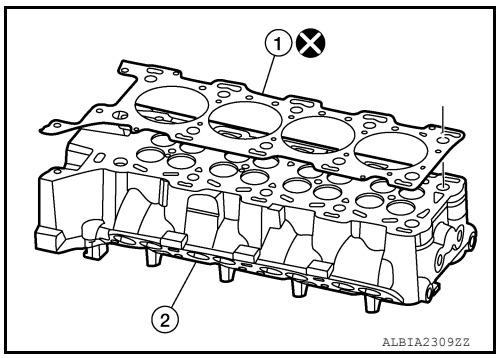
⇦ : Front



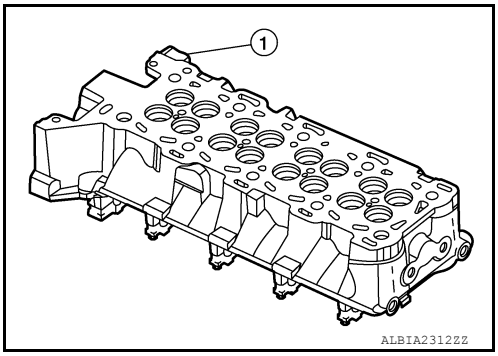
8. Remove the cylinder head bolts (A) and then remove the cylinder head (1).
CAUTION:
Do not reuse the cylinder head bolts.
NOTE:
Bank 2 shown, Bank 1 similar.



9. Remove and discard the cylinder head gasket (1).
CAUTION:
Do not reuse the cylinder head gasket.
NOTE:
- Bank 2 shown, Bank 1 similar.
- To reduce the possibility of damage to the combustion surfaces, set the cylinder head (2) down with the combustion deck facing up.



INSPECTION AFTER REMOVAL



- Clean the cylinder head (1) with contact cleaner and a lint-free cloth. Be sure to remove all leftover gasket residue.

  WARNING:
  When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:
  - **Do not exceed 30psi (207 kPa).**
  - **Wear appropriate eye protection and protective clothing including gloves.**

  CAUTION:
  - **Do not use abrasive pads to clean the cylinder head. Only use pads that do not contain abrasive materials and thoroughly remove all debris after cleaning.**
  - **Do not use metal tools to clean the cylinder head. Metal tools can scratch the combustion face.**
- Use a suitable tool to clean the valve guide bores, injector bores, and the glow plug bores.
- Clean the carbon from the injector seats with Tool and WD-40. Do **not** use solvent in place of WD-40.

  CAUTION:
  Do not use any solvents to clean the injector seats.

  Tool : — (J-54428)
- Clean the carbon deposits from the valve seats.
- Clean the intake and exhaust ports and other surfaces and bores with a brass brush and WD-40.
- Clean the springs, valves, and valve guides.

Cylinder Head
- Wash the cylinder head in a hot, soapy water solution.
- Rinse the cylinder head with clean water.
- Dry the cylinder head with compressed air. Be sure to blow out the valve guides and seats.
- Spray the valve guide seats with WD-40 to prevent rust.
- Inspect the cylinder head combustion decks for damage.
- If cracks are found, replace the cylinder head.
- Inspect the area within 3.175 mm (0.125 in) of the firing ring diameter and sealing locations.

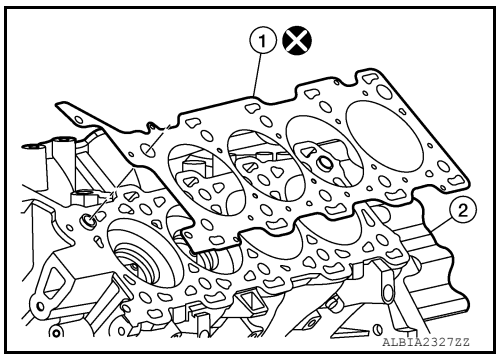
  NOTE:
  Place the old cylinder head gasket onto the cylinder head to identify the sealing path for the gasket.
- Any wear that can be felt with a fingernail within the 3.175 mm (0.125 in) area is unacceptable and the cylinder head **must** be replaced.
- Wear beyond this 3.175 mm (0.125 in) area will have no effect on future combustion sealing and the usability of the cylinder head.
- Inspect the valve seat inserts for cracks or burnt spots.
- If the valve seat inserts are damaged, replace the cylinder head.
- Inspect the valves for damage. Inspect the valve collet grooves for wear.
- Inspect the valve guides for scuffing or scoring.
- Inspect the valve springs for damage or excessive wear. If a damaged spring is found, replace the spring.
- Inspect the valve retainers and valve collets for damage or worn areas.
- Inspect the camshaft bores and camshaft caps for signs of wear, nicks, or gouges. If the camshaft bore has corresponding damage on the camshaft, the cylinder head and camshaft **must** be replaced.
- Inspect the camshafts. If damage is found, replace the component as necessary.
- Inspect the cylinder block. If damage is found, replace the component as necessary.

INSTALLATION

NOTE:
- Make sure that the cylinder 1 piston is at top dead center before installing the cylinder heads (bank 1) and (bank 2).
- Be sure the cylinder head bolt holes are free of fluids before installing the cylinder heads (bank 1) and (bank 2).

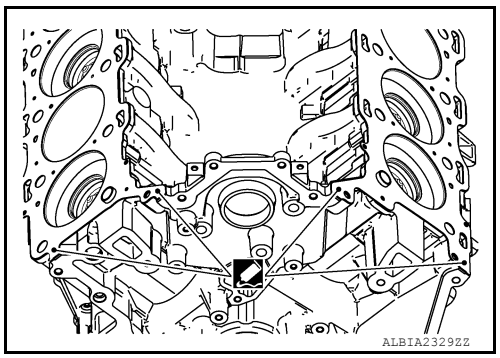
1. Clean the surfaces of the cylinder head and cylinder block.

2. Install the cylinder head gasket (1) onto the cylinder block (2).
CAUTION:
Do not reuse the cylinder head gasket.
NOTE:
Bank 2 shown, Bank 1 similar.

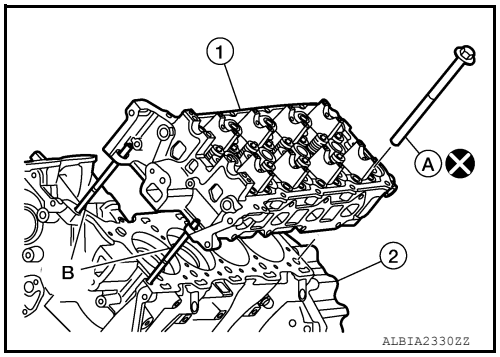


3. Clean the surfaces indicated with isopropyl alcohol and a lint-free towel and allow time to dry. Prepare surfaces with a Bonderite M-NT 5700 or equivalent wipe and allow surfaces to dry.

a. Apply a 9 mm (0.35 in) diameter drop of Loctite 5900 RTV or equivalent sealant to the top of the cylinder head gaskets as shown.
NOTE:
The cylinder heads **must** be installed within 5 minutes of applying sealant. Final torque **must** be completed within 30 minutes of the application of sealant.



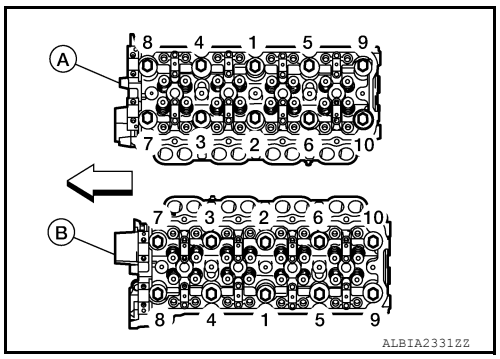
4. Install suitable tool (B) in the top corner holes of the cylinder head.
5. Carefully place the cylinder head (1) on the cylinder block (2) and seat the head onto the dowels and remove the suitable tool.
6. Install and tighten the bolts (A) by hand.
CAUTION:
Do not reuse cylinder head bolts.
NOTE:
Bank 2 shown, Bank 1 similar.



7. Tighten the bank 1 cylinder head (1) or bank 2 cylinder head (2) bolts in three steps in the sequence shown to the specified torque.

Step 1 : 40 N·m (30 ft-lb)
Step 2 : 120 N·m (89 ft-lb)
Step 3 : Tighten 180 degrees

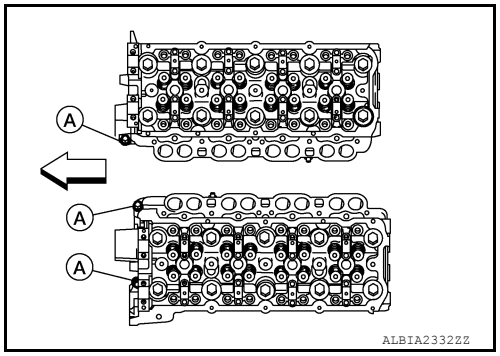
⇦ : Front



8. Tighten the bolts (A) to the specified torque.

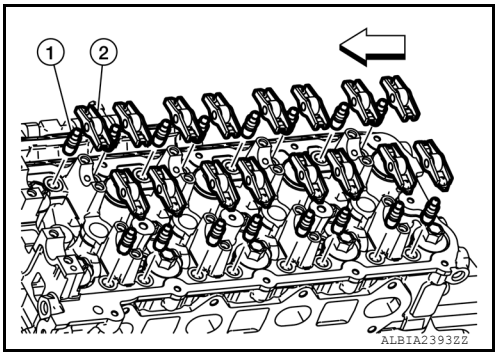
Bolts (A) : 23 N·m (2.3 kg-m, 17 ft-lb)

⇦ : Front

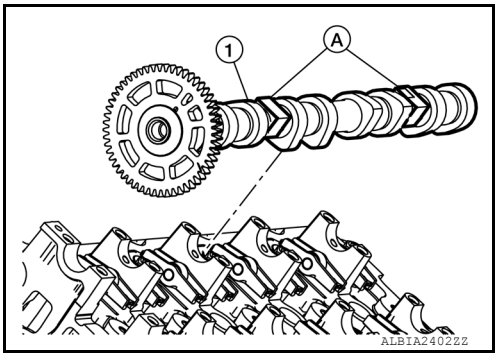


9. Install the rocker arms (2) and hydraulic lash adjusters (1).
NOTE:
• Bank 2 shown, Bank 1 similar.

⇦ : Front

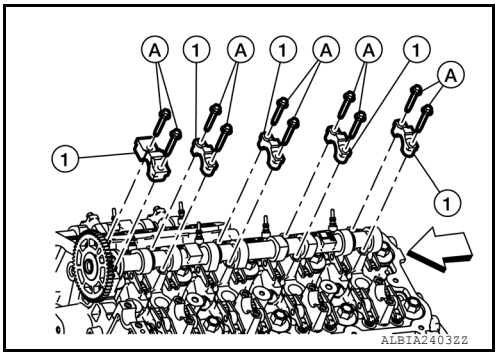


10. Install the intake camshaft (1) first with the camshaft flats (A) facing upward in plane with the valve cover sealing surface.
NOTE:
The valve springs will prevent the flats from being perfectly horizontal, this is acceptable. The camshaft orientation should be approximately the same as when it was removed.



11. Install the camshaft caps (1) and finger-tighten the bolts (A).
NOTE:
The camshaft caps are labeled with their position and have an arrow that points toward the front.

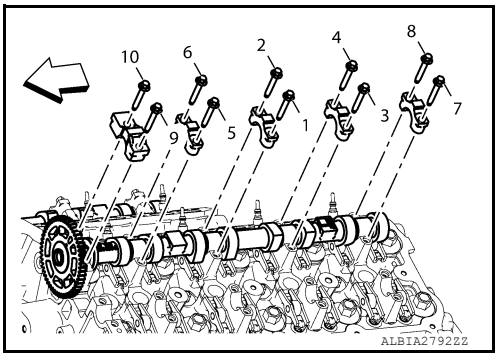
⇦ : Front



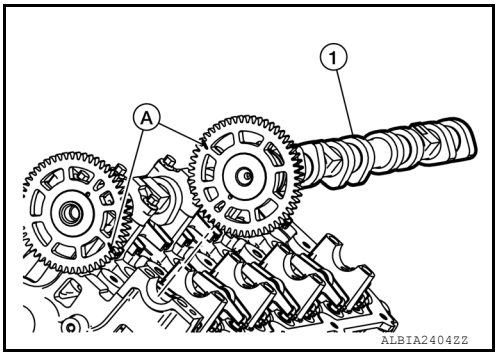
12. Tighten the bolts in the sequence shown to the specified torque.
NOTE:
Make sure the rockers arms have seated correctly.

Camshaft cap bolts : 11 N·m (1.1 kg-m, 8 ft-lb)

⇦ : Front

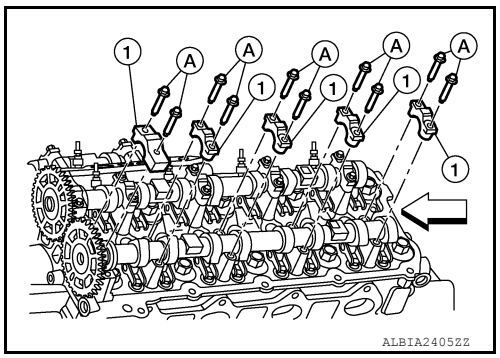


13. Install the exhaust camshaft (1). While holding the exhaust camshaft, engage the camshaft gears so that the timing marks (A) will align once the camshaft is placed in the camshaft towers. Carefully roll the exhaust camshaft in place while maintaining gear contact.



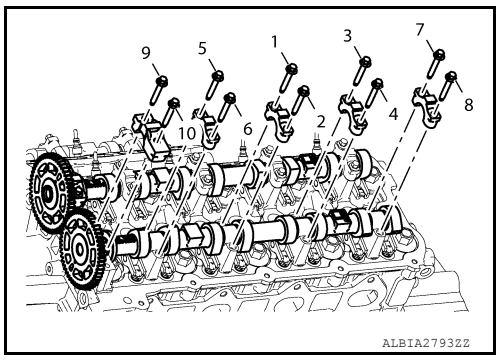
14. Install the camshaft caps (1) and finger-tighten the bolts (A).
NOTE:
The camshaft caps are labeled with their position and have an arrow that points toward the front.

⇦ : Front



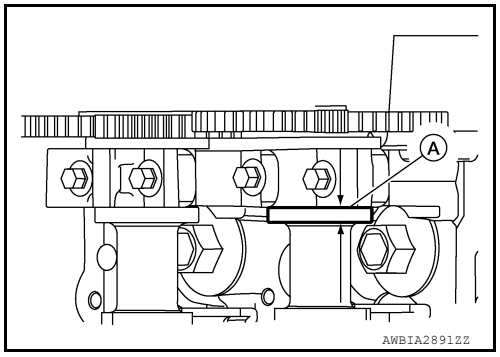
15. Tighten the bolts in the sequence shown to the specified torque.

Camshaft cap bolts : 11 N·m (1.1 kg-m, 8 ft-lb)



16. Measure camshaft end clearance (A) on each camshaft.

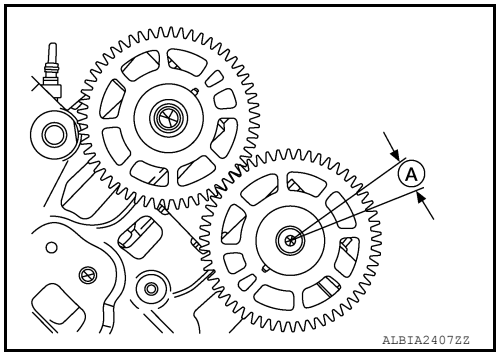
Camshaft end play : Refer to EM-529, "CAMSHAFT".



17. Measure gear backlash (A) on each camshaft gear.

Camshaft gear backlash : Refer to EM-529, "CAMSHAFT".

NOTE:
Gear backlash should be measured with the camshaft sprocket torqued to the camshaft. This will allow the intake camshaft to be held in place while backlash is measured on the exhaust camshaft gear.



18. Installation of the remaining components is in the reverse order of removal.
NOTE:
Operate the engine and check for leaks.

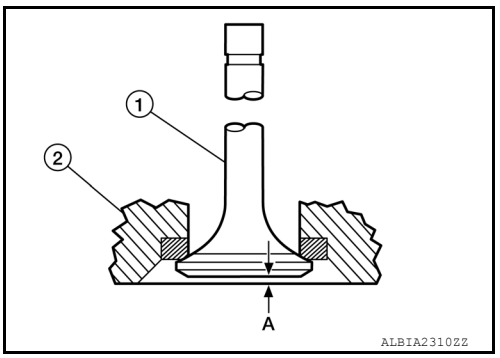
Disassembly and Assembly

INFOID:0000000014418673

INPECTION BEFORE DISASSEMBLY

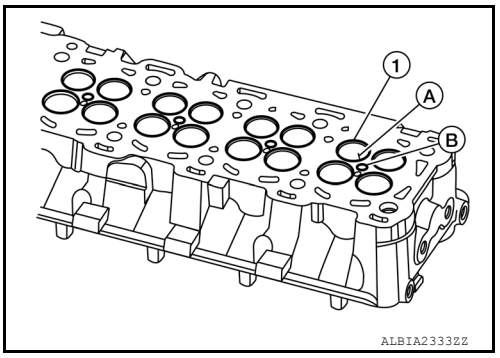
1. Measure the depth (A) of the valve (1) in the cylinder head (2). If measurements are out of specification, replace the cylinder head.

Standard : Refer to EM-530, "CYLINDER HEAD".

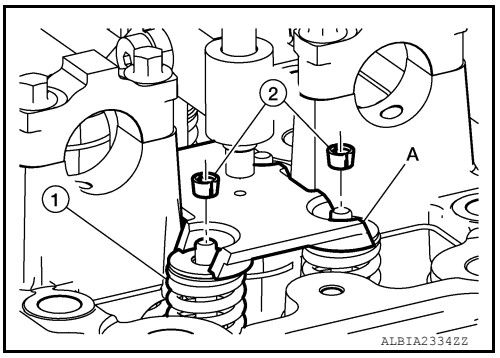


DISASSEMBLY

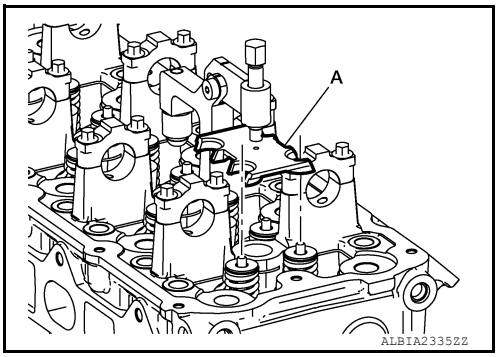
1. Mark the valves (1) to identify their locations and draw a line (A) on each valve toward the fuel injector bore (B).
NOTE:
The location of the mark on the valve will help identify the location of the valve in the cylinder head and its relation to the valve seat prior to removal.



2. Compress the valve springs (1) with suitable tool (A).
3. Remove the valve collets (2) with a suitable magnetic tool.
NOTE:
Use care to **not** drop the valve collets into the cylinder head.

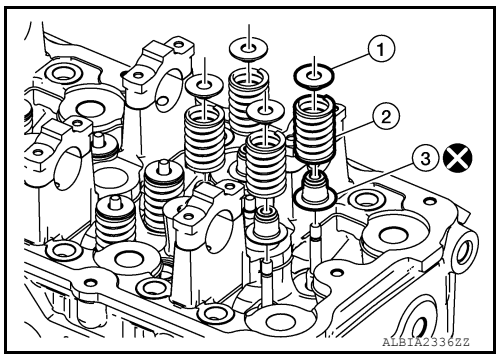


4. Remove the suitable tool (A).
NOTE:
Bank 2 shown, Bank 1 similar.

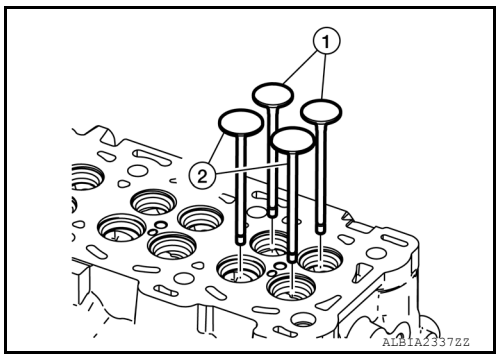


5. Remove the valve spring retainers (1) and valve springs (2).
6. Remove the valve guide seals (3).

CAUTION:
Do not reuse valve guide seal.
NOTE:
Bank 2 shown, Bank 1 similar.



7. Remove the intake valves (1) and exhaust valves (2).

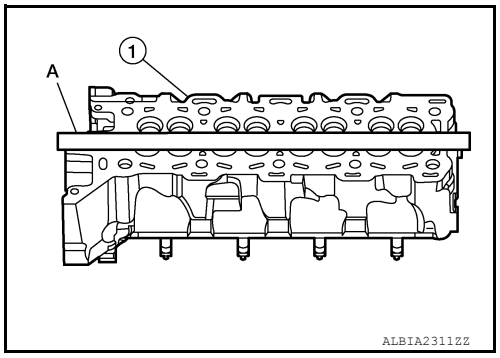


INSPECTION AFTER DISASSEMBLY

Cylinder Head Distortion

- Use a suitable tool (A) to inspect the cylinder head (1) combustion surfaces for flatness. If the cylinder head is not within specifications, it must be replaced.

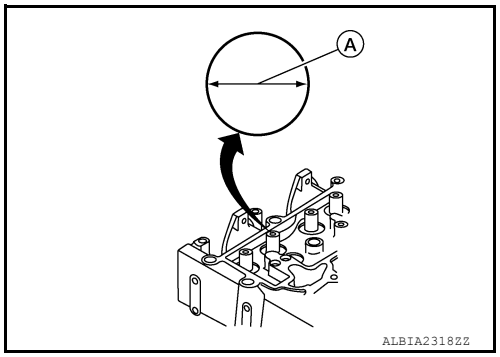
Standard and Limit : Refer to EM-530, "CYLINDER HEAD".



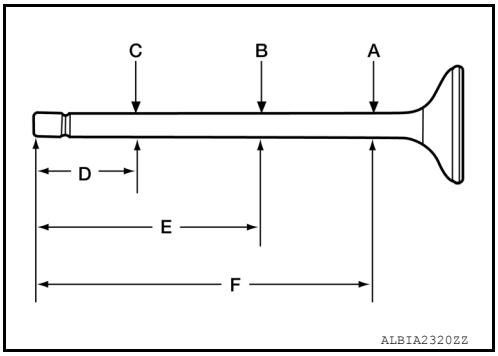
Valve Guide Clearance

- Measure the inside diameter (A) of the valve guides. If a valve guide is worn larger than specification or is damaged, replace the cylinder head.

Standard : Refer to EM-530, "CYLINDER HEAD".



- Measure the outside diameter of the valve stem near the center.
  NOTE:
  Three measurements **must** be performed on each valve stem. Measure from the small end of the valve, at locations (A), (B) and (C).



(D) : 22 mm (0.87 in)
(E) : 47 mm (1.85 in)
(F) : 72 mm (2.83 in)

Standard and Limit : Refer to EM-530, "CYLINDER HEAD".

- If the valves are damaged or the valve stems are worn smaller than the minimum specified, the valves **must** be replaced.

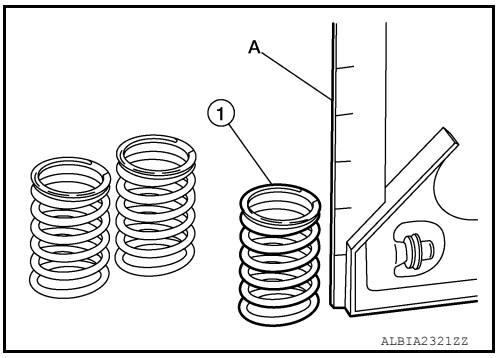
Valve Spring

- Measure the valve spring (1) free length.

Standard : Refer to EM-530, "CYLINDER HEAD".

- Place a suitable tool (A) adjacent to the valve spring and use a suitable tool to measure the clearance at the top spring coil.

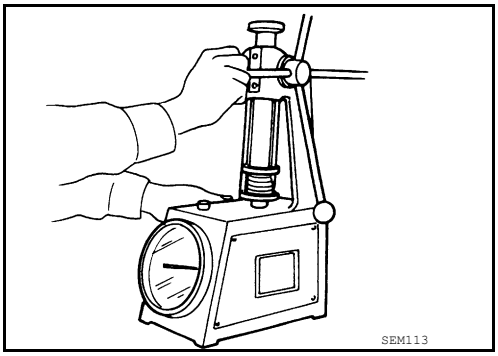
Standard : Refer to EM-530, "CYLINDER HEAD".



Valve Spring Pressure Load

- Compress the valve spring. If the valve spring is not within specification, replace the valve spring.

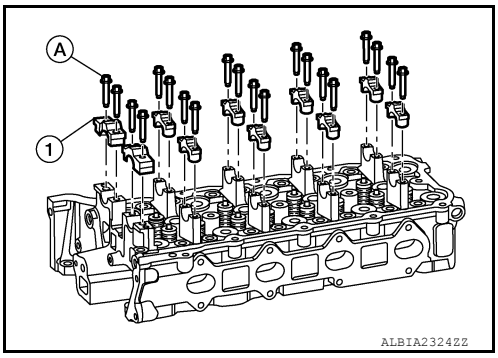
Standard : Refer to EM-530, "CYLINDER HEAD".



Camshaft Journal Clearance

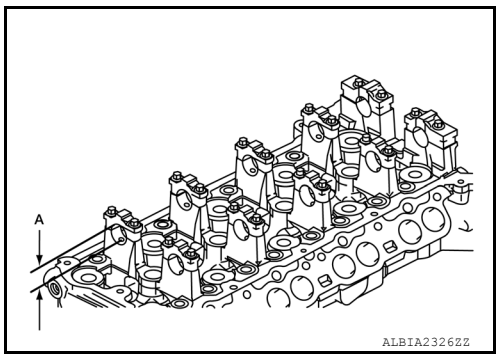
- Install the camshaft caps (1) and tighten bolts (A) to the specified torque.

Bolts (A) : 11 N·m (1.1 kg-m, 8 ft-lb)



- Measure the camshaft bores (A) using a suitable tool. If the camshaft bores are out of specification, replace the cylinder head.

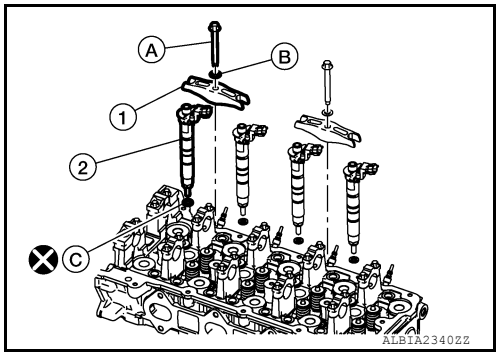
Standard : Refer to EM-530, "CYLINDER HEAD".



Injector Protrusion

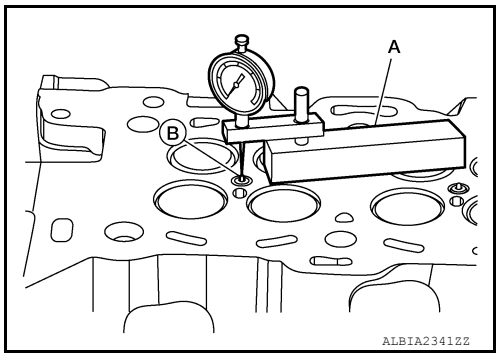
1. Install the injectors (2) with new sealing washers (C) into the cylinder head.
CAUTION:
Do not reuse sealing washers.
NOTE:
- Bank 2 shown, Bank 1 similar.
- Make sure the spherical washer (B) is installed with the flat side mating against the bolt (A).
- Injectors (2,4), (6,8), (1,3) and (5,7) are held down in pairs with one hold-down clamp (1) and bolt (A) between the injectors.

Step 1 : 24 N·m (2.4 kg-m, 18 ft-lb)
Step 2 : Tighten 90°



2. Measure the injector protusion (B) by installing suitable tool (A) on the cylinder head.
NOTE:
Record the measurement for each injector.

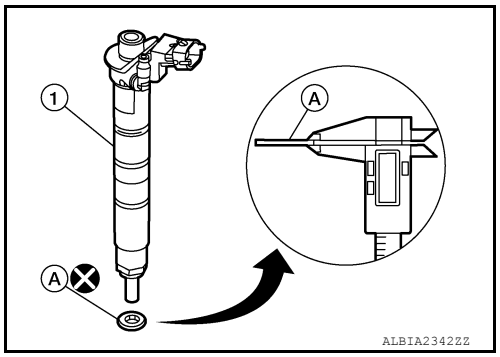
Standard : Refer to EM-530, "CYLINDER HEAD".



3. If the injector protrusion is out of specification, check the thickness of the injector sealing washer (A) using suitable tool.
NOTE:
If the injector sealing washer is the correct thickness, make sure the injector bore is clean and free of debris. Also make sure that injector sealing washers are **not** stacked in the injector bore.

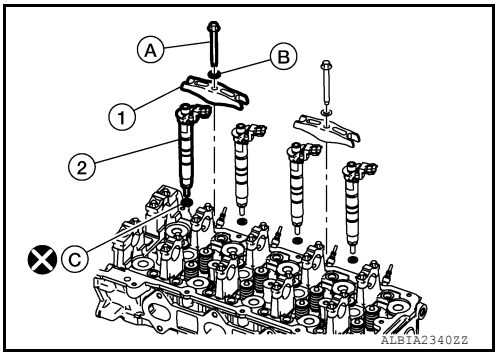
Injector sealing washer thickness : 2.5 mm (0.10 in)

(1) : Injector



4. If the injector protrusion is within specification, remove the injector (2) and discard the injector sealing washer (C).
CAUTION:
Do not reuse the injector sealing washers.

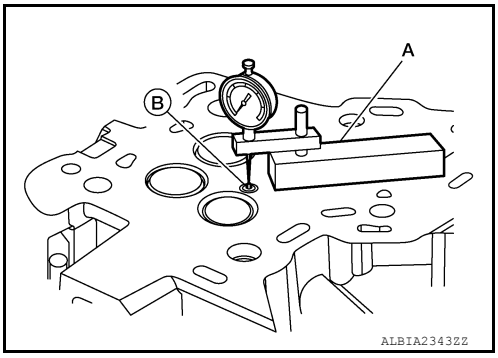
(1) : Hold-down clamp
(A) : Bolt
(B) : Spherical washer



Glow Plug Protrusion

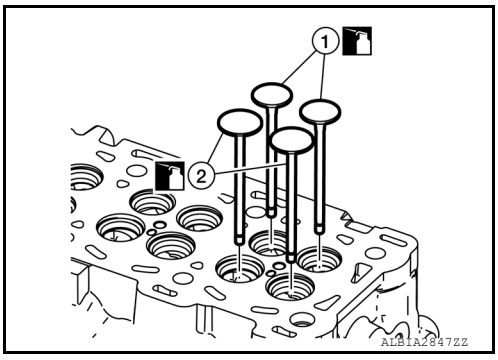
- Use the suitable tool (A) to measure the glow plug protrusion (B).
NOTE:
Record the glow plug protrusion for each glow plug.

Standard : Refer to EM-530, "CYLINDER HEAD".

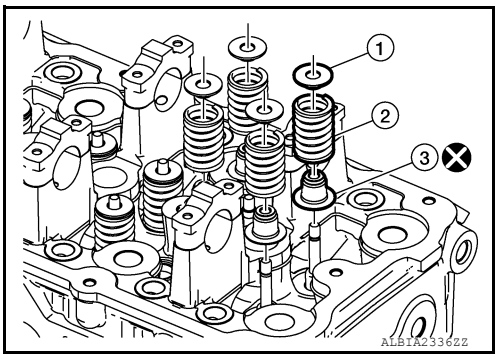


ASSEMBLY

1. Lubricate the valve stems with clean engine oil before installation.
2. Install the intake valves (1) and exhaust valves (2).
NOTE:
- The valves **must** be installed in the same location as marked during disassembly. Be sure the marks on the valves are aligned toward the injector bore.
- If the cylinder head will **not** be used immediately, apply a coating of preservative oil and cover the cylinders to prevent dirt from sticking to the oil.



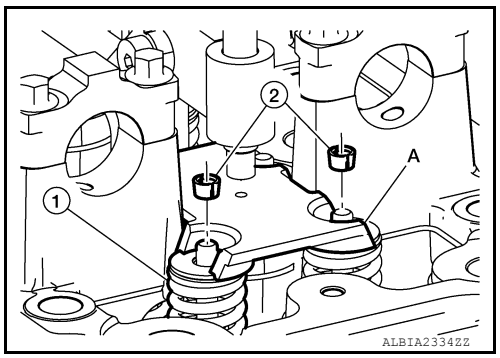
3. Install the valve guide seals (3), valve springs (2) and valve spring retainers (1).
CAUTION:
Do not reuse valve guide seal.



4. Compress the valve springs (1) with suitable tool (A).

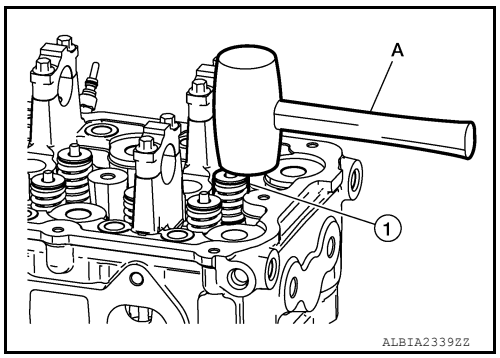
WARNING:
Valve springs are under tension and can act as projectiles if released. To reduce the possibility of eye injury, wear safety glasses with side shields.

5. Install the valve collets (2) and remove the suitable tool.



6. After assembly, strike the valve spring retainers (1) with a suitable tool (A) to make sure the valve collets are seated.

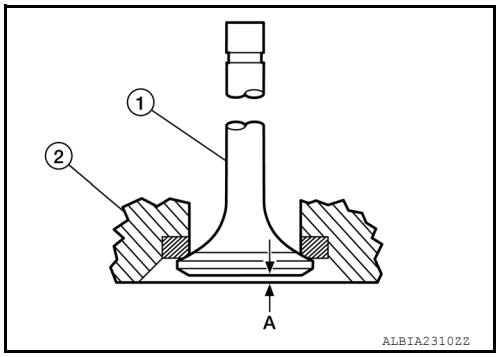
WARNING:
Valve springs are under tension and can act as projectiles if released. To reduce the possibility of eye injury, wear safety glasses with side shields.



7. Measure the valve depth (A). If the measurement is out of specification, replace the cylinder head.

Standard : Refer to EM-530, "CYLINDER HEAD".

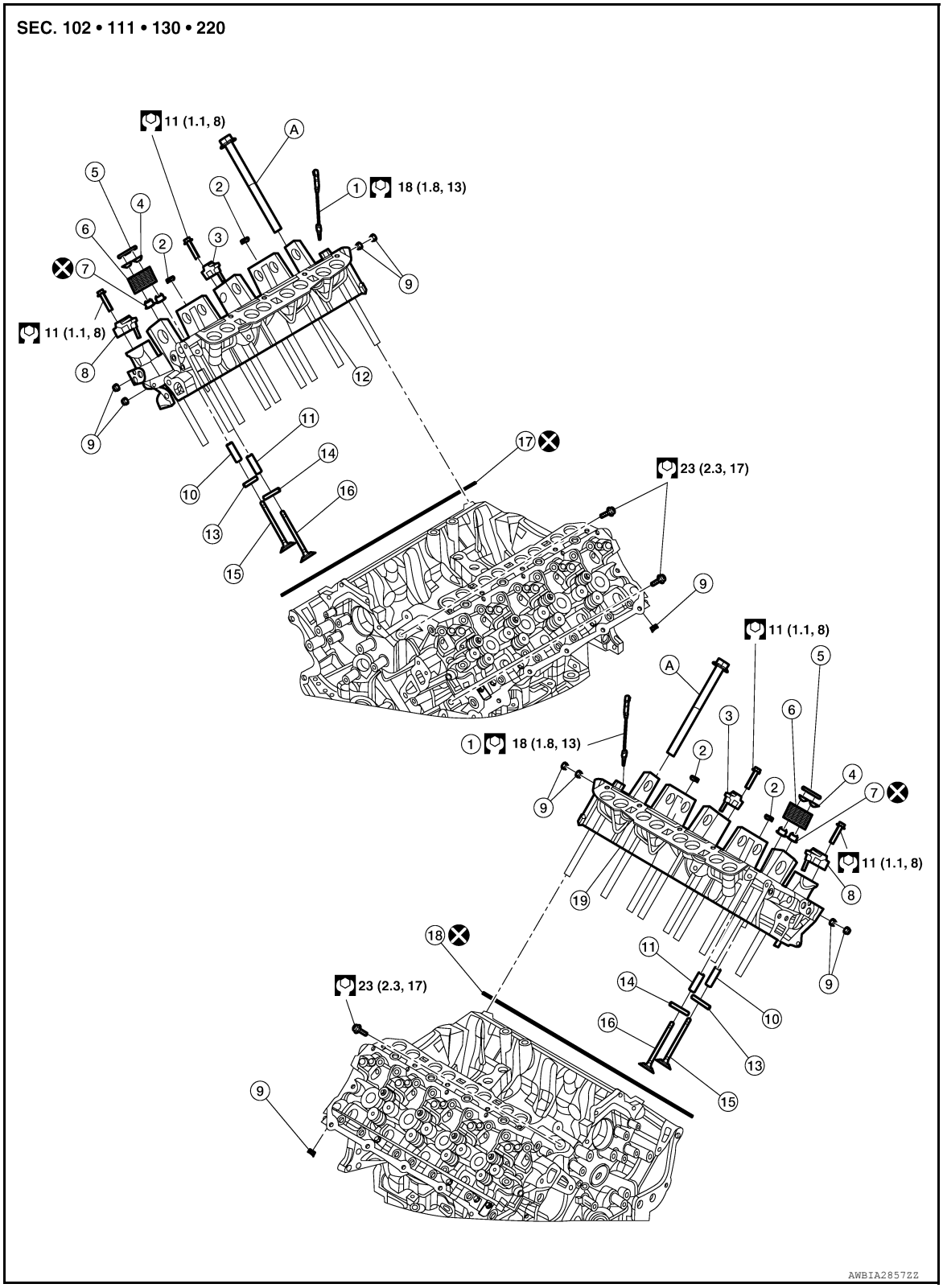
(1) : Valve
(2) : Cylinder head



VALVE GUIDE SEAL

Exploded View

INFOID:0000000014418674



1. Glow plug
2. Welch plug
3. Camshaft cap
4. Valve spring retainer
5. Valve collet
6. Valve spring
7. Valve guide seal
8. Camshaft cap
9. Welch plug

10. Exhaust valve stem guide
11. Intake valve stem guide
12. Cylinder head (bank 1)
13. Exhaust valve insert
14. Intake valve insert
15. Exhaust valve
16. Intake valve
17. Cylinder head gasket (bank 1)
18. Cylinder head gasket (bank 2)
19. Cylinder head (bank 2)
A. Refer to INSTALLATION

CAUTION:
Valve collet and valve (intake or exhaust) are serviced as an assembly.

Removal and Installation

INFOID:0000000014418675

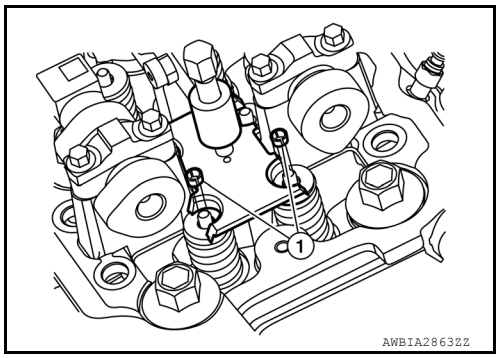
GENERAL INFORMATION

- The following procedure describes how to remove the valve guide seals with the cylinder heads installed. This procedure can also be used to remove the valve springs, spring retainers, and valve collets with the cylinder heads installed.

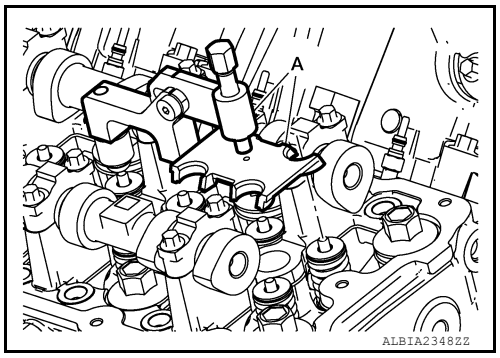
REMOVAL

NOTE:
This valve guide seal replacement procedure is to be completed one cylinder at a time.

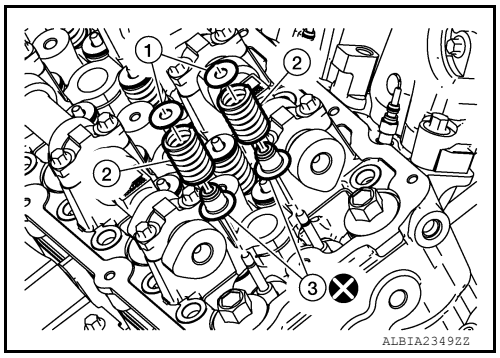
1. Remove the rocker arm. Refer to EM-326, "Removal and Installation".
2. Remove the valve collets (1) with a magnetic tool. Use care **not** to drop the valve collets into the cylinder head.
   CAUTION:
   Once the valve collets are removed, do not bar the engine over until the valve springs, seals, and collets are installed.
   NOTE:
   Use a lint-free cloth to cover openings in the cylinder head to prevent the valve collets from falling into the engine.



3. Remove the suitable tool (A).



4. Remove the valve spring retainers (1) and valve springs (2).
5. Remove the valve guide seals (3).
   CAUTION:
   Do not reuse valve guide seal.



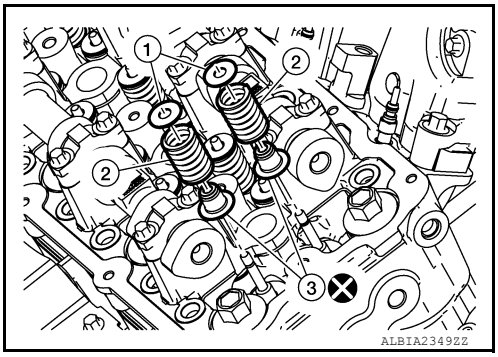
INSPECTION AFTER REMOVAL

- Inspect the valve stems and cylinder head for debris or damage.
- If the valve stems or the cylinder head are damaged, replace the cylinder head.
- Inspect the rocker arms, valve springs, collet retainers, and valve guide seals for excessive wear, cracks, and other damage.

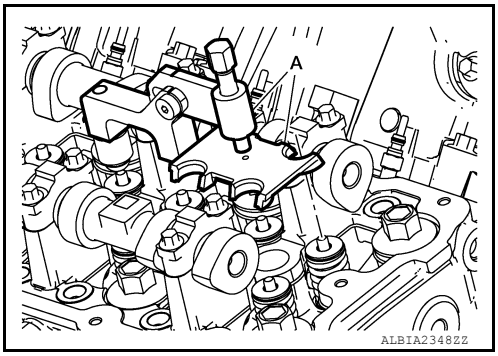
• Replace all damaged components.

INSTALLATION

1. Lubricate the valve stems with clean engine oil.
2. Install the valve guide seals (3) and press them to the bottom of the cylinder head.
3. Install the valve springs (2) and retainers (1).
   CAUTION:
   Do not reuse valve guide seal.

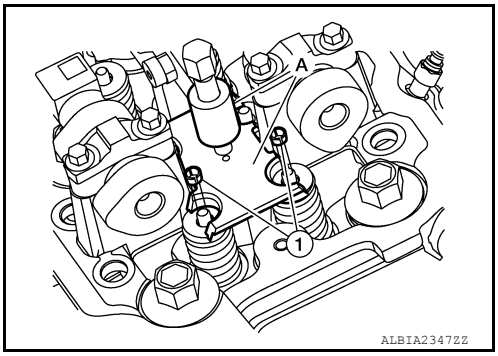


4. With the piston for the current cylinder at TDC, compress the valve springs using suitable tool (A).

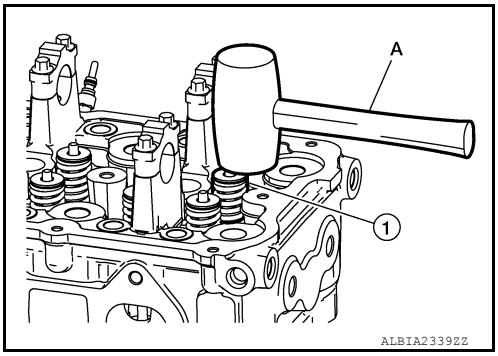


5. Install the valve collets (1).
   NOTE:
   Use a lint-free cloth to cover openings in the cylinder head to prevent the collets from falling into the engine.

   (A) : Suitable tool



6. Remove the suitable tool and strike the valve stems (1) with a suitable tool (A) to make sure the valve collets are seated.
   NOTE:
   Repeat the above steps for all other cylinders that require repair.

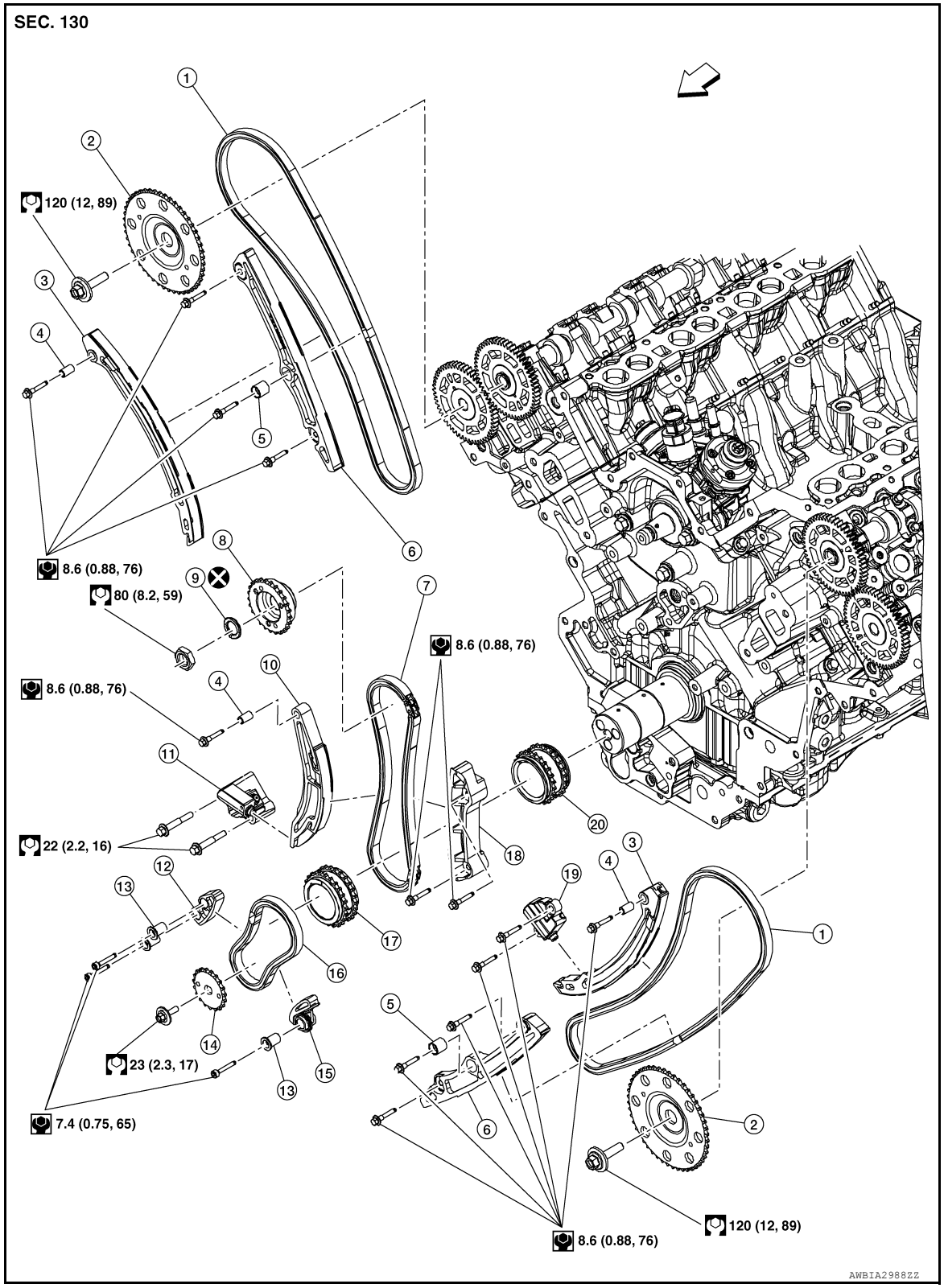


7. Installation of the remaining components is in the reverse order of removal.
   NOTE:
   Operate the engine and check for leaks.

CAMSHAFT DRIVE CHAIN

Exploded View

INFOID:0000000014418676



1. Camshaft timing chain
2. Camshaft sprocket
3. Slack guide
4. Bushing
5. Bushing
6. Camshaft tension guide
7. Fuel pump timing chain
8. Fuel pump sprocket
9. Washer

10. Fuel pump tensioner guide
11. Dual timing chain tensioner (bank 1)
12. Oil pump tensioner guide
13. Bushing
14. Oil pump sprocket
15. Oil Pump Chain Tensioner / Guide
16. Oil pump drive chain
17. Crankshaft sprocket (oil/fuel pump)
18. Fuel pump slack guide
19. Camshaft chain tensioner (bank 2)
20. Crankshaft sprocket (camshaft)
⇦ Front

Removal and Installation

INFOID:0000000014418677

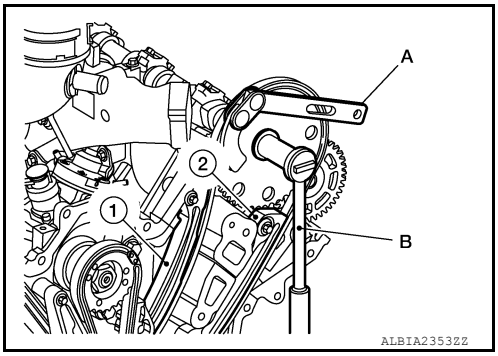
GENERAL INFORMATION

CAUTION:

Loosening and tightening the camshaft, oil pump, and fuel pump sprocket bolts must be completed with the aid of a suitable tool. Damage to the chain can occur.

- It is very important to avoid loading the chain while loosening and tightening the bolts on the camshaft, fuel and oil pump sprockets. Always hold the sprockets with a suitable tool (A) when loosening or tightening the bolts with a suitable tool (B).

(1) : Slack guide
(2) : Camshaft tension guide

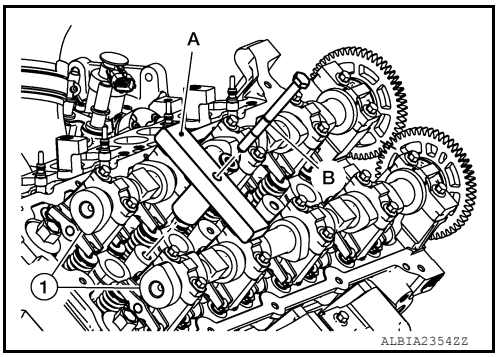


- **NOTE:**
  If there is a lack of tension on the fuel pump or camshaft timing chains after removing the front cover, this does not indicate chain tensioner failure. The chain tensioners are fed oil pressure to keep tension on the chains. During removal, the chains may not be under full tension, this does not warrant replacement.

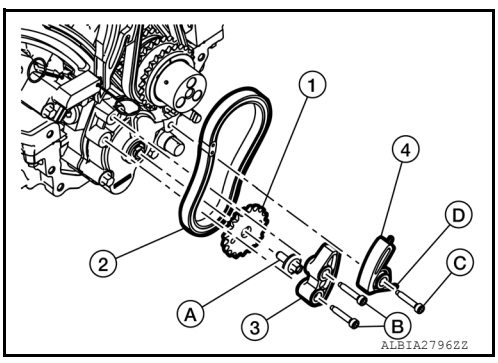
REMOVAL

1. Remove the front cover. Refer to EM-338, "Removal and Installation".
   NOTE:
   The blue links on the fuel pump timing chain may not align with the crankshaft sprocket (camshaft) and fuel pump sprocket timing marks, as outlined in the installation steps. This is acceptable due to an odd number of links in the timing chains.
2. Lock the intake and exhaust camshafts (1) for bank 1 and bank 2 in place with Tool (A) and tighten bolt (B).
   NOTE:
   - Bank 1 shown, Bank 2 similar.
   - It may be necessary to rotate the camshafts slightly using a suitable tool on the camshaft flats to get the camshaft flats to align with the Tool.

   Tool (A) : — (J-54409)
   Bolt (B) : 25 N·m (2.6 kg-m, 18 ft-lb)

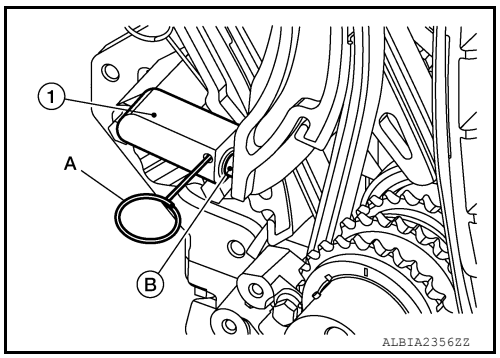


3. Release the oil pump slack guide spring (D). Remove the bolt (C) and slack guide (4).
4. Remove bolts (B) and remove the oil pump tension guide (3).
5. Hold the oil pump sprocket with a suitable tool and remove the oil pump sprocket bolt (A).
6. Remove the oil pump sprocket (1) and oil pump drive chain (2).



7. On the dual timing chain tensioner [bank 1 (1)], push the front plunger (B) into the dual timing chain tensioner [bank 1 (1)].
8. Insert Tool (A) into dual timing chain tensioner [bank 1 (1)].
NOTE:
Slowly release pressure on the plunger and ensure the Tool is engaged and tension is relieved from the timing chain.

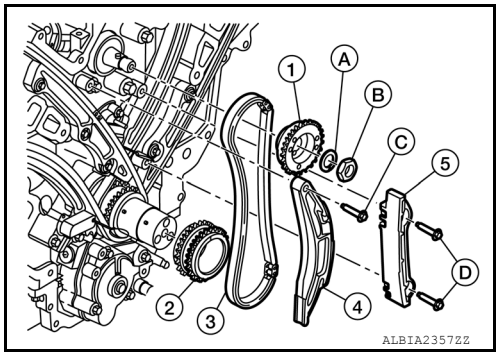
Tool (A) : — (J-54418)



9. Remove bolt (C) and the fuel pump slack guide (4).
10. Remove bolts (D) and remove the fuel pump tension guide (5).
11. Hold the fuel pump sprocket (1) using Tool and loosen the nut (B).
CAUTION:
Do not reuse the washer (A).

Tool : — (J-54411)

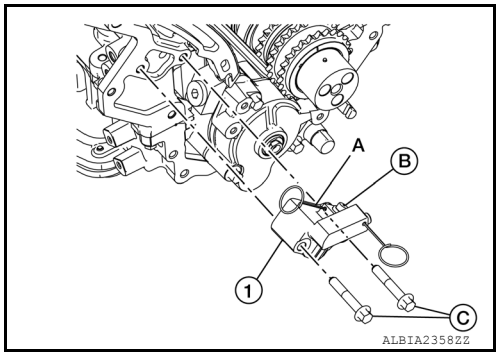
12. Remove the fuel pump timing chain (3) and crankshaft sprocket [oil/fuel pump (2)].



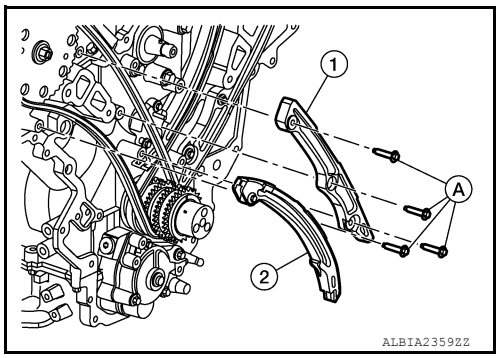
13. On the dual timing chain tensioner [bank 1 (1)], push the rear plunger (B) into the dual timing chain tensioner.
14. Insert Tool (A) into dual timing chain tensioner [bank 1 (1)].
NOTE:
Slowly release pressure on the plunger and ensure the Tool is engaged and tension is relieved from the timing chain.

Tool (A) : — (J-54418)

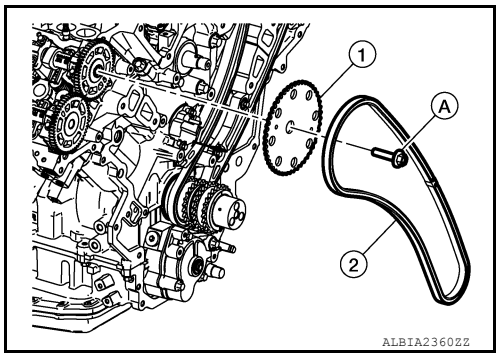
15. Loosen bolts (C) for the camshaft chain tensioner (1) and remove.



16. Remove bolts (A) and remove the camshaft tension guide [bank 1 (1)] and slack guide [(bank 1 (2)].
NOTE:
Remove the bushings from the camshaft tension guide (bank 1) and slack guide (bank 1) (if necessary).

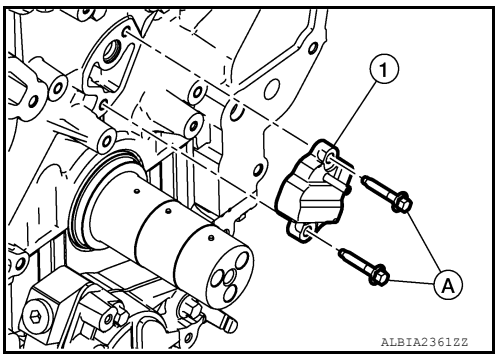


17. Hold the cam sprocket [bank 1 (1)] with a suitable tool and loosen bolt (A).
18. Remove the camshaft sprocket (bank 1) and camshaft timing chain (2).

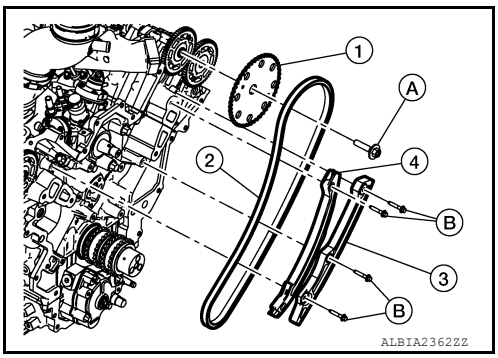


19. On the camshaft chain tensioner [bank 2 (1)] push the plunger into the camshaft chain tensioner body.
20. Insert the Tool into the camshaft chain tensioner (bank 2).
    NOTE:
    Slowly release pressure on the plunger and make sure the Tool is engaged and tension is relieved from the camshaft timing chain.

    Tool : — (J-54418)
21. Remove bolts (A) and remove the camshaft chain tensioner.



22. Remove bolts (B) and remove the camshaft timing chain slack guide [bank 2 (3)] and tension guide [bank 2 (4)].
    NOTE:
    Remove the bushings from the camshaft tension guide (bank 2) and slack guide (bank 2) (if necessary).
23. Hold the camshaft sprocket [bank 2 (1)] with a suitable tool and loosen bolt (A).
24. Remove bolt (A) and remove the camshaft sprocket [bank 2 (1)], and camshaft timing chain [bank 2 (2)].



25. Remove the crankshaft sprocket from the crankshaft.

INSPECTION AFTER REMOVAL

WARNING:

- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufactures recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**

- Do not exceed 30 psi (207 kPa).
- Wear appropriate eye protection and protective clothing including gloves.

- Clean the sprockets, tension guides, and slack guides with solvent and dry with compressed air.
- Coat the components with clean engine oil. Cover with a clean cloth to prevent contamination.
- Do **not** clean the chains or tensioners with solvent or submerge in a wash tank.
- Do **not** disassemble the tensioner. Cleaning and inspection should take place with the Tool in place. Wipe the tensioners down with a clean towel. Inspect for contamination.

Tool : — (J-54418)

Timing Chains

- Inspect the chains for broken links and other damage.
- Check that the links move freely.
- If damage is found, replace the chain.
- Discoloration or sharp edges indicate over-heating. Over-heating can be caused by low oil pressure, excessive oil pressure, excessive chain tension, or improper assembly of the chain drive system.
- If cleaning is required, the chains can be cleaned with a brush and clean engine oil. If the chains will **not** be reused immediately coat the chains in clean engine oil and place in a container to prevent contamination.

Timing Chain Tensioners

- Inspect the oil pump tensioner/guide assembly for damage.
- Inspect the fuel pump and camshaft tensioners for damage and proper operation.
- Inspect the chain tensioner housings for cracks.
- If any of the tensioners are damaged, replace the tensioner.

Sprockets

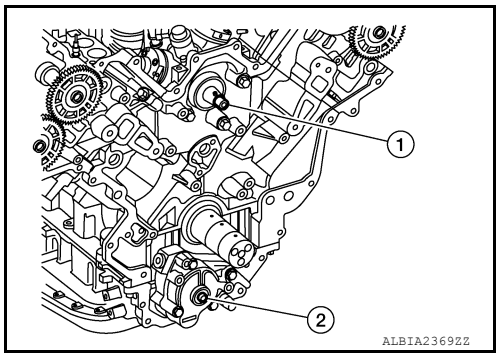
- Inspect the sprockets for broken or bent teeth, cracking, wear, warpage, or other damage.
- Polishing at the valley of the teeth is normal.
- If any of the sprockets are damaged, replace the sprocket.

Tension Guides and Slack Guides

- Inspect the guides, arms, and pivots for galling, cracks or excessive wear. Replace if damage is present.

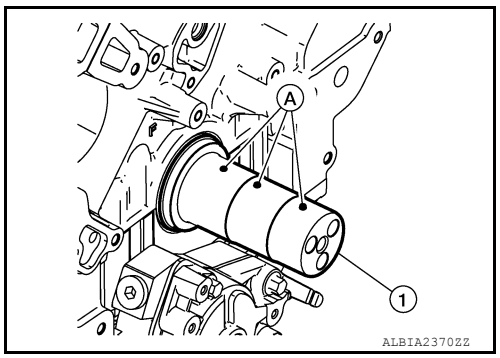
Oil and Fuel Pump

- Inspect the lubricating oil pump (2) and fuel pump (1) drive shafts.
- If damage is suspected, remove the pumps for further inspection. Refer to LU-51, "Exploded View" (OIL PUMP) or EM-429, "Exploded View" (FUEL PUMP).



Crankshaft

- Inspect the crankshaft (1) for damage.
- Discoloration of the crankshaft nose is normal.
- If the dowel pins (A) are bent or missing, the crankshaft **must** be replaced. Refer to EM-502, "Exploded View".



If any components in the chain drive are damaged, inspect the lubricating oil system for debris and address any progressive damage.

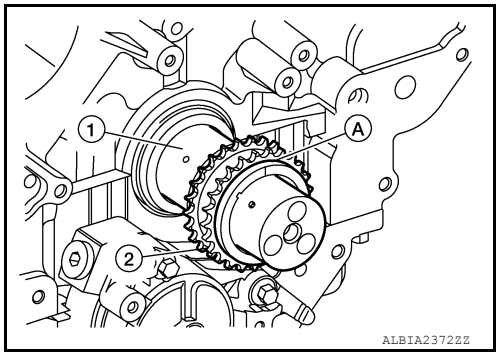
INSTALLATION

1. If the crankshaft has been removed or rotated after timing chain drive removal, follow these steps to place the crankshaft at TDC for cylinder number 1.

a. Install the crankshaft sprocket (oil/fuel pump) (2) on the crankshaft (1).

b. Use Tool to rotate the crankshaft until the mark (A) on the crankshaft sprocket (oil/fuel pump) (2) is at the top.

Tool : — (J-54401)



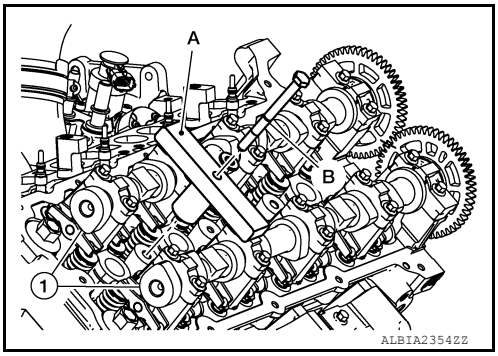
c. Remove the crankshaft sprocket (oil/fuel pump) (2).

CAUTION:
If the camshafts have been installed with the engine not at top dead center for cylinder 1, the rocker arms will have been improperly loaded and must be replaced.

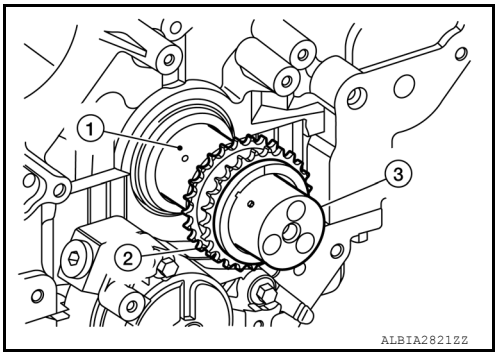
2. Install the Tool (A) on the camshafts (1) for bank 1 and bank 2.

Tool (A) : — (J-54409)

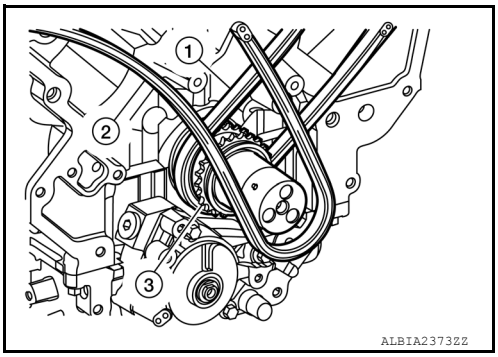
Bolt (B) : 25 N·m (2.6 kg-m, 18 ft-lb)



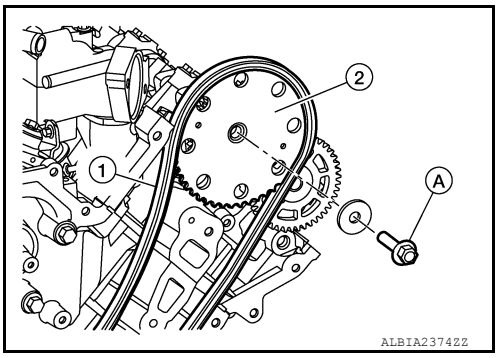
3. Align the rear crankshaft sprocket (2) with the crankshaft dowel pins (1) and slide onto the crankshaft (3).



4. Install the camshaft timing chain [bank 2 (1)] first and then install the camshaft timing chain [bank 1 (2)].
NOTE:
The camshaft timing chain (bank 2) goes on the rear teeth of the crankshaft sprocket (3).



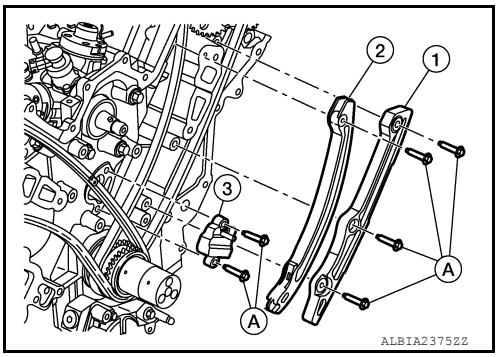
5. Install the camshaft timing chain [bank 2 (1)] to the camshaft sprocket [bank 2 (1)]. Finger-tighten bolt (A).
CAUTION:
- **Make sure the camshaft and camshaft sprocket are properly seated before tightening the camshaft sprocket bolt or the camshaft will be damaged.**
- **Do not tighten the camshafts in this step. The camshaft sprockets need to turn slightly once chain tension is applied, before the final torque, to maintain proper timing.**



6. Install the camshaft timing chain tension guide [bank 2 (1)], the camshaft timing chain slack guide [bank 2 (2)], the camshaft timing tensioner [bank 2 (3)], and tighten bolts (A). Verify that the left camshaft drive chain runs across the camshaft tension guide and camshaft chain tensioner.

Bolt (A) : 8.6 N·m (0.9 kg-m, 6 ft-lb)

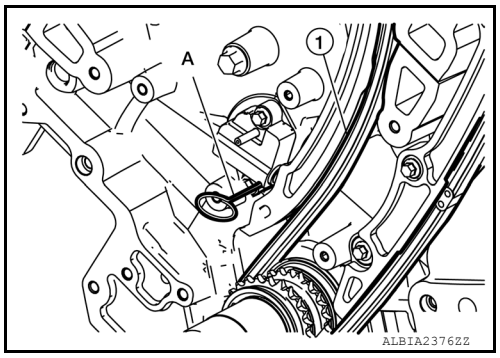
NOTE:
- Make sure bushings are installed in camshaft timing chain tension guide (bank 2) before installation.



- Make sure the bushing are installed in camshaft timing chain slack guide [bank 2 (1)] before installation.

7. Remove the Tool (A) to apply tension to the camshaft timing chain (1).

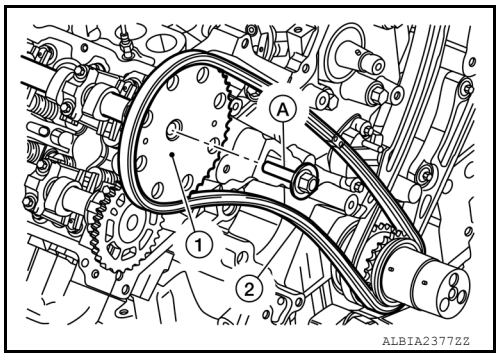
Tool : (J-54418)



8. Install the camshaft timing chain [bank 1 (1)] on the camshaft sprocket [bank 1 (2)]. Hand-tighten the camshaft bolt (A).

CAUTION:

- **Make sure the camshaft and camshaft sprocket are properly seated before tightening the camshaft sprocket bolt or the camshaft will be damaged.**
- **Do not tighten the camshafts in this step. The camshaft sprockets need to turn slightly once chain tension is applied, before the final torque, to maintain proper timing.**

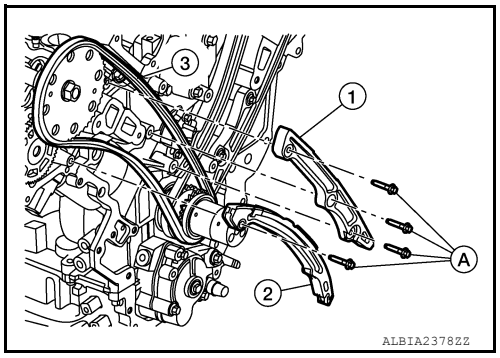


9. Install the camshaft timing chain tension guide [bank 1 (1)] and slack guide [bank 1 (2)] and tighten the bolts (A).

NOTE:

Verify that the camshaft timing chain [bank 1 (3)] runs across the slack guide (2) and tension guide (1).

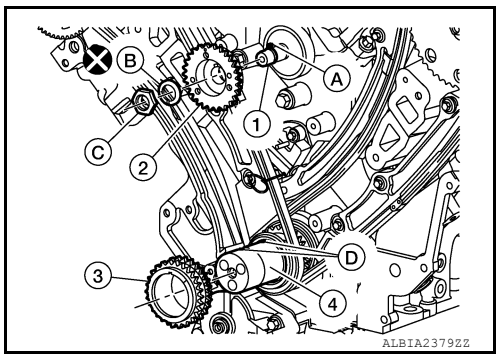
Bolt (A) : 8.6 N·m (0.9 kg-m, 6 ft-lb)



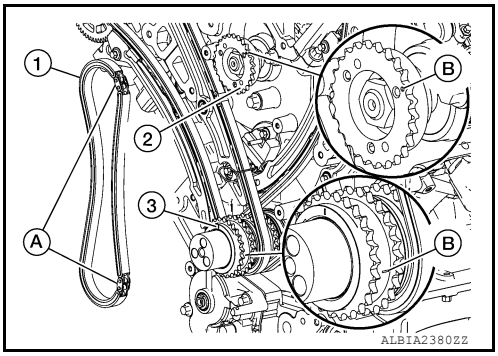
10. Align the crankshaft sprocket (3) with the crankshaft dowel pins (D) and install the crankshaft sprocket on the crankshaft (4).
11. Align the fuel pump sprocket (2) with the fuel pump dowel pin (A) and install it on the fuel pump (1).
12. Finger-tighten the fuel pump sprocket nut (C).

CAUTION:

Do not reuse the washer (B).

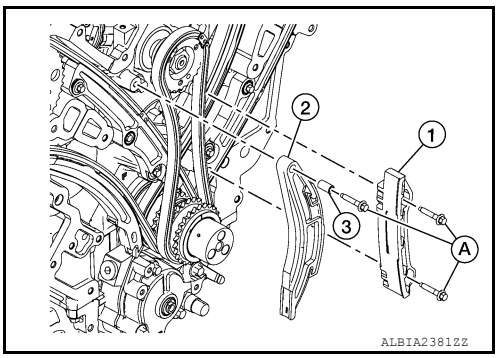


13. Install the fuel pump timing chain (1) on the fuel pump sprocket (2) and the crankshaft sprocket (oil/fuel pump) (3). Place the fuel pump timing chain on the rear teeth of the crankshaft sprocket (oil/fuel pump). Match the blue links (A) with the timing marks (B) on both sprockets.
NOTE:
The fuel pump shaft and sprocket may have turned slightly during disassembly. To align the fuel pump with cylinder number 1 TDC, it can be necessary to put the sprocket on and align it using a suitable tool.



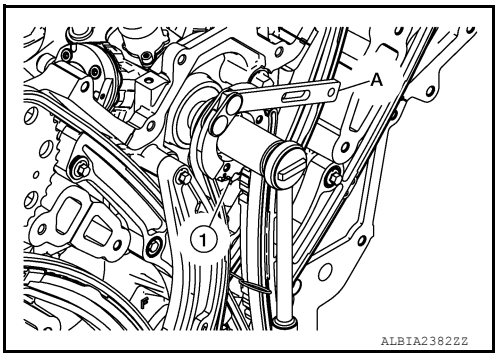
14. Install the fuel pump tension guide (1), slack guide (2) and tighten the bolts (A).
NOTE:
- Make sure bushing (3) is installed in the fuel pump chain slack guide (2) before installation.
- Verify that the fuel pump chain runs across the guide and tensioner arm.

Bolt (A) : 8.6 N·m (0.9 kg-m, 6 ft-lb)



15. Tighten the nut for the fuel pump sprocket (1) while holding the sprocket with a suitable tool (A).

Bolt (A) : 80 N·m (8.2 kg-m, 59 ft-lb)

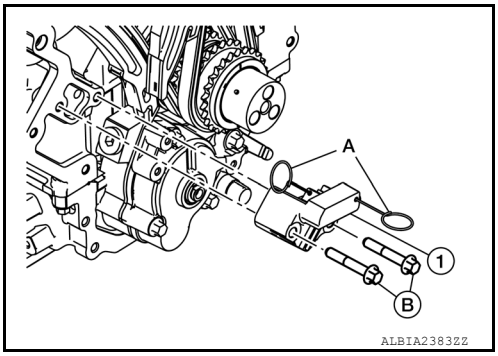


16. Install the dual timing chain tensioner [bank 1 (1)] and tighten bolts (B).

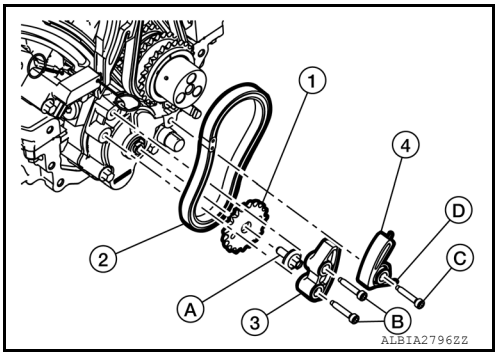
Bolts (B) : 22 N·m (2.2 kg-m, 16 ft-lb)

17. Remove Tool (A) from the dual timing chain tensioner [bank 1 (1)] to apply tension to the chains.
NOTE:
Check that the slack has been removed from the chains.

Tool : (J-54418)

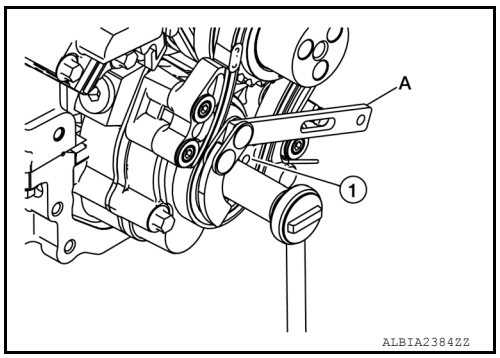


18. Install the oil pump sprocket (1) and finger-tighten bolt (A). Install the oil pump drive chain (2) on the oil pump sprocket and crankshaft sprocket (oil /fuel pump).
19. Install the oil pump tensioner guide (3) and tighten the bolts (B).
20. Install the oil pump tensioner and oil pump slack guide (4) and tighten bolt (C).
21. Install the leg (D) of the tensioner spring in the slot in the arm.
NOTE:
Verify that the oil pump chain runs across the slack guide and tension guide. Check for excessive slack in the oil pump chain.



22. Tighten the bolt for the oil pump sprocket (1) while holding the sprocket with a suitable tool (A).

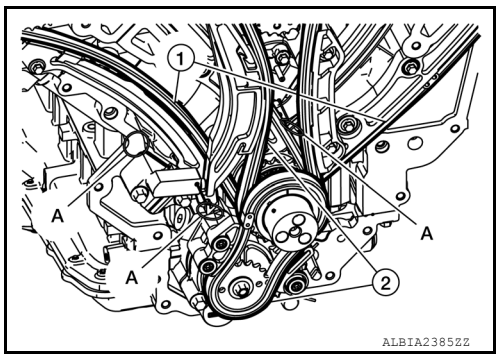
Bolt : 23 N·m (2.3 kg-m, 17 ft-lb)



23. Check that Tools (A) have been removed from chain tensioners.

CAUTION:
- **Releasing and tightening the camshaft sprockets (bank 1) and (bank 2) releases any unwanted tension in the chain due to installation which will affect the engine's timing once the Tool is released.**
- **Make sure the camshaft and camshaft sprocket are properly seated before tightening the camshaft sprocket bolt or the camshaft will be damaged.**

Tool : — (J-54409)



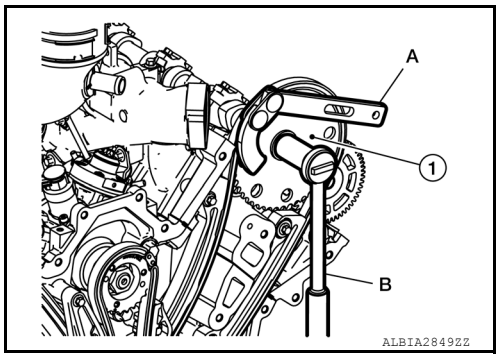
NOTE:
Check for slack in the camshaft timing chains [bank 1 (1)] and [bank 2 (1)], fuel pump timing and oil pump drive chains (2).

24. Tighten the camshaft sprocket bolts [bank 1 (1)] and [bank 2 (2)] while holding the camshaft sprocket (1) with a suitable tool (A).

CAUTION:
Loosening and tightening the camshaft, oil pump, and fuel pump sprocket bolts must be completed with the aid of a suitable tool. Damage to the chain can occur.
- It is very important to avoid loading the chain while loosening and tightening the bolts on the camshaft, fuel and oil pump sprockets. **Always** hold the sprockets with a suitable tool (A) when loosening or tightening the bolts with a suitable tool (B).

NOTE:
Bank 1 shown, Bank 2 similar.

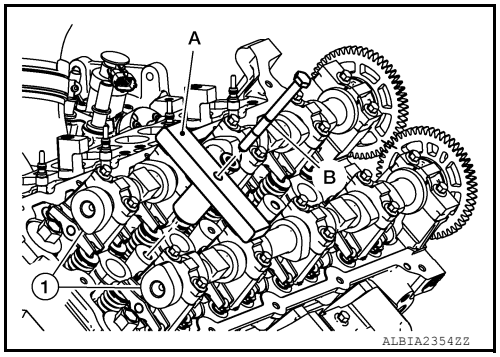
Camshaft sprocket bolt : 120 N·m (12 kg-m, 89 ft-lb)



25. Remove the bolt (B) and remove Tool (A) from the camshafts (1).

NOTE:
- Bank 1 shown, Bank 2 similar.
- After removing Tool, rotate the engine over two full revolutions using Tool and observe to make sure the timing chains operate smoothly.

Tool : — (J-54409)
: — (J-54401)



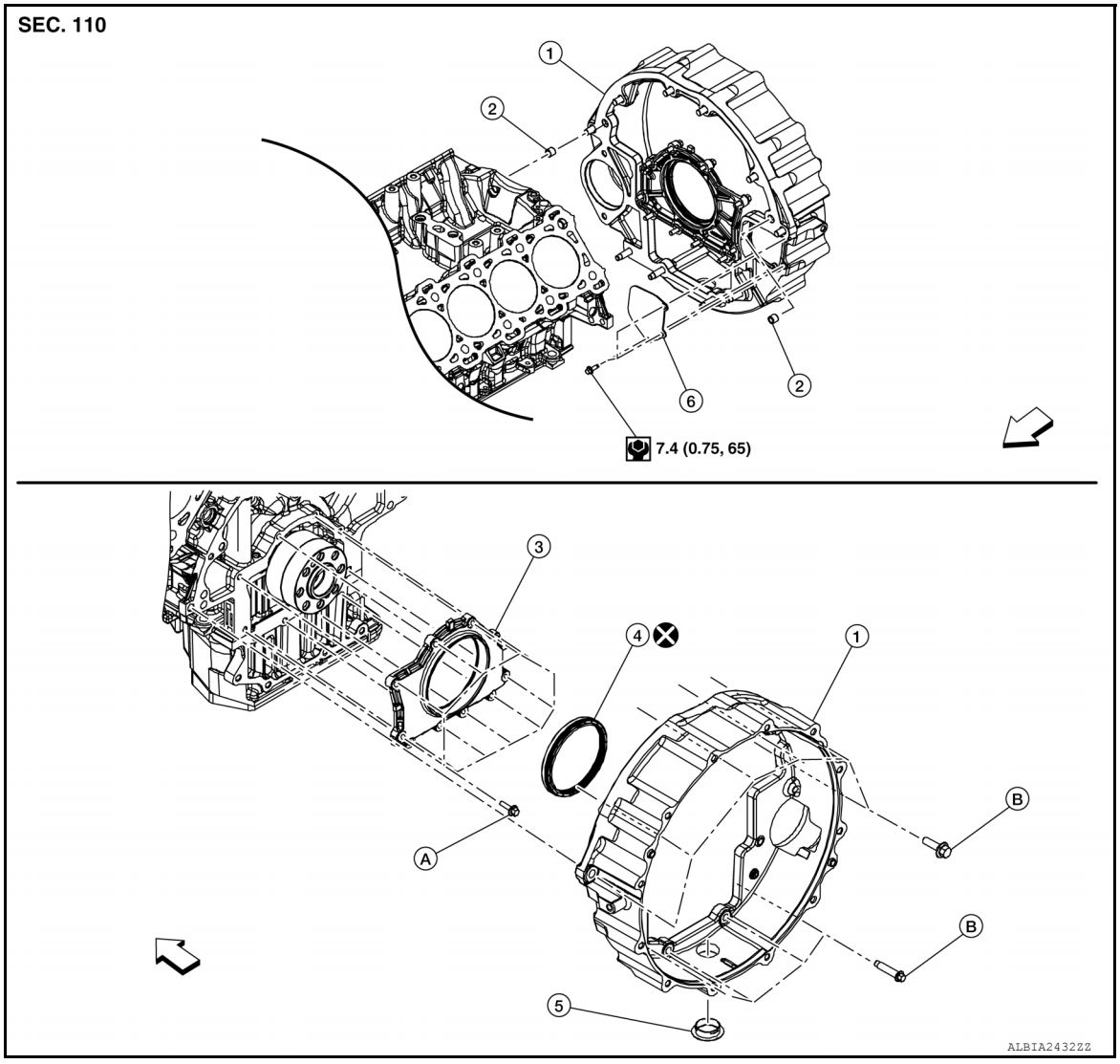
26. Installation of the remaining components is in the reverse order of removal.

NOTE:
- If the drive chain was removed and reinstalled or removed and replaced, in CONSULT click the Timing button on the Fuel or Timing System Table Reset in Work Support. Refer to EC-806, "CONSULT Function".
- Operate the engine and check for leaks.

FLYWHEEL HOUSING

Exploded View

INFOID:0000000014418678



1.	Flywheel housing	2.	Dowel	3.	Seal carrier
4.	Rear oil Seal	5.	Plug	6.	Access cover
A.	Refer to EM-393, "Removal and Installation - Rear Oil Seal".	B.	Refer to INSTALLATION	⇦	Front

Removal and Installation

INFOID:0000000014418679

REMOVAL

WARNING:

- **To avoid the risk of personal injury by moving or shifting drive train components, always properly support the drive train components not being removed.**
- **To avoid the risk of personal injury, use lifting equipment or acquire assistance when lifting components or assemblies that weight more than 23 kg (50 lbs).**

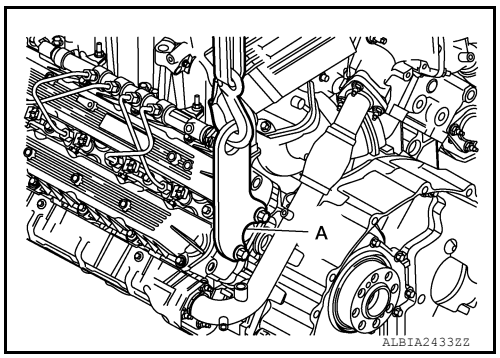
1. Remove the flexplate. Refer to EM-388, "Removal and Installation".

2. Install Tool (A) to support the rear of the engine.

WARNING:
To avoid the risk of personal injury from a falling or shifting engine. Use only lifting equipment designed to lift the weight of the engine and transmission assemblies safely. To determine the weight of the engine and transmission assemblies refer to EM-529, "GENERAL SPECIFICATIONS" and TM-257, "General Specification".

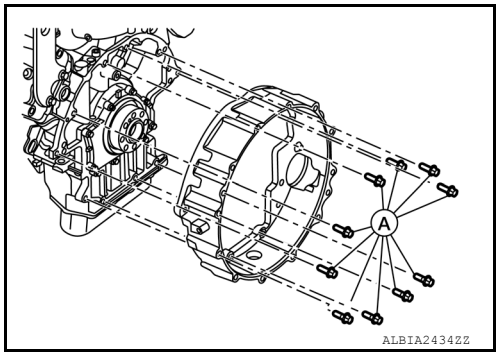
Tool A : — (J-54419)

Engine slinger bolts : 64 N·m (6.5 kg-m, 47 ft-lb)



3. While supporting the flywheel housing, remove bolts (A) and the flywheel housing.

WARNING:
To avoid the risk of personal injury, use lifting equipment or acquire assistance when lifting components or assemblies that weight more than 23 kg (50 lbs).
NOTE:
Note the location of the flywheel housing bolts as removed. Some of the bolts are different length/size fasteners and must be installed in the same location as removed.



INSTALLATION

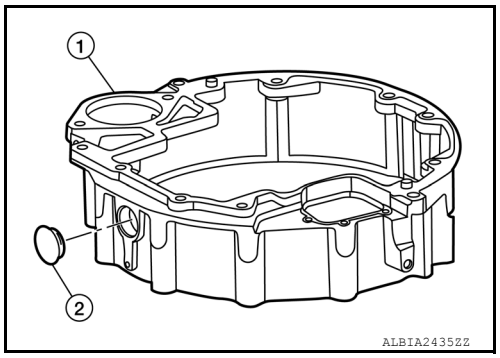
Installation is in the reverse order of removal.
NOTE:
Operate the engine and check for leaks.

Disassembly and Assembly

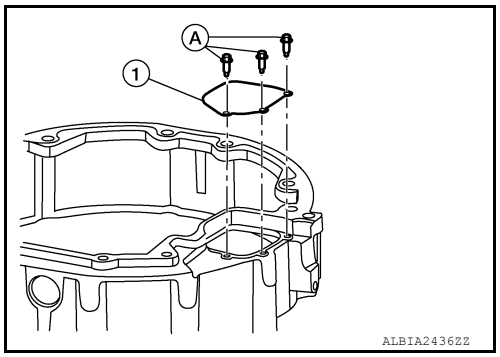
INFOID:0000000014418680

DISASSEMBLY

1. Remove plug (1) in the flywheel housing (1).



2. Remove bolts (A) and remove the access plate (1).



INSPECTION AFTER DISASSEMBLY

WARNING:

- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturers recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**

- Wear appropriate eye protection and protective clothing including gloves and a face shield.

- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**

- Do not exceed 30 psi (207 kPa).

- Wear appropriate eye protection and protective clothing including gloves.

NOTE:

- Use steam or solvent to clean the flywheel housing.
- Dry with compressed air.

Flywheel Housing

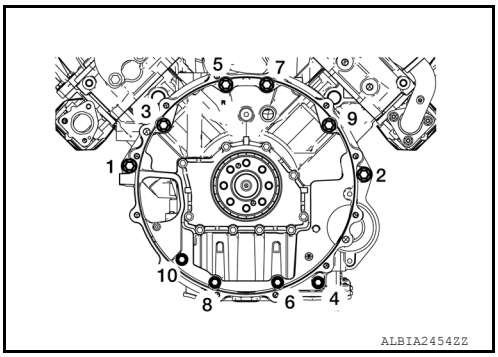
- Inspect the flywheel housing for cracks.
- Inspect the flywheel housing transmission/drive unit mounting surface for cracks.
- Also inspect for damaged threads commonly caused by cross-threaded bolts or installing an incorrect bolt.
  NOTE:
  If thread damage is found, repair threads or replace component as required.

Cylinder Block

- Inspect the rear face of the cylinder block and flywheel housing mounting surface for cleanliness and raised nicks or burrs. Use fine crocus cloth to remove small nicks and burrs.
- Thoroughly clean the flywheel housing and cylinder block mating surfaces. These surfaces must be clean of oil and debris.

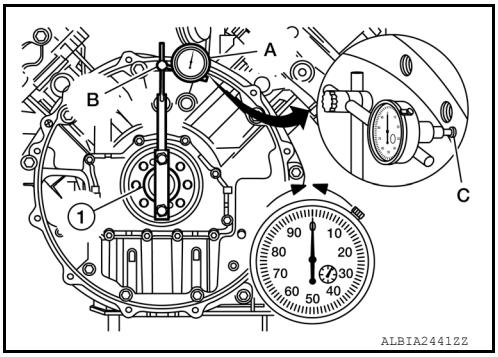
MEASURE

- Install the flywheel housing and hand-tighten bolts in the sequence shown but do not torque the bolts.
  NOTE:
  Follow this step only if the flywheel housing is being replaced or if troubleshooting a vibration/alignment issue. It is not necessary to measure bore alignment or face alignment when installing the original flywheel housing unless the dowel rings were removed during a previous repair.



FACE ALIGNMENT

1. Attach the suitable tool (B) to the crankshaft (1).
   CAUTION:
   The dial indicator tip must not enter the bolt holes, or the gauge will be damaged.
   NOTE:
   - Face alignment is determined by calculating the total indicator reading (TIR).
   - The suitable tool can be mounted by any method that holds the extension bar of the indicator rigid, so it does not sag. If the bar sags or the indicator (C) slips, the readings obtained will not be accurate.

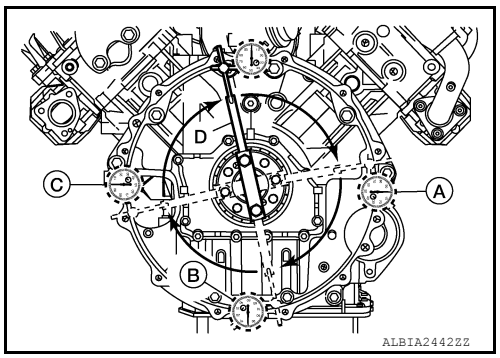


2. Position the suitable tool at the 12 o'clock position, and zero the gauge (A).
   NOTE:
   The crankshaft must be pushed toward the front of the engine to remove the crankshaft end clearance each time a position is measured.

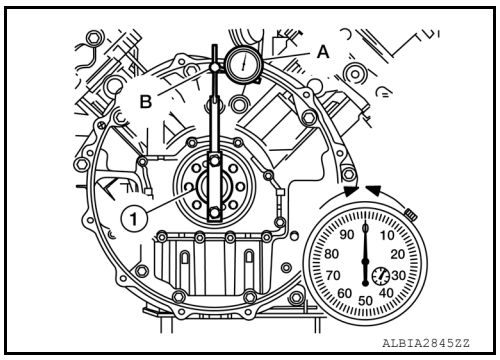
3. Use the Tool to slowly rotate the crankshaft and record the readings at positions (A), (B) and (C).
NOTE:
The values for (A), (B), and (C) can be positive or negative.

Tool : — (J-54424)

(D) : Suitable tool

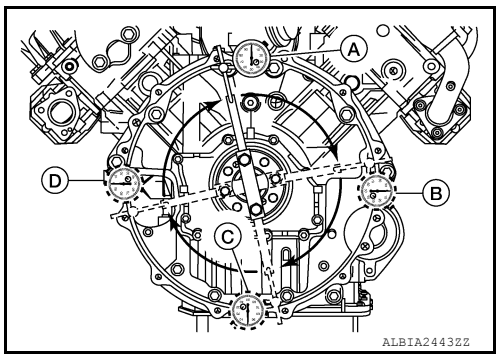


4. Continue to rotate the crankshaft (1) until the suitable tool (A) is at the 12-o'clock position (B) and check the suitable tool to make sure the needle points to zero. If it does not, the readings will be incorrect and the procedure will have to be repeated.



5. Determine the TIR.
NOTE:
- TIR is determined by calculating the difference between the highest and lowest measurement from the four locations measured.
- As the example below illustrates, the TIR is:

- + 0.08 mm (0.003 in) - (-0.05 mm [-0.002 in]) = 0.13 mm (0.005 in)



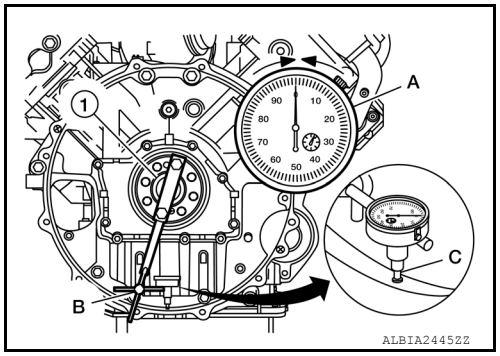
(A)	0.00 mm (0.000 in)
(B)	+ 0.08 mm (+ 0.003 in)
(C)	- 0.05 mm (- 0.002 in)
(D)	+ 0.08 mm (+ 0.003 in)
Equals TIR	0.13 mm (0.005 in)

The maximum allowable TIR is determined by the diameter of the housing bore. If out of specifications, replace the flywheel housing.

Maximum allowable total Indicator Reading : 0.25 mm (0.010 in)

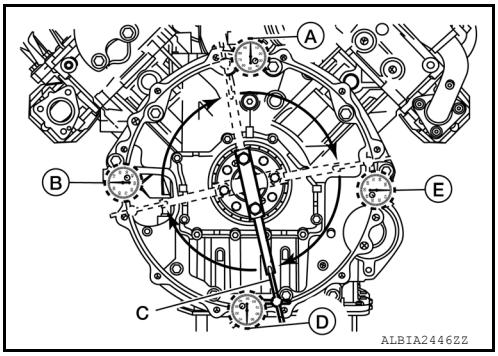
BORE ALIGNMENT

1. Attach the suitable tool (B) to the crankshaft (1).
NOTE:
The suitable tool (B) can be attached by any method that holds the extension bar (C) of the suitable tool (A) rigid, so it does not sag. If the suitable tool (B) sags or the suitable tool (A) slips, the readings obtained will not be accurate.
2. Position the suitable tool (A) in the 6 o'clock position, and zero the suitable tool.

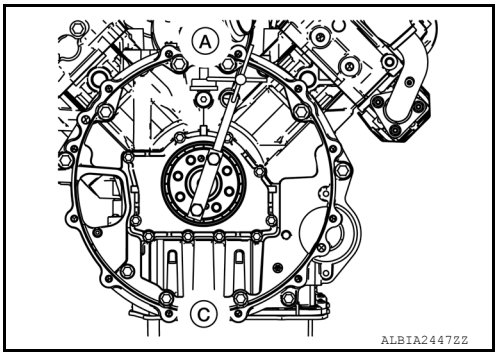


3. Slowly rotate the crankshaft with Tool (C). Record the readings obtained at the positions (A), (B) and (E) in the concentricity work sheet.
NOTE:
- Check zero at the position (D). If it does not, the readings will be incorrect and the procedure will have to be redone.
- The values for (A), (B), and (E) can be positive or negative. See the accompanying figure to determine the correct sign when recording these values.

Tool : — (J-54424)



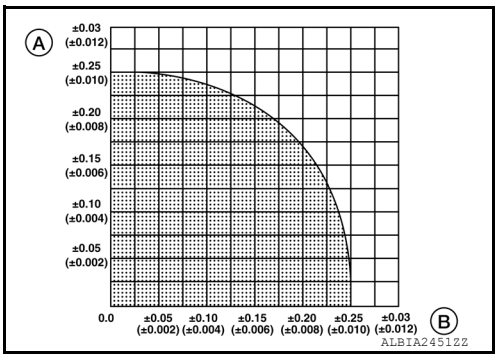
4. Rotate the crankshaft to position (A) and zero the gauge.
CAUTION:
Do not force the crankshaft beyond the point where the bearing clearance has been removed. Do not pry against the flywheel housing. These actions could cause false bearing clearance readings and result in engine damage.
5. Using a suitable tool, raise the rear of the crankshaft to its upper limit. Record the value as position (C) on the concentricity work sheet. This is the vertical bearing clearance adjustment, which will always be positive.



6. Create a concentricity work sheet as shown to determine the values for the total vertical and total horizontal values.
NOTE:
The values listed in the concentricity work sheet illustrated are for example only. The actual numbers measured may differ.
- Input the values recorded for (A), (B), (C) and (D) into the concentricity work sheet.
- The total horizontal is position (D) minus position (B).
- The total vertical is position (A) plus position (C).

Concentricity Worksheet	
Position (D)	0.10 mm (0.004 in)
Position (B)	- 0.05 mm (-0.002 in)
Total Horizontal (D - B)	0.15 mm (0.006 in)
Position (A)	0.08 mm (0.003 in)
Position (C)	0.05 mm (0.002 in)
Total Horizontal (A + C)	0.13 mm (0.005 in)

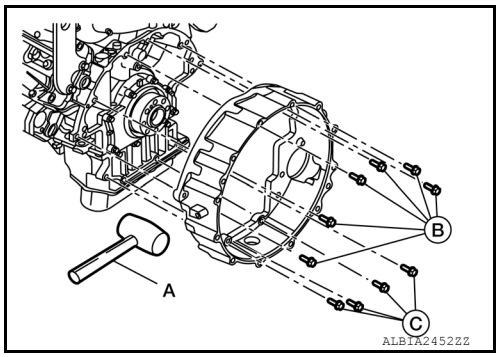
7. Using the total horizontal and total vertical values from the previous example, the intersection point falls within the shaded area. Therefore, the flywheel housing concentricity is within specification.
NOTE:
- Using the illustration, mark the total horizontal value (B) on the X-axis of the chart and the total vertical (A) on the Y-axis of the chart.
- Use a straightedge to find the intersection point of the total horizontal and total vertical values. The intersection point must fall within the shaded area for the flywheel housing concentricity to be within specification.



8. If the bore alignment is out of specification:
- Determine if the flywheel housing or cylinder block has recently been replaced. If any of these components have been replaced, remove and inspect/replace the component.
- If the flywheel housing or cylinder block have not been recently replaced. Remove the flywheel housing. Inspect the cylinder block and flywheel housing mounting surfaces.

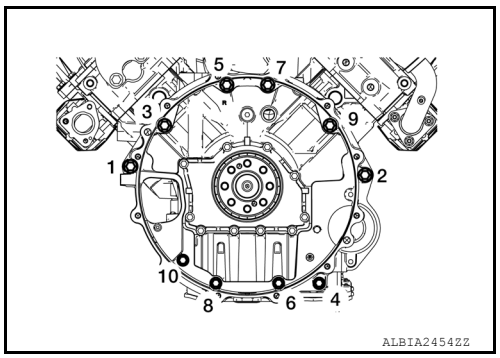
9. Install the flywheel housing and hand-tighten bolts (B) and (C) but do not torque the bolts.
10. Check the bore alignment. If the bore alignment is not within specifications, lightly tap the flywheel housing with suitable tool (A) and measure bore alignment.

Bolt (B) : M12
Bolt (C) : M10



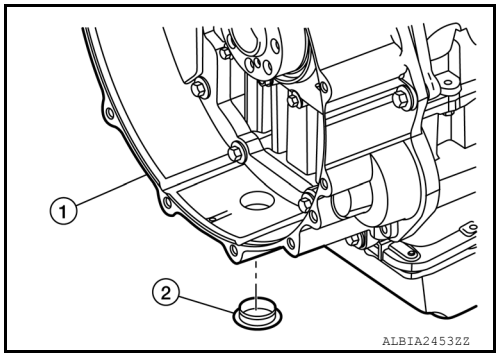
11. When bore alignment is within specification, tighten the bolts (A) in the sequence shown.

Bolt No. 4, 6, 8, 10 : 80 N·m (8.2 kg-m, 59 ft-lb)
Bolt No. 1, 2, 3, 5, 7, 9 : 36 N·m (3.7 kg-m, 27 ft-lb)

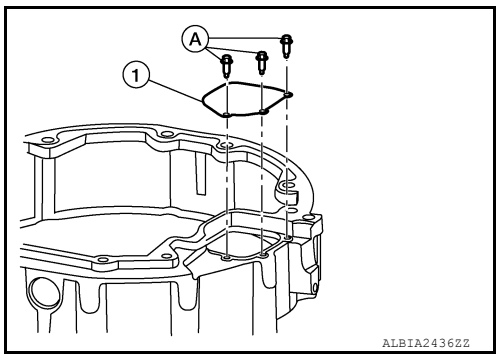


ASSEMBLY

1. Install the plug (2) at the bottom of the flywheel housing (1).



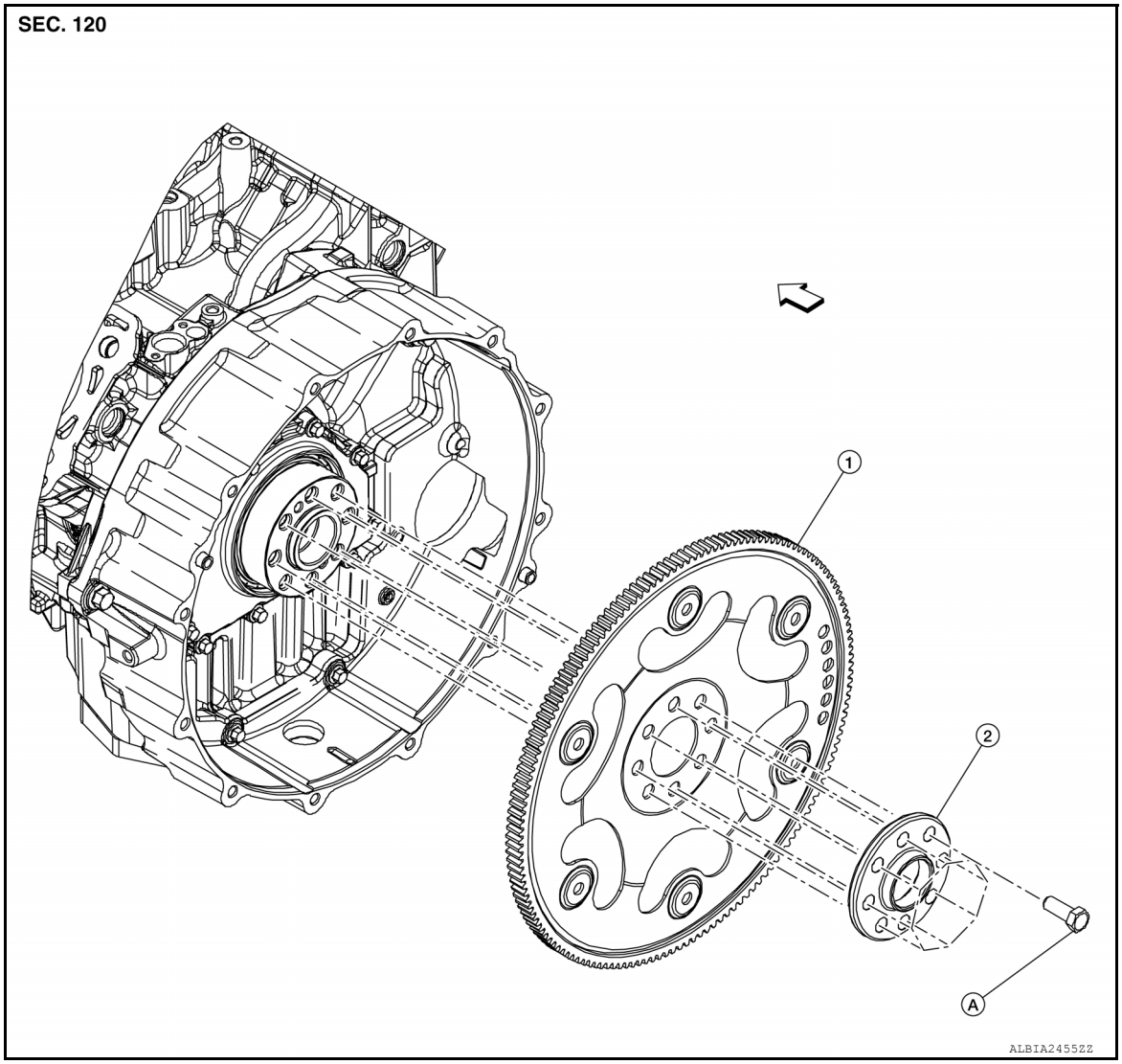
2. Install the access plate (1) and tighten the bolts (A).



FLEXPLATE

Exploded View

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1. Flexplate
2. Spacer
A. Refer to INSTALLATION

⇦ Front

Removal and Installation

INFOID:0000000014418682

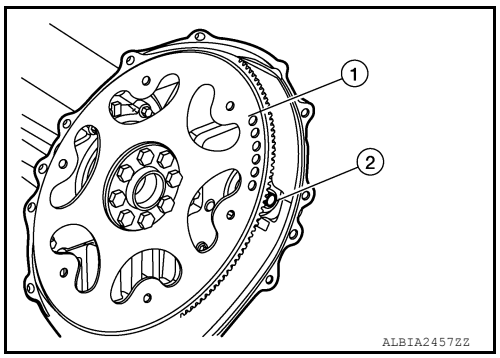
INSPECTION BEFORE REMOVAL

- Inspect the flexplate ring gear teeth for damage.
- If the flexplate ring gear is damaged, make sure to evaluate the following possible causes prior to replacing the flexplate.

Mechanical

- A mechanical issue can typically be identified by observation of damage to the ring gear of the flexplate:

- Upon inspection of the flexplate (1), make sure to check for proper starting motor (2) spacing.
- Interference between the flexplate ring gear land area and the starting motor pinion.
- There can be a problem with the starting motor pinion. Inspect the pinion for nicks and burrs. Replace the starting motor (if necessary). Refer to STR-35, "Removal and Installation - For CUMMINS 5.0L".
- The torque converter/transmission is damaged/incorrectly mounted.

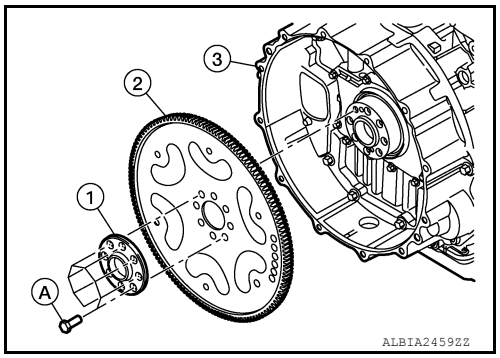


Electrical
- An electrical issue can typically be identified by seeing damage to the flexplate ring gear of the flywheel 360 degrees around the circumference of the flexplate ring gear (commonly called 360 degree milling). The following could be causes for electrical issues:
- Operator is attempting to start engine while engine is already running.
- Keyswitch causing intermittent starting motor engagement when the engine is running. Inspect the keyswitch.
- Intermittent starting motor wiring issues.

REMOVAL

1. Remove the transmission assembly. Refer to TM-248, "2WD : Removal and Installation" (2WD) or TM-252, "4WD : Removal and Installation" (4WD).
2. Remove bolts (A) and remove the flexplate (2) and spacer (1).

(3) : Flywheel housing



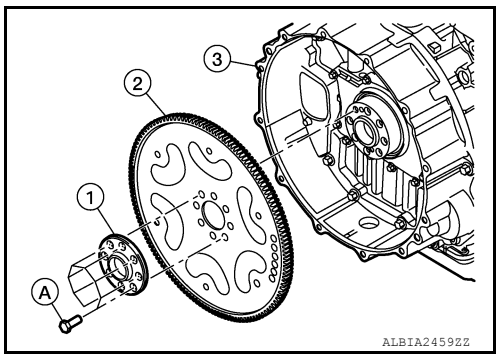
INSPECTION AFTER REMOVAL

- Inspect the teeth of the ring gear for chips or uneven wear.
- Check the flexplate for cracks or other damage.
- Replace the flexplate if any damage is found.

INSTALLATION

1. Install the flexplate (2) and spacer (1) and finger-tighten the bolts (A).

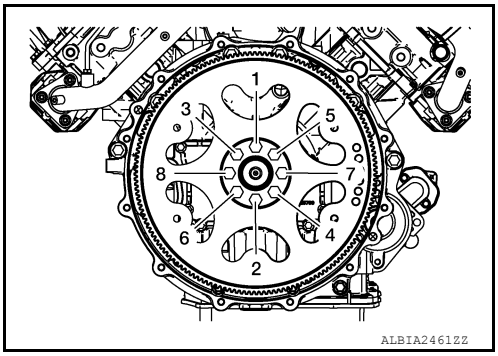
(3) : Flywheel housing



2. Tighten the bolts in the sequence shown to the specified torque.
NOTE:
To prevent the crankshaft from rotating while tightening the flexplate, hold the vibration damper using Tool.

Tool : — (J-54424)

Step 1 : 56 N·m (5.7 kg-m, 41 ft-lb)
Step 2 : Tighten 60°



3. Installation of the remaining components is in the reverse order of removal.
NOTE:
Operate the engine and check for leaks.

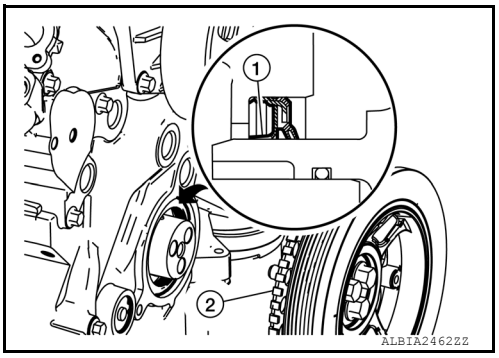
OIL SEAL

Removal and Installation - Front Oil Seal

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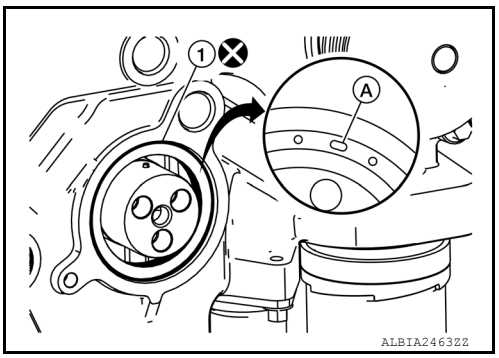
GENERAL INFORMATION

- This engine uses a lip style front oil seal (1) in which the rotating portion of the sealing occurs at the contact surface between the lip of the front oil seal and the vibration damper (2).

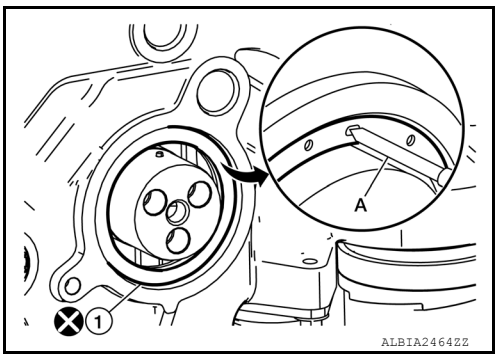


REMOVAL

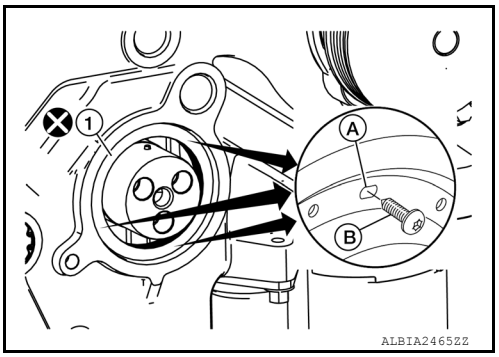
1. Remove the vibration damper. Refer to EM-489, "Removal and Installation".
2. This front oil seal (1) has pre-drilled slots (A) in the casing, covered with rubber molding. These slots are designed into the seals to aid with removal, so drilling of the seals is **not** necessary.
   NOTE:
   The front cover does **not** need to be removed to remove and install the front oil seal.



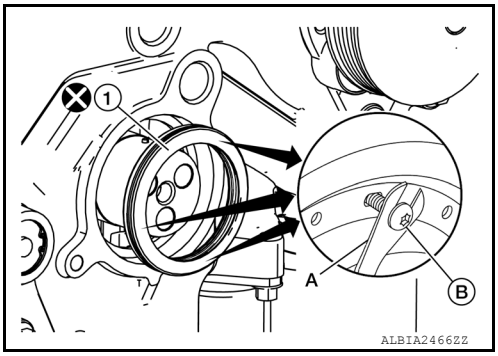
3. Clean the surface of the front oil seal.
4. Push a suitable tool (A) through the dimples to further identify the locations of the pre-drilled slots in the front oil seal (1).
   NOTE:
   - The rubber molding over the pre-drilled slots in the seal casing is recessed. "Dimples" that identify the pre-drilled slots are visible on the front oil seal surface.
   - Be certain that debris does **not** fall into the front gear cover.



5. Install 3.5 x 35 mm (0.14 x 1.38 in) self-tapping screws (B) into the pre-drilled slots (A) in the front oil seal (1).



6. Use a suitable tool (A) to grip the screws (B) and pull the front oil seal (1) out.
CAUTION:
Do not reuse the front oil seal.



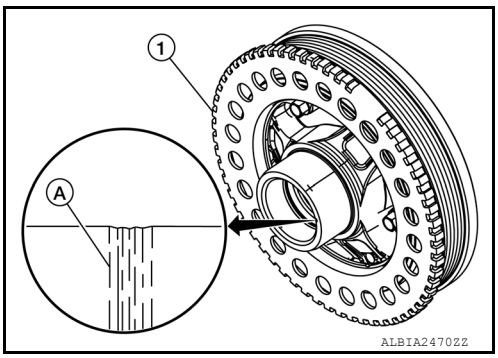
INSPECTION AFTER REMOVAL

WARNING:
- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturer's recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- **Some solvents are flammable and toxic. Read the manufacturer's instructions before using.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**

- Do not exceed 30 psi (207 kPa).
- Wear appropriate eye protection and protective clothing including gloves.

NOTE:
Be certain that debris does **not** fall into the front gear cover.
- Use solvent to clean the oil and seal residue from the crankshaft surface.
- Clean the surface between the front oil seal and front gear cover.
- Clean the crankshaft nose and front gear cover with solvent.
- Clean the front gear cover seal bore of any seal or oil residue.
- Inspect the front gear cover seal bore for nicks or burrs.
- Do **not** use an abrasive pad containing metal on the crankshaft.
- Dry with compressed air.

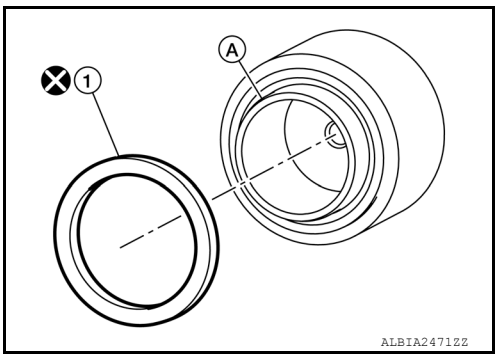
- Inspect the seal contact area on the vibration damper (1) for a wear groove (A). If the groove is deeper than 0.25 mm (0.010 in), the vibration damper must be replaced.
CAUTION:
The seal lip and the sealing surface on the vibration damper must be free from all oil residue to prevent seal leaks.



INSTALLATION

1. Position the front oil seal (1) on Tool (A) with the front oil seal dust lip facing outward.
CAUTION:
- **Do not reuse the front oil seal.**
- **Do not lubricate the front oil seal.**

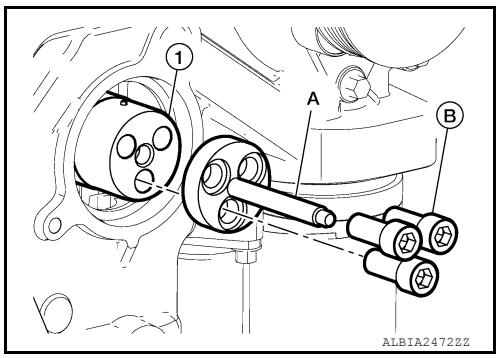
Tool : — (J-54406)



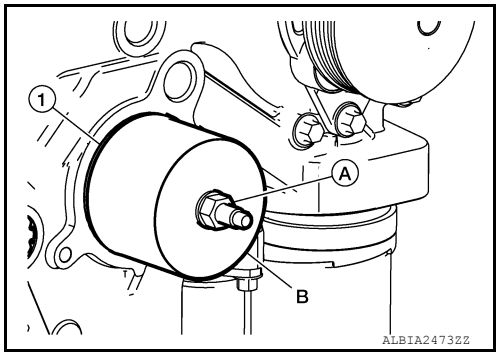
2. Position the part of the Tool (A) that attaches on the nose of the crankshaft (1).
3. Install the bolts (B) in the Tool (A) and tighten.

Tool : — (J-54406)

Bolts (B) : 23 N·m (2.3 kg-m, 17 ft-lb)



4. Install the Tool (B) and nut (A) on the threaded part of the Tool. Tighten the nut on the Tool to press the front oil seal until the Tool comes to a stop on the face of the front cover (1).
5. Remove the Tool from the crankshaft and verify that the front oil seal is seated well into the front cover and the dust lip is not damaged.
6. Installation of the remaining components is in the reverse order of removal.
   - Operate the engine and check for leaks.

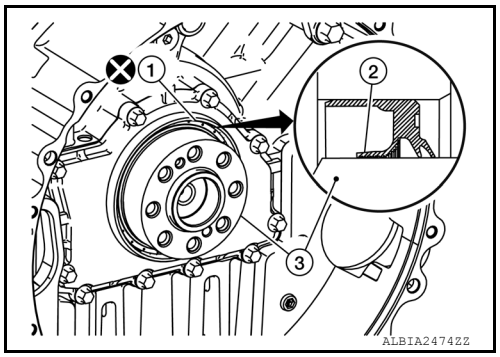


Removal and Installation - Rear Oil Seal

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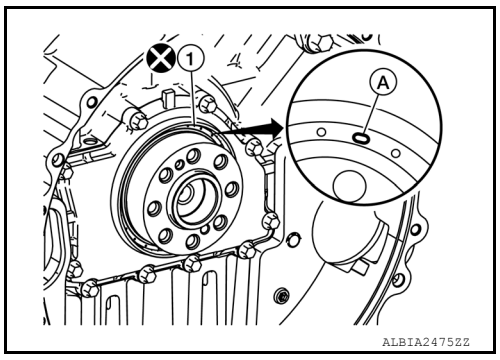
GENERAL INFORMATION

- This engine uses a lip style rear oil seal (1) in which the rotating portion of the sealing occurs at the contact surface between the lip of the rear oil seal (2) and the crankshaft (3).



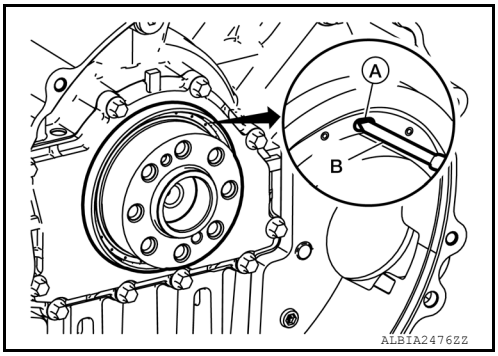
REMOVAL (WITHOUT REMOVING REAR SEAL CARRIER)

1. Remove the flexplate. Refer to EM-388, "Removal and Installation".
2. This engine features a rear oil seal (1) with pre-drilled slots (A) in the casing, covered with rubber molding. These slots are designed into the seals to aid with removal, so drilling of the seals is **not** necessary.

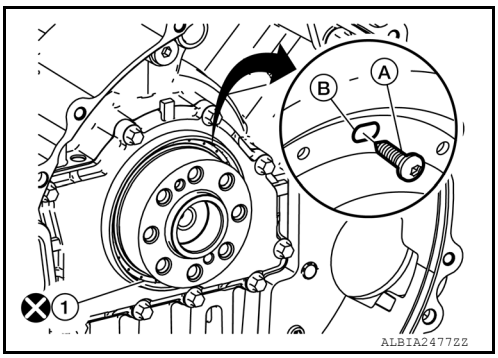


3. Clean the surface of the rear oil seal.

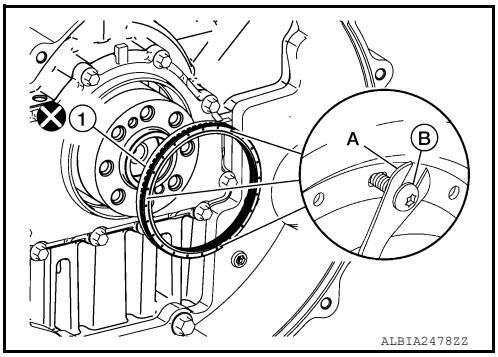
4. Push a suitable tool (B) through the dimples (A) to further identify the locations of the pre-drilled slots.



5. Install 3.5 x 50 mm (0.14 x 1.97 in) self-tapping screws (A) into the pre-drilled slots (B) in the rear oil seal (1).



6. Use a suitable tool (A) to grip the screws (B) and pull the rear oil seal (1) out.
CAUTION:
Do not reuse the rear oil seal.



INSPECTION AFTER REMOVAL

WARNING:
- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturers recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- **Some solvents are flammable and toxic. Read the manufacturer's instructions before using.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**

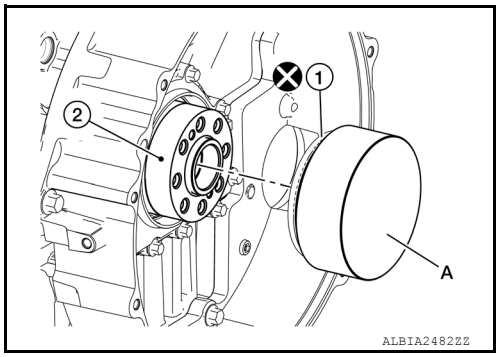
- Do not exceed 30 psi (207 kPa).
- Wear appropriate eye protection and protective clothing including gloves.

CAUTION:
The rear oil seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.
- Clean the rear crankshaft sealing surface and bore with solvent.
  NOTE:
  Do **not** use abrasive pads to clean the seal carrier or the block.
- Dry the surface with compressed air.
- If the rear seal carrier was removed, use solvent to clean oil, seal residue, and gasket residue from the rear seal carrier.
- Dry with compressed air.
- Inspect the rear seal carrier for damage. If damage is found, replace the rear seal carrier.

- Inspect the crankshaft seal contact area for a wear groove. If the groove is deeper than 0.25 mm (0.010 in), the crankshaft **must** be replaced.
- Use a fine crocus cloth to remove any nicks or burrs. No wear sleeve is available if the crankshaft sealing surface is damaged.

INSTALLATION (WITHOUT REMOVING REAR SEAL CARRIER)

1. The rear oil seal is supplied with a plastic guide installed in its center. Do **not** remove this guide before the installation. It should be used to locate the seal on the crankshaft (2).
2. Use Tool (A) to install the rear oil seal (1) into the rear seal carrier.



Tool : — (J-54405)

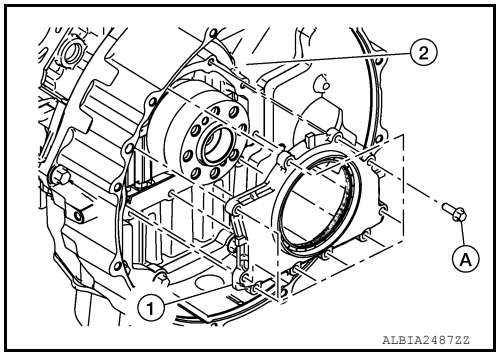
CAUTION:
Do not reuse the rear oil seal.
NOTE:
The Tool fits over the rear oil seal and installs the seal to the proper depth when it is flush with the face of the rear seal carrier.

3. Use a suitable tool to tap the Tool equally at 90 degree intervals until the rear oil seal is installed.
4. Installation of the remaining components is in the reverse order of removal.
   - Operate engine and check for leaks.

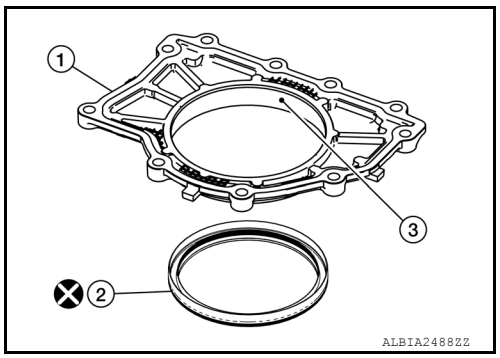
REMOVAL (WITH REMOVING REAR SEAL CARRIER)

NOTE:
This optional method should **only** be used if damage has occurred to the rear seal carrier or if the rear seal carrier **must** be removed for other service procedures that require the removal of the rear seal carrier.

1. Remove the flexplate. Refer to EM-388, "Removal and Installation".
2. Remove the bolts (A) from the rear seal carrier (1) and remove the rear seal carrier from the engine block (2).



3. Holding the seal carrier (1) face down, use a suitable tool to drive the rear oil seal (2) out of the carrier boss (3).



CAUTION:
Do not reuse the rear oil seal.

INSPECTION AFTER REMOVAL

WARNING:
- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturers recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**

- **Some solvents are flammable and toxic. Read the manufacturer's instructions before using.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**

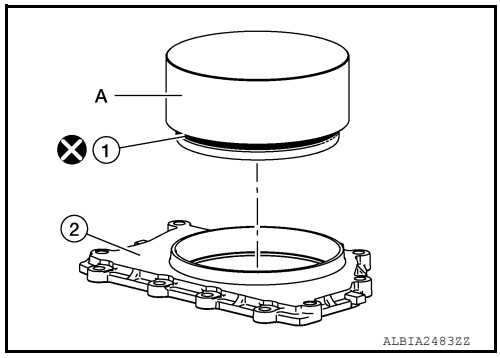
- Do not exceed 30 psi (207 kPa).
- Wear appropriate eye protection and protective clothing including gloves.

CAUTION:
The rear oil seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

- Clean the rear crankshaft sealing surface and bore with solvent.
  NOTE:
  Do **not** use abrasive pads to clean the seal carrier or the block.
- Dry the surface with compressed air.
- Use solvent to clean oil, seal residue, and gasket residue from the rear seal carrier.
- Dry with compressed air.
- Inspect the rear seal carrier for damage. If damage is found, replace the rear seal carrier.
- Inspect the crankshaft seal contact area for a wear groove. If the groove is deeper than 0.25 mm (0.010 in), the crankshaft **must** be replaced.
- Use a fine crocus cloth to remove any nicks or burrs. No wear sleeve is available if the crankshaft sealing surface is damaged.

INSTALLATION (WITH REMOVING REAR SEAL CARRIER)

1. The rear oil seal (1) is supplied with a plastic sleeve installed in its center. Do **not** remove this sleeve before the rear seal carrier installation. It should be used to locate the seal on the crankshaft when sliding the carrier and the seal in place.
2. Position the rear seal carrier (2) so the front is facing upward.
3. Use Tool (A) to install the rear oil seal (1) into the rear seal carrier (2).
   CAUTION:
   Do not reuse the rear oil seal.

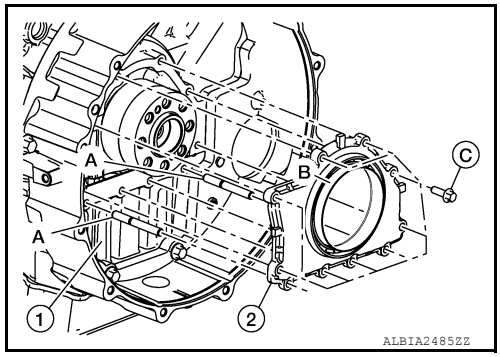


Tool : — (J-54405)

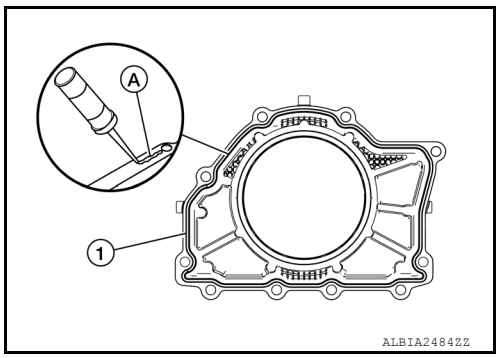
NOTE:
- Use a press to press the Tool and rear oil seal into place. The Tool fits over the rear oil seal and installs the seal to the proper depth when it is flush with the face of the rear seal carrier. If a press is **not** available, use a suitable tool to tap the tool equally at 90 degree intervals until the seal is installed.
- When using a press or a suitable tool, place the rear seal carrier on a piece of wood or something softer to protect the sealing surface from damage.

4. Prepare the mating surfaces by wiping them with a lint-free cloth and isopropyl alcohol. After surface is clean, prepare it with Bonderite M-NT 5700 or equivalent wipe. Allow time for the surface to dry before applying sealant.
5. Install suitable tools (A) into the cylinder block (1).

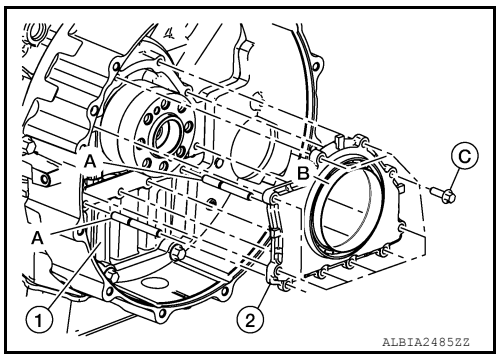
(2) : Rear seal carrier
(B) : Plastic installation sleeve
(C) : Rear seal carrier bolt



6. Apply Loctite 5900 RTV or equivalent sealant (A) to the rear seal carrier (1) in the pattern shown. Apply the bead 1 - 2 mm (0.04 - 0.08 in) away from the chamfer on the inside of the rear seal carrier.
NOTE:
The rear seal carrier **must** be installed within 5 minutes of applying the sealant. The final tightening **must** be completed within 30 minutes of the sealant application.



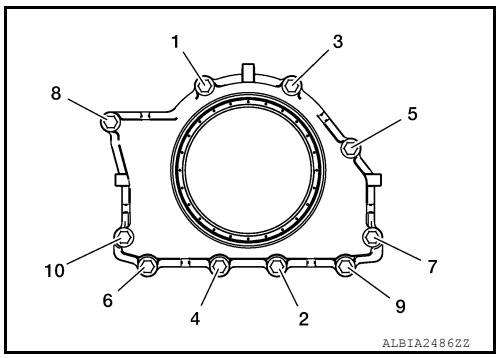
7. Slide the rear seal carrier (2) over the crankshaft and suitable tools (A) until it is seated against the cylinder block (1). Discard the plastic installation sleeve (B).



8. Install and hand tighten bolts (C).
CAUTION:
Be sure to remove the plastic installation sleeve.
NOTE:
Remove suitable tools and install and hand tighten remaining bolts.

9. Tighten the rear seal carrier bolts in the sequence shown.

Bolts : 23 N·m (2.3 kg-m, 17 ft-lb)

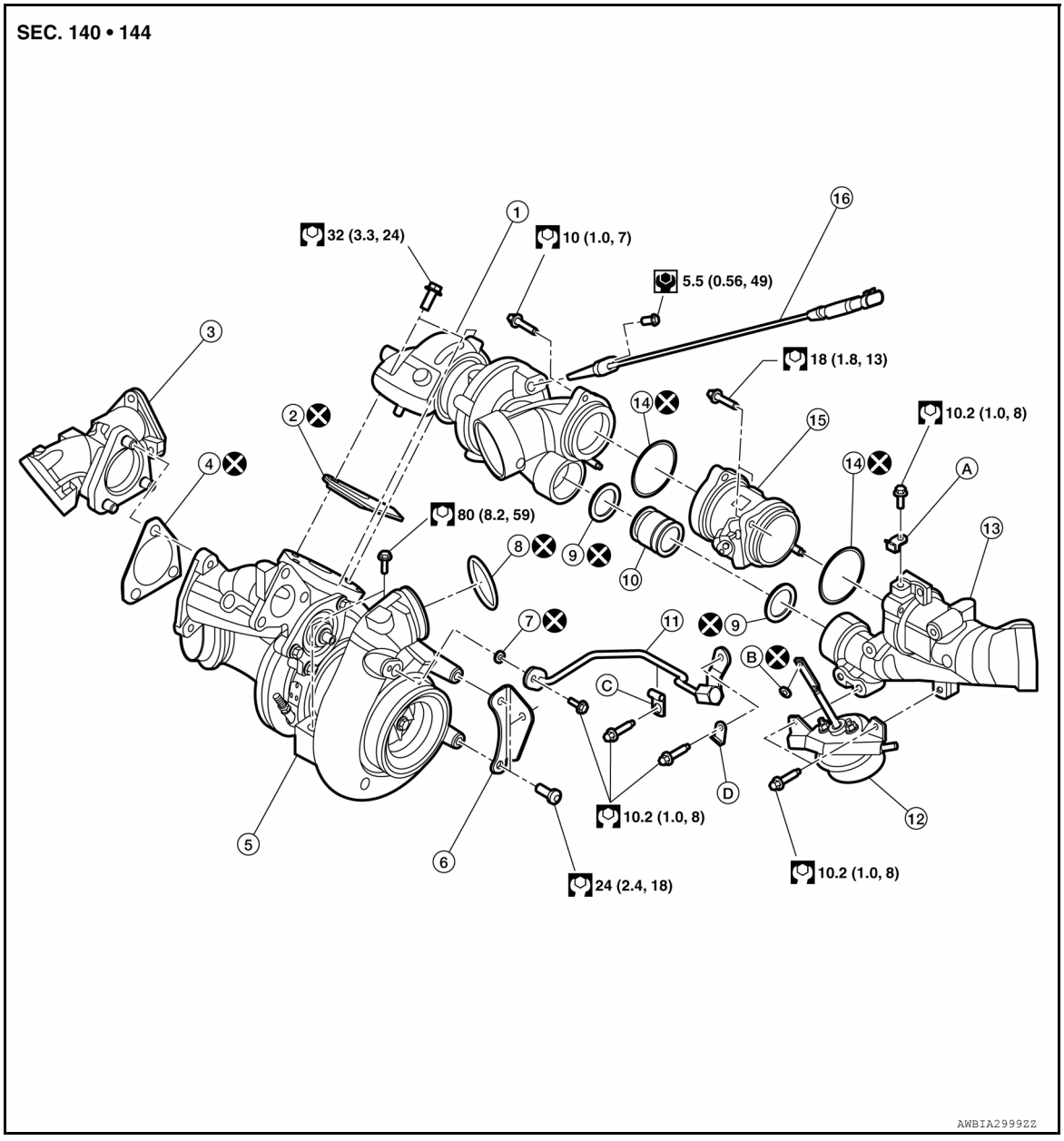


10. Installation of the remaining components is in the reverse order of removal.
• Operate engine and check for leaks.

TURBOCHARGER

Exploded View

INFOID:0000000014418685



1. High-pressure turbocharger*
2. High-pressure turbocharger gasket*
3. Exhaust manifold collector pipe
4. Exhaust manifold collector pipe gasket
5. Low-pressure turbocharger*
6. Support bracket*
7. O-ring*
8. O-ring*
9. O-ring*
10. Jumper tube*
11. Low-pressure turbocharger boost pressure sensor tube*
12. Turbocharger compressor bypass valve actuator*
13. Turbocharger compressor outlet connection*
14. O-ring*
15. Turbocharger compressor bypass valve*
16. Turbocharger speed sensor
A. Clip*
B. Retaining clip*
C. Clip*
D. Clip*

*: Always check with parts department for the latest parts information.

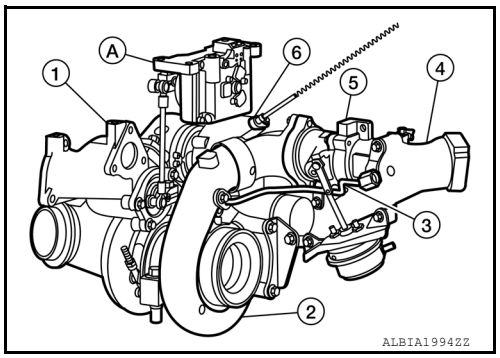
Removal and Installation

INFOID:0000000014418686

GENERAL INFORMATION

- The turbocharger assembly is a compound system composed of two turbochargers and contains the following components:

(1) : High-pressure turbocharger
(2) : Low-pressure turbocharger
(3) : Low-pressure turbocharger boost pressure sensor tube
(4) : Turbocharger compressor outlet connection
(5) : Turbocharger compressor bypass valve
(6) : Turbocharger speed sensor
(A) : Rotary turbine control valve (non-serviceable component of the low-pressure turbocharger exhaust housing)



- The turbocharger's axial and radial clearances can **not** be inspected because the compressor and/or turbine wheel can **not** be accessed.

CAUTION:
Do not operate the engine with the charge-air piping removed. The lack of boost pressure on the outlet side of the compressor outlet can cause progressive damage to the turbocharger.

INSPECTION BEFORE REMOVAL

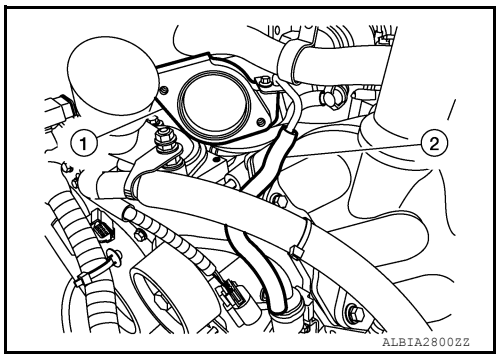
- If a pool of oil (**not** wall wetting) is found in the turbocharger compressor inlet or air inlet connection of the turbocharger, check the system for high air intake restriction. Refer to EM-209, "Inspection".
- If a pool of oil is found on the compressor outlet connection and there is **not** a pool of oil on the intake side, remove and replace the entire turbocharger assembly.

REMOVAL

WARNING:
• To avoid the risk of personal injury:
- Be careful not to burn yourself, as engine oil may be hot.
- Prolonged and repeated contact with used engine oil may cause skin cancer; try to avoid direct skin contact with used engine oil. If skin contact is made, wash thoroughly with soap or hand cleaner as soon as possible. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.
- If not reused, dispose of in accordance with local environmental regulations.

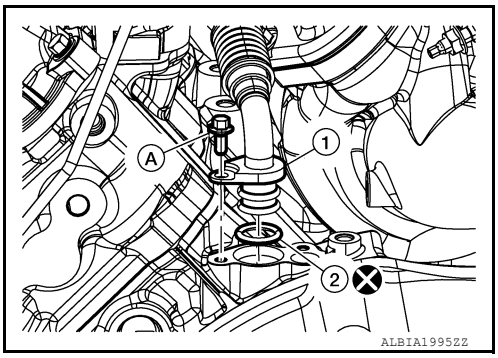
CAUTION:
Brush away all loose dirt from around the area of the air handling connections to avoid contamination of the interior of the engine.

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".
2. Remove the intake manifold. Refer to EM-239, "Removal and Installation".
3. Remove the nuts and studs that connect the exhaust manifold collector pipe to the turbocharger. Refer to EM-271, "Exploded View".
4. Remove the charge-air cooler outlet tube from the turbocharger compressor outlet connection. Refer to EM-256, "Exploded View".
5. Disconnect the vacuum hose (2) from the turbocharger compressor bypass valve actuator (1).

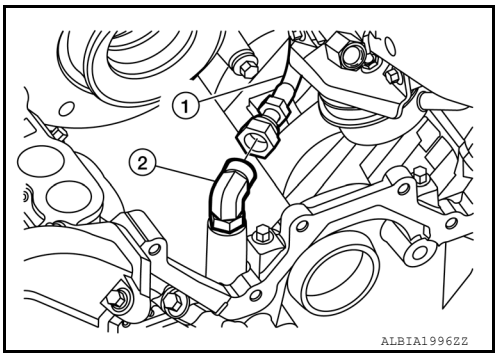


6. Disconnect the downpipe from the turbocharger. Refer to EX-28, "Exploded View".

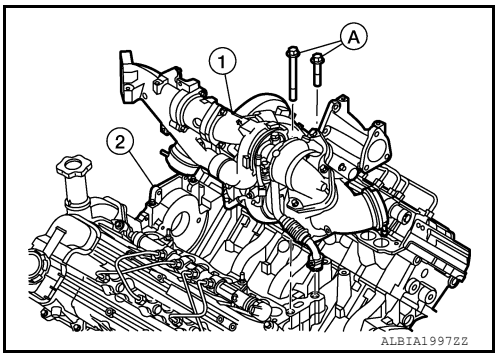
7. Disconnect the harness connector from the turbocharger speed sensor and from the low pressure turbocharger boost pressure sensor.
8. Remove the bolt (A) for the turbocharger oil drain line (1) on the cylinder block.
   CAUTION:
   Do not reuse the O-ring (2).



9. Remove the turbocharger oil supply line (1) from the turbocharger oil supply line-to-cylinder block fitting (2).
   CAUTION:
   Do not remove the oil supply fitting from the block unless damaged. If fitting is required to be removed, vacuum all loose dirt from around the area of the oil supply fitting to avoid oil system contamination and potential engine damage.



10. Remove bolts (A) from the turbocharger (1) and remove the turbocharger from the engine (2).
    WARNING:
    To avoid the risk of personal injury, use lifting equipment or acquire assistance when lifting components or assemblies that weight more than 23 kg (50 lbs).
    CAUTION:
    - **While lifting slowly, make sure the high-pressure turbocharger oil drain line disconnects from the cylinder block. Use a suitable tool to help release the line.**
    - **Route the sling so that the low-pressure turbocharger boost pressure sensor tube or the turbocharger compressor bypass valve, actuator, or linkage are not damaged during removal.**
    - **Once the turbocharger is removed, place it on a clean flat surface. Make sure that the turbocharger rests on the housings away from sensors and linkages. Damage to components can occur.**



    NOTE:
    - When removing the turbocharger, cap all open air handling ports with Tool.

    Tool : — (J-54423)

    - While lifting slowly, make sure the high-pressure turbocharger oil drain line disconnects from the cylinder block. Using a suitable tool may help to release the line.
    - Make sure **not** to damage the low pressure turbocharger boost pressure sensor tube or the turbocharger compressor bypass valve, actuator, or linkage, while using a strap to remove the turbocharger.
    - If the full diagnostic procedures have already found that the turbocharger assembly **must** be replaced, disassembly steps are **not** needed. Replace the turbocharger assembly.

INSPECTION AFTER REMOVAL

- Inspect the turbochargers for external leaks. If an oil leak or soot trace is present from the bearing housing clamps, the leaking turbocharger **must** be replaced.

WARNING:
- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturers recommendations for use and wear appropriate eye protection**

and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
- **Wear appropriate eye protection and protective clothing including gloves and a face shield.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- Remove all carbon deposits.
- Use solvent or steam to clean the exterior of the turbocharger.
- Dry with compressed air.
- Inspect the turbocharger gasket and O-ring surfaces for cracks and other damage.
- Surfaces for inspection include:
- Gasket surface between low-pressure and high-pressure turbocharger turbine housings.
- Exhaust transfer tube joints.
- Low-pressure turbocharger housing to the exhaust bypass tube.
- Inspect the compressor housings and turbine housings for cracks.
- If damage is found, replace the damaged turbocharger or the high-pressure and low-pressure turbocharger as an assembly.
- Inspect the compressor blades of the turbocharger for damage.

NOTE:
A mirror or borescope can be used to inspect the high-pressure turbocharger compressor wheel.
- If damage is found, replace the damaged turbocharger.
- If the engine experiences a turbocharger malfunction or any other occasion in which oil or debris is put into the charge-air system, the charge-air system **must** be inspected. If damage is found, replace charge-air system components as necessary.
- If the engine experiences a turbocharger malfunction or any other occasion where oil is put into the exhaust the aftertreatment components **must** be inspected. Inspect the diesel oxidation catalyst (DOC)/diesel particulate filter (DPF) assembly.
- These components that are integral to the turbocharger assembly and need to be cleaned and inspected when replacing the turbocharger assembly.
- Turbocharger compressor bypass valve.
- Turbocharger compressor bypass valve actuator.
- Rotary turbine control valve linkage.
- Air intake connection.
- Turbocharger oil supply line.
- High-pressure turbocharger drain line.
- Turbocharger compressor outlet connection.
- Low-pressure turbocharger boost pressure sensor and tube.
- Turbocharger speed sensor.

INSTALLATION

Installation is in the reverse order of removal.

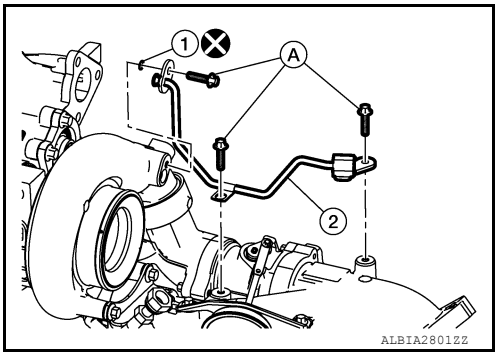
NOTE:
- If a stationary aftertreatment regeneration is needed to complete the repair, make sure that the engine is brought up to operating temperature before the regeneration is started.
- Operate the engine and check for leaks.

Disassembly and Assembly

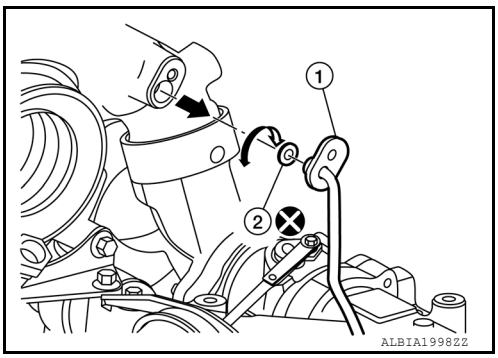
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DISASSEMBLY

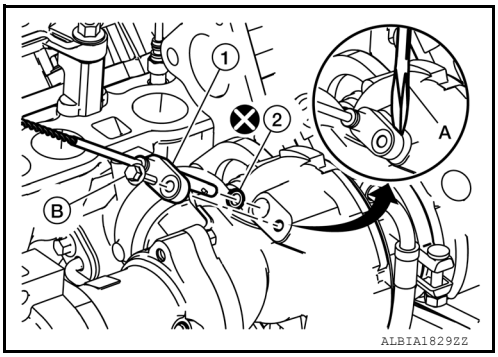
1. Remove the bolts (A) securing the low-pressure turbocharger boost pressure sensor tube (2).
CAUTION:
Do not reuse O-ring (1).



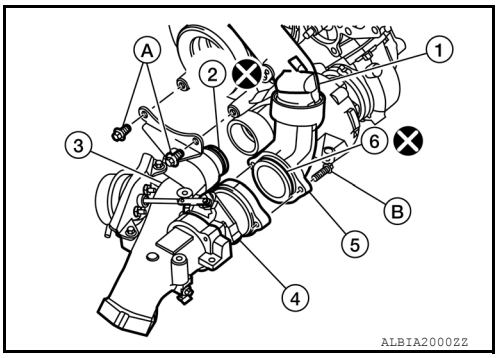
2. Remove the low-pressure turbocharger boost pressure sensor tube (1) by pulling with light force in the axial direction as shown and rotating **clockwise** and **counter-clockwise** of the O-ring (2).
CAUTION:
Do not reuse the O-ring.



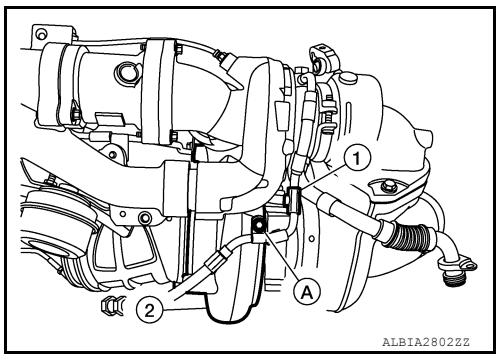
3. Remove bolt (B), then use suitable tool (A) to remove the turbocharger speed sensor (1).
CAUTION:
Do not reuse O-ring (2).
NOTE:
Apply a twisting motion to the turbocharger speed sensor while pulling upward.



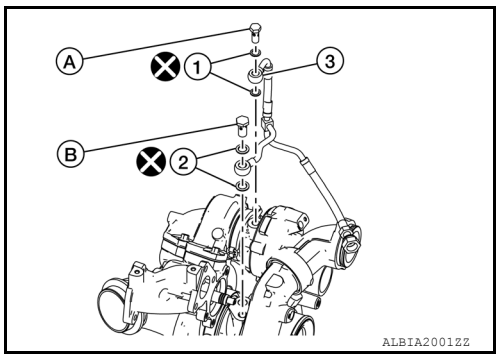
4. Remove the rotary turbine control valve linkage from the turbocharger assembly.
CAUTION:
Do not reuse the rotary turbine control valve linkage.
5. Remove the bolts (A) that hold the turbocharger compressor outlet connection (3) to the low-pressure compressor housing (1).
6. Remove the bolts (B) that hold the turbocharger compressor bypass valve (4) to the high-pressure compressor housing (5).
7. Remove the turbocharger compressor bypass valve and turbocharger compressor outlet connection assembly from the turbocharger assembly.
CAUTION:
- **Do not reuse the O-rings (2) and (6).**
- **Use of a soft mallet is recommended to help in separation of the compressor bypass valve. Avoid prying against the housing for removal, as damage can result.**



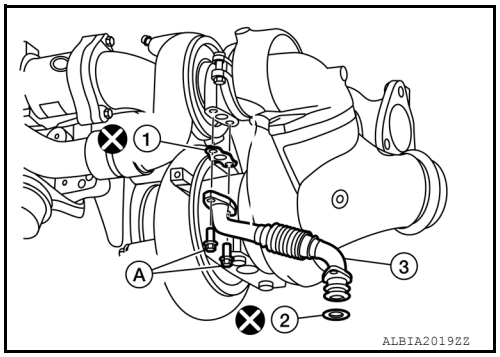
8. Remove the bolt (A) that attaches the oil supply line (1) to the low-pressure turbocharger compressor housing (2).



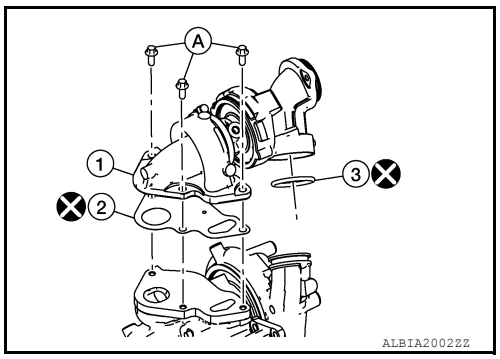
9. Remove the high pressure turbocharger banjo bolt (A) and the low-pressure turbocharger banjo bolt (B) for the oil supply line (3) to both the high-pressure and low-pressure turbochargers.
CAUTION:
Do not reuse copper sealing washers (1, 2).



10. Remove bolts (A) and remove the high-pressure turbocharger oil drain line (3).
CAUTION:
Do not reuse the O-ring (2) or gasket (1).



11. Remove the bolts (A) that secure the high-pressure turbocharger (1) to the low-pressure turbocharger. Use suitable tool to separate the housings.
CAUTION:
Do not reuse the gasket (2) or O-ring (3).
NOTE:
- Penetrating oil should be used on the bolts (A) for the high-pressure turbocharger.
- The low-pressure and high-pressure compressor housings are sealed by an O-ring (3). Evenly distribute the pulling force between the compressor housings as well as the turbine housings.

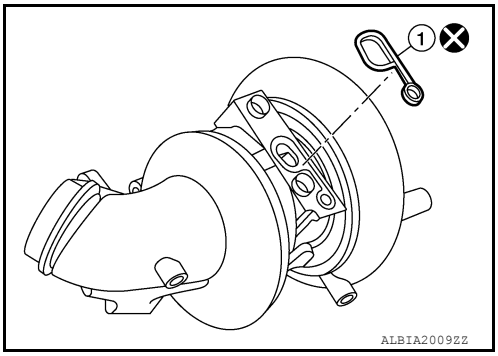


INSPECTION AFTER DISASSEMBLY

Turbocharger
- Check turbocharger for damage. Repair as necessary.
- Check turbocharger sealed areas for oil leaks. Repair as necessary.

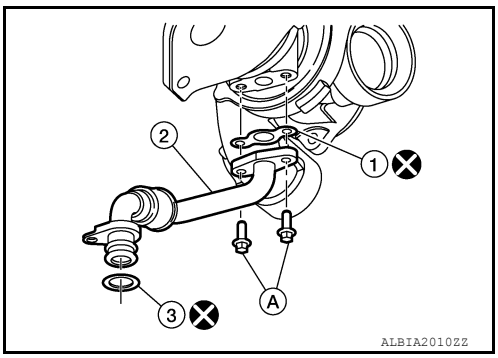
ASSEMBLY

1. Install a new low-pressure turbocharger gasket (1) on the low-pressure turbocharger.
CAUTION:
Do not reuse the gasket.



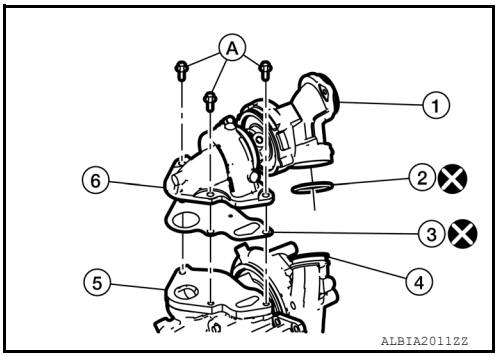
2. Lubricate the O-ring with clean engine oil.
3. Install the turbocharger oil drain line (2) and tighten bolts (A).
CAUTION:
Do not reuse the gasket (1) or O-ring (3).

Bolts (A) : 9.8 N·m (1.00 kg-m, 87 in-lb)



4. Lubricate the O-ring with a suitable water-based lubricant.
5. Install a new O-ring (2) on the low-pressure turbocharger compressor housing (4).
6. Install a new gasket (3) between the low-pressure turbocharger compressor (5) and high-pressure turbocharger compressor housing (6).
7. Mount the high-pressure turbocharger to the low-pressure turbocharger, install and tighten the bolts (A).
NOTE:
Apply a light film of high temperature anti-seize compound to the threads of the bolts (A).

Bolts (A) : 32 N·m (3.3 kg-m, 24 ft-lb)

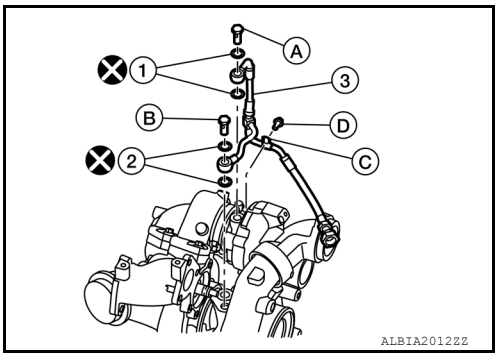


8. Install the turbocharger oil supply line (3) on the turbocharger with new copper sealing washers (1, 2) and tighten high-pressure turbocharger banjo bolt (A) and low-pressure. turbocharger banjo bolt (B).

Bolt (A) : 22 N·m (2.2 kg-m, 16 ft-lb)
Bolt (B) : 34 N·m (3.5 kg-m, 25 ft-lb)

9. Install the bolt (D) for the oil supply line clip (C) to the low-pressure turbocharger compressor housing.

Bolt (D) : 7 N·m (0.7 kg-m, 62 in-lb)

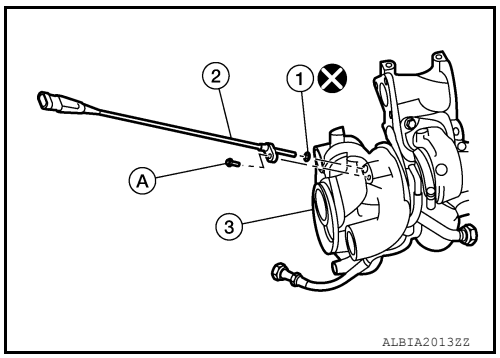


10. Lubricate the O-ring with a suitable water-based lubricant.
11. Install the turbocharger speed sensor (2) and tighten bolt (A).

CAUTION:
Do not reuse the O-ring (1).

(3) : High-pressure turbocharger housing

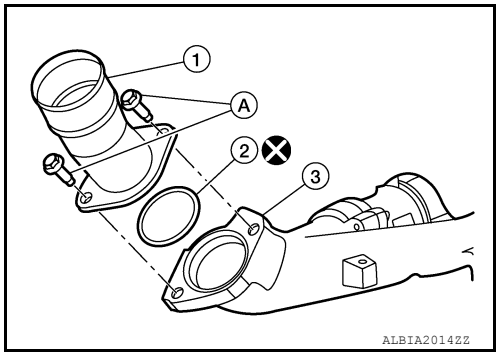
Bolt (A) : 5.5 N·m (0.6 kg-m, 49 in-lb)



12. Lubricate the O-ring with a suitable water-based lubricant.
13. Install the charge-air cooler outlet (1) onto the turbocharger compressor outlet connection (3) and tighten bolts (A).

CAUTION:
Do not reuse the O-ring (2).

Bolts (A) : 18 N·m (1.8 kg-m, 13 ft-lb)



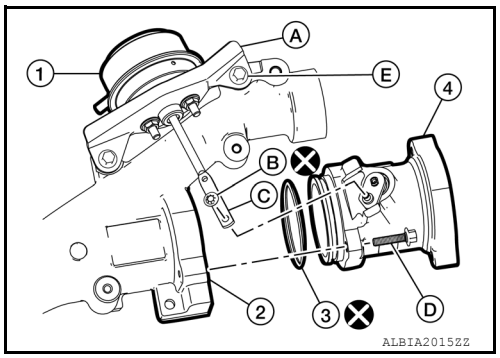
14. Lubricate the O-ring with a suitable water-based lubricant.
15. Install a new O-ring (3) on the turbocharger compressor bypass valve (4) and install the turbocharger compressor bypass valve into the turbocharger compressor outlet connection (2) and tighten bolt (D).

CAUTION:
Do not reuse the O-ring.

Bolt (D) : 18 N·m (1.8 kg-m, 13 ft-lb)

16. Install the turbocharger compressor bypass valve actuator (1) and mounting bracket (A) onto the turbocharger compressor outlet connection and tighten bolt (E).

Bolt (E) : 10.2 N·m (1.0 kg-m, 8 ft-lb)



17. Connect the turbocharger compressor bypass valve actuator linkage (C) to the turbocharger compressor bypass valve and install a new retainer clip (B).

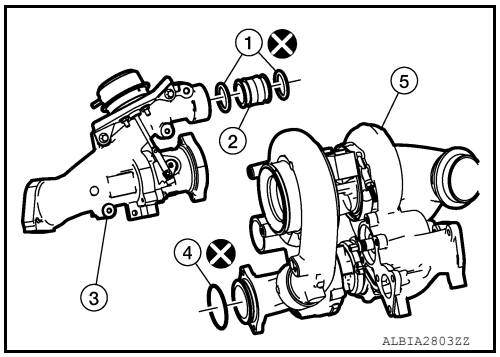
CAUTION:
Do not reuse the retaining clip.

18. Lubricate the O-rings with a suitable water-based lubricant.
19. Install new O-rings (1) on the compressor outlet connection jumper tube (2) and install into the turbocharger compressor outlet connection (3).

CAUTION:
Do not reuse the O-rings.

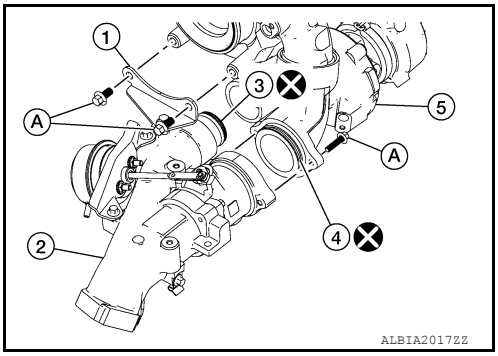
20. Install a new O-ring (4) on the turbocharger (5).

CAUTION:
Do not reuse the O-rings.



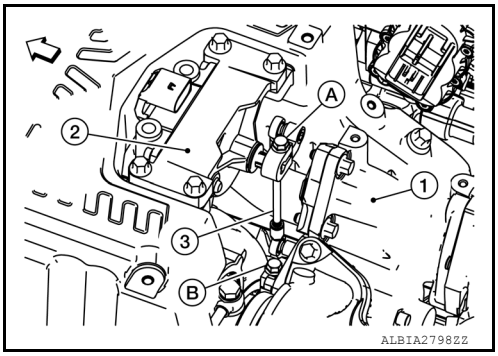
21. Install the turbocharger compressor outlet connection assembly (2) onto the turbocharger assembly (5).
22. Install the compressor outlet connection support bracket (1) to the low-pressure turbocharger compressor housing and tighten bolts (A).
CAUTION:
Do not reuse the O-rings (3) and (4).

Bolts (A) : 24 N·m (2.4 kg-m, 18 ft-lb)



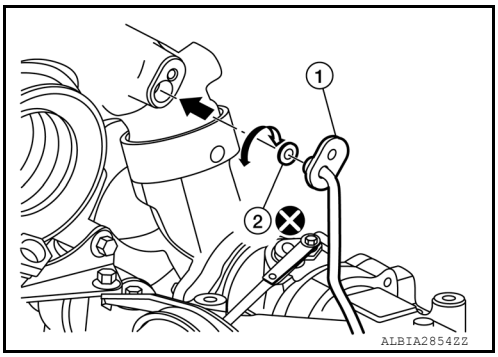
23. Install new rotary turbine control valve linkage (3) and tighten bolt (B) to the turbocharger assembly (1).
CAUTION:
Once the rotary turbine control valve linkage is loosened from the turbine control valve shaft, the linkage must be discarded. The linkage can not be reused.
NOTE:
- Use care while locating, installing, and tightening the D-clamp and linkage.

Bolt (B) : 10 N·m (1.0 kg-m, 7 ft-lb)



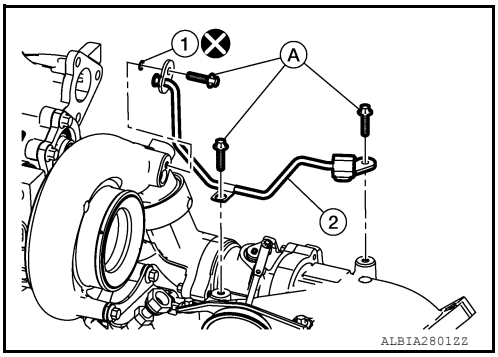
(2) : Rotary turbine control valve actuator
(A) : Bolt
⇦ : Front

24. Insert the tube (1) into the low-pressure turbocharger compressor housing in the axial direction of the O-ring seal (2).
CAUTION:
Do not reuse the O-ring.
NOTE:
Lubricate the O-ring with a suitable water-based lubricant.



25. Install the bolts (A) for the low-pressure turbocharger boost pressure sensor tube (2).
CAUTION:
Do not reuse O-ring (1).

Bolts (A) : 10.2 N·m (1.0 kg-m, 8 ft-lb)



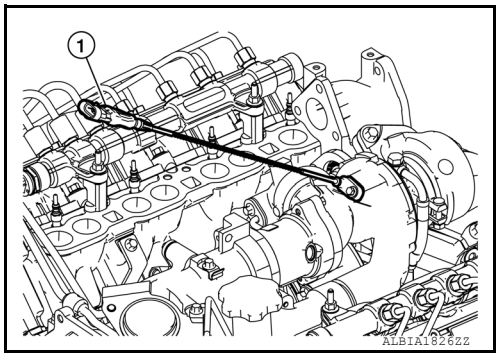
TURBOCHARGER SPEED SENSOR

Removal and Installation

INFOID:0000000014418688

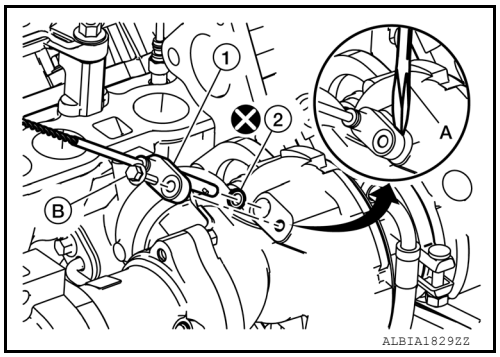
GENERAL INFORMATION

The turbocharger speed sensor is located on the high-pressure compressor housing. The turbocharger speed sensor (1) detects the blades of high-pressure compressor as they pass through the sensor and determines the speed of the high-pressure compressor of the turbocharger based on the time duration between electromagnetic pulses the blades create. Use the following procedure for a detailed component location view. Refer to EM-181, "INTAKE AIR SYSTEM : System Description".



REMOVAL

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".
   WARNING:
   Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:
   - **Wear appropriate goggles and protective clothing.**
   - **Always properly ventilate the area where the service is being performed.**
   - **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
   - **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
   - **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**
2. Remove the air intake manifold. Refer to EM-239, "Removal and Installation".
3. Clean the area around the turbocharger speed sensor.
4. Lift up on the locking tab and disconnect the turbocharger speed sensor harness connector.
5. Remove the bolt.
   CAUTION:
   When removing the turbocharger speed sensor, use a twisting motion while pulling upward. Prying on the sensor body with a screwdriver can lead to broken sensors and could result in unwarranted turbocharger replacement. Pliers are recommended for turbocharger speed sensor removal.
   NOTE:
   Take note of the proper routing of the harness, when removing, for proper installation.
6. Use suitable tool (A) to remove the turbocharger speed sensor (1).
   CAUTION:
   Do not reuse O-ring.
   NOTE:
   - Apply a twisting motion while pulling upward.



INSPECTION AFTER REMOVAL

- Inspect the turbocharger speed sensor body and wiring harness for signs of melting or other damage.
- Inspect the engine harness connector and sensor for the following:
- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins

- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor.

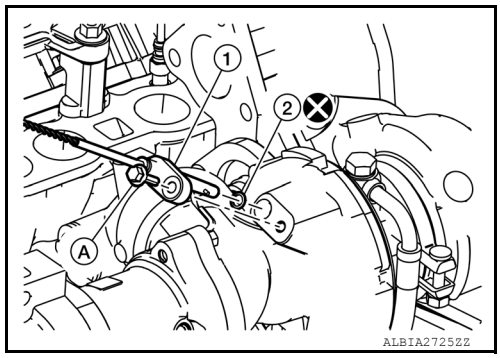
• Repair or replace parts as necessary.

NOTE:

If the turbocharger speed sensor is being removed due to an air leak, replace the o-ring.

INSTALLATION

1. Install the turbocharger speed sensor (1) and tighten the bolt (A).



Turbocharger speed sensor bolt (A) : 5.5 N·m (0.56 kg-m, 49 in-lb)

CAUTION:

- **The turbocharger speed sensor harness must be tied up and away from any heat sources and hard or sharp surfaces. Failure to do so will cause damage to the harness.**
- **Do not reuse O-ring**

NOTE:

- Use the same routing that was noted during removal of the sensor.
- Secure the turbocharger speed sensor wiring harness to the engine harness.

2. Install the air intake manifold. Refer to EM-239, "Removal and Installation".
3. Connect the battery or batteries. Refer to PG-185, "Battery Disconnect".

WARNING:

Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:

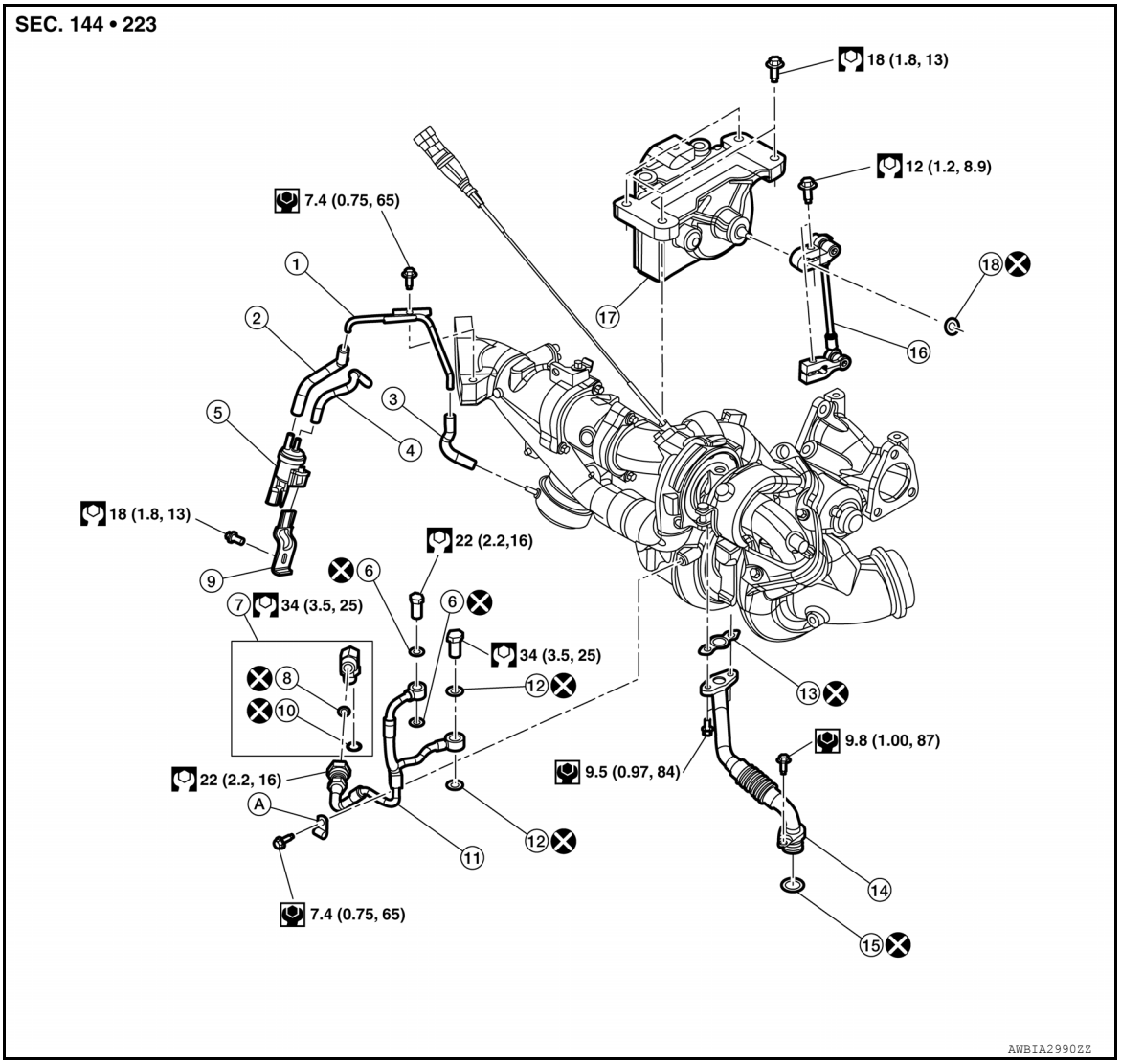
- **Wear appropriate goggles and protective clothing.**
- **Always properly ventilate the area where the service is being performed.**
- **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
- **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
- **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**

4. Operate the engine and check for leaks.

TURBOCHARGER OIL DRAIN LINE

Exploded View

INFOID:0000000014418689



1. Vacuum tube
2. Vacuum hose
3. Vacuum hose
4. Vacuum hose
5. Turbocharger compressor bypass solenoid
6. Copper sealing washer
7. Turbocharger oil supply cylinder block fitting
8. O-ring
9. Turbocharger compressor bypass solenoid bracket.
10. O-ring
11. Turbocharger oil supply line
12. Copper sealing washer
13. Turbocharger oil drain line gasket
14. Turbocharger oil drain line
15. O-ring
16. Rotary turbine control valve linkage
17. Rotary turbine control valve actuator
18. Rotary turbine control valve linkage retaining clip

A. Clip

CAUTION:

If the rotary turbine control valve linkage was only removed from the actuator side, the rotary turbine control valve linkage can be reattached to the actuator and reused. If the rotary turbine control valve linkage was removed from the turbine valve shaft, the rotary turbine control valve linkage must be replaced.

Removal and Installation

INFOID:0000000014418690

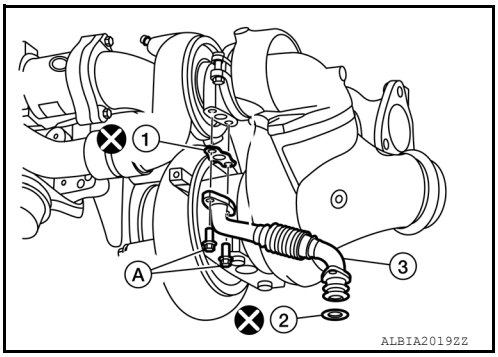
GENERAL INFORMATION

The turbocharger oil drain line (3), drains oil from the high-pressure turbocharger. The low pressure turbocharger oil drain is integrated into the bearing housing and drains directly into the engine cylinder block.

CAUTION:

Do not reuse the turbocharger oil drain line gasket (1) or O-ring (2).

(A) : Bolt

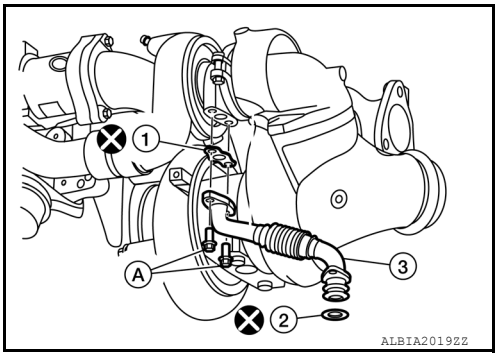


INSPECTION BEFORE REMOVAL

- Inspect the turbocharger oil drain line for oil leaks and damage.
- Inspect all joining surfaces for oil leaks.
- Repair or replace as necessary.

REMOVAL

1. Remove the turbocharger assembly. Refer to EM-399, "Removal and Installation".
2. Remove bolts (A).
3. Remove the turbocharger oil drain line (3).
4. Remove the turbocharger oil drain line gasket (1) and the O-ring (2).
   CAUTION:
   - **Do not reuse the O-ring (2).**
   - **Do not reuse the gasket.**



INSPECTION AFTER REMOVAL

WARNING:

- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturers recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**

Clean the following:

- Turbocharger oil drain line with solvent and dry with compressed air.
- Gasket sealing surfaces on the oil drain line and the turbocharger.
- O-ring seating bore in the cylinder block. Use a clean, lint free cloth.

CAUTION:

Do not allow any debris to fall into the engine.

Turbocharger Oil Drain Line Inspection:

- Inspect the turbocharger oil drain line for any restriction. Clean the inside of the turbocharger oil drain line if any restriction is found.
- Inspect the turbocharger oil drain line for cracks, wear or damage. Replace the turbocharger oil drain line as necessary.
- Inspect the turbocharger oil drain line O-ring sealing surfaces in the cylinder block for damage.

CAUTION:

Do not allow any debris to fall into the engine.

INSTALLATION

Installation is in the reverse order of removal.

CAUTION:

- **Do not reuse the O-ring.**
- **Do not reuse the gasket.**

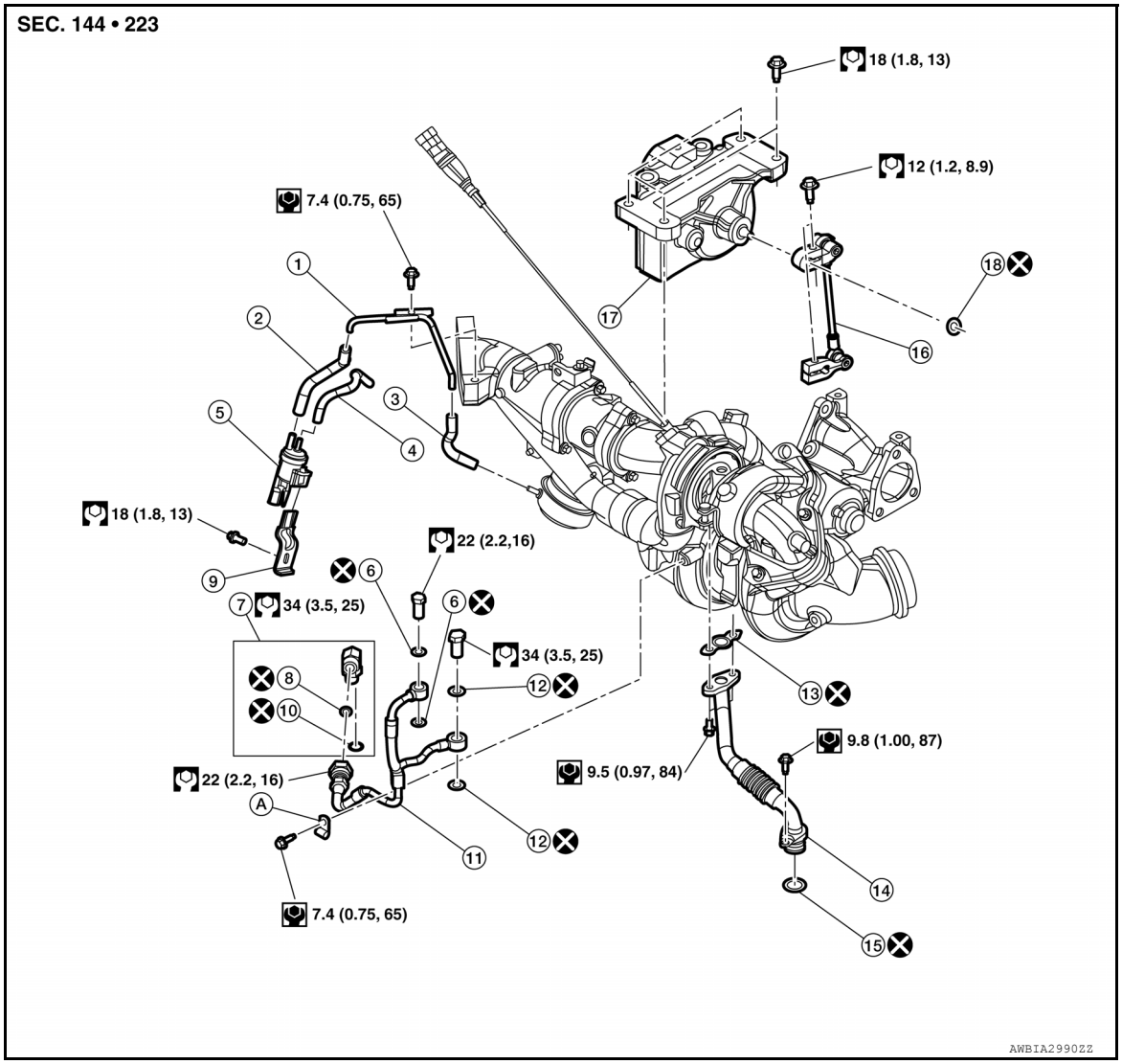
NOTE:

- Lubricate the turbocharger oil drain line O-ring with clean engine oil.
- Do not bend the turbocharger oil drain line during installation.
- Operate the engine and check for leaks.

TURBOCHARGER OIL SUPPLY LINE

Exploded View

INFOID:0000000014418691



1. Vacuum tube	2. Vacuum hose	3. Vacuum hose
4. Vacuum hose	5. Turbocharger compressor bypass solenoid	6. Copper sealing washer
7. Turbocharger oil supply cylinder block fitting	8. O-ring	9. Turbocharger compressor bypass solenoid bracket.
10. O-ring	11. Turbocharger oil supply line	12. Copper sealing washer
13. Turbocharger oil drain line gasket	14. Turbocharger oil drain line	15. O-ring
16. Rotary turbine control valve linkage	17. Rotary turbine control valve actuator	18. Rotary turbine control valve linkage retaining clip
A. Clip		

CAUTION:

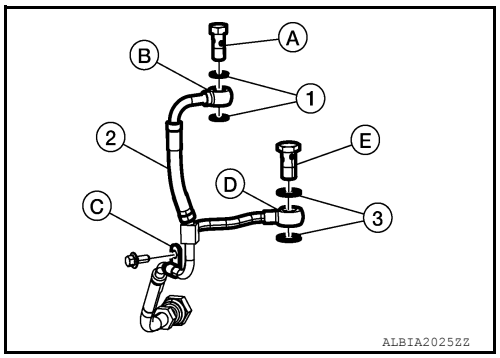
If the rotary turbine control valve linkage was only removed from the actuator side, the rotary turbine control valve linkage can be reattached to the actuator and reused. If the rotary turbine control valve linkage was removed from the turbine valve shaft, the rotary turbine control valve linkage must be replaced.

Removal and Installation

INFOID:0000000014418692

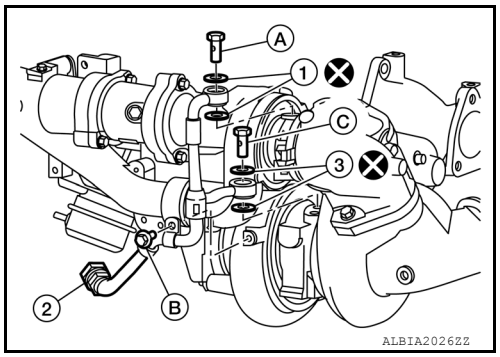
GENERAL INFORMATION

Oil from the engine cylinder block flows though the turbocharger oil supply line to the high-pressure and low-pressure turbochargers.



(1) : High-pressure turbocharger banjo copper washers
(2) : Turbocharger oil supply line
(3) : Low-pressure turbocharger banjo copper washers
(A) : High-pressure turbocharger banjo bolt
(B) : High-pressure turbocharger banjo fitting
(C) : Turbocharger oil supply line bracket
(D) : Low-pressure turbocharger banjo fitting
(E) : Low-pressure turbocharger banjo bolt

REMOVAL



1. Remove the turbocharger assembly. Refer to EM-399, "Removal and Installation".
2. Remove the turbocharger oil supply line bolt (B).
3. Remove the high-pressure banjo bolt (A).
4. Remove the high-pressure banjo bolt sealing washers (1).
   CAUTION:
   Do not reuse the copper sealing washers
5. Remove the low-pressure banjo bolt (C).
6. Remove the low-pressure banjo bolt sealing washers (3).
   CAUTION:
   Do not reuse the copper sealing washers
7. Remove the turbocharger oil supply line (2) from the turbocharger.
   CAUTION:
   Do not remove the oil supply fitting from the block unless damaged. If fitting is required to be removed, vacuum all loose dirt from around the area of the oil supply fitting to avoid oil system contamination and potential engine damage.

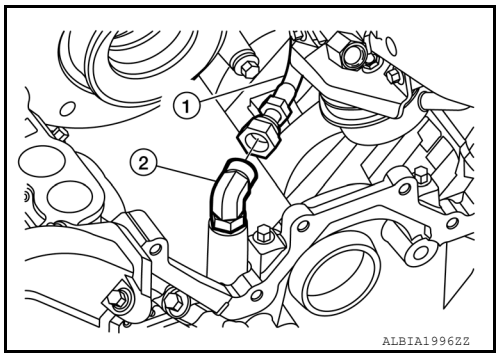
INSPECTION AFTER REMOVAL

- Clean the oil supply line with a clean, lint free cloth.
- Keep dirt and debris out of the turbocharger oil supply line.
- Inspect the turbocharger oil supply line for cracks, wear, kinks, burns or other damage.

INSTALLATION

Installation is in the reverse order of removal.

- If fitting was removed:



1. Tighten the cylinder block fitting (2), to the cylinder block to specification.

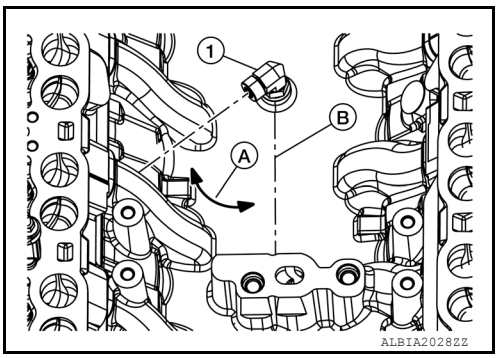
   Cylinder block fitting (2) : 34 N·m (3.5 kg-m, 25 ft-lb)

2. Tighten the male union for the turbocharger oil supply line connection (1) to the cylinder block fitting (2) to specification.

   Turbocharger oil supply line connection (1) : 22 N·m (2.2 kg-m, 16 ft-lb)

CAUTION:

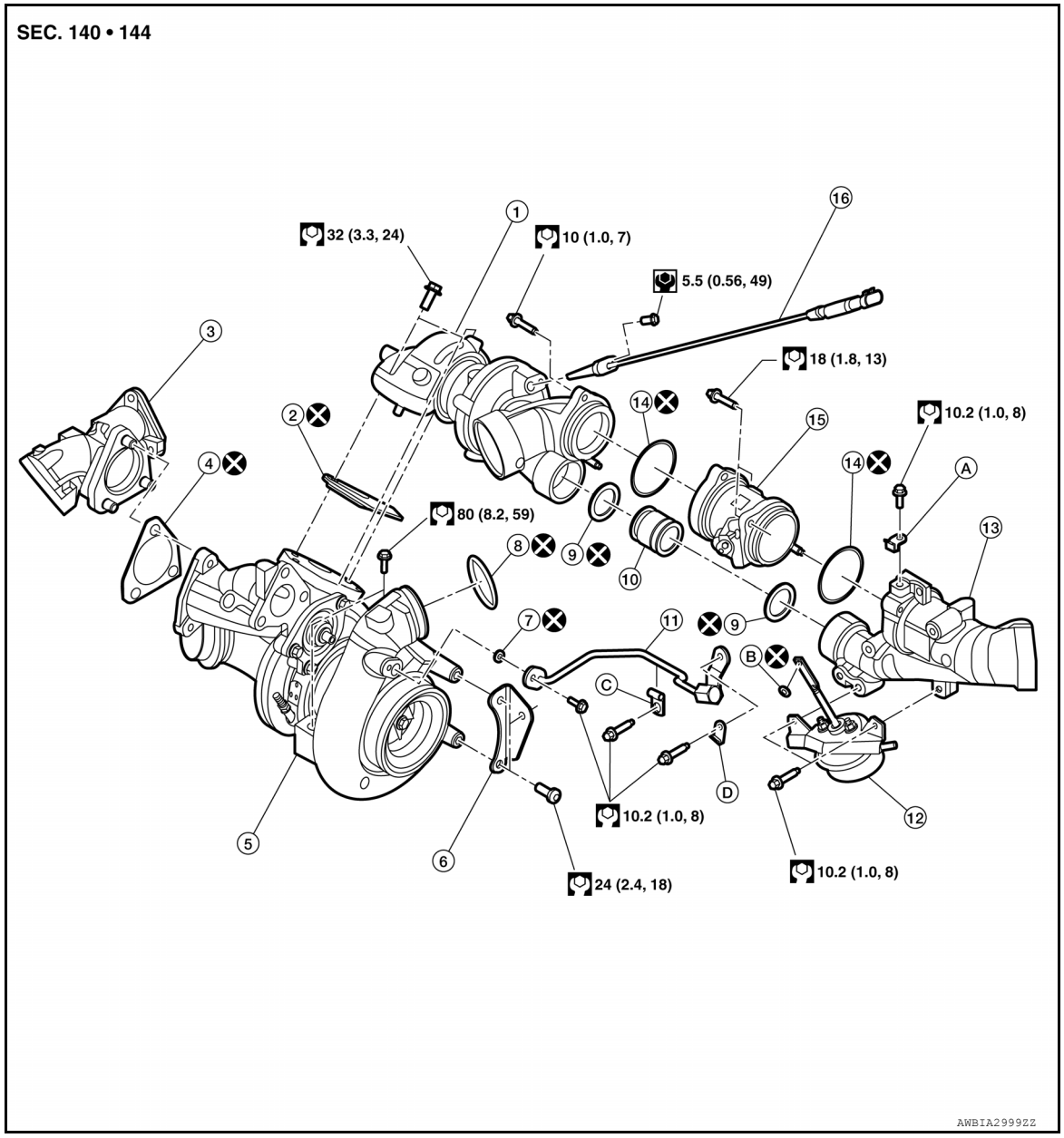
Confirm that the male union for the cylinder block fitting (1) to the cylinder block is in place and properly aligned. The fitting should be oriented 45 degrees (A) from the crankshaft axis (B), toward the rear, left of the engine.



TURBOCHARGER COMPRESSOR OUTLET CONNECTION

Exploded View

INFOID:0000000014418693



1. High-pressure turbocharger*
2. High-pressure turbocharger gasket*
3. Exhaust manifold collector pipe
4. Exhaust manifold collector pipe gasket
5. Low-pressure turbocharger*
6. Support bracket*
7. O-ring*
8. O-ring*
9. O-ring*
10. Jumper tube*
11. Low-pressure turbocharger boost pressure sensor tube*
12. Turbocharger compressor bypass valve actuator*
13. Turbocharger compressor outlet connection*
14. O-ring*
15. Turbocharger compressor bypass valve*
16. Turbocharger speed sensor
A. Clip*
B. Retaining clip*
C. Clip*
D. Clip*

*: Always check with parts department for the latest parts information.

Removal and Installation

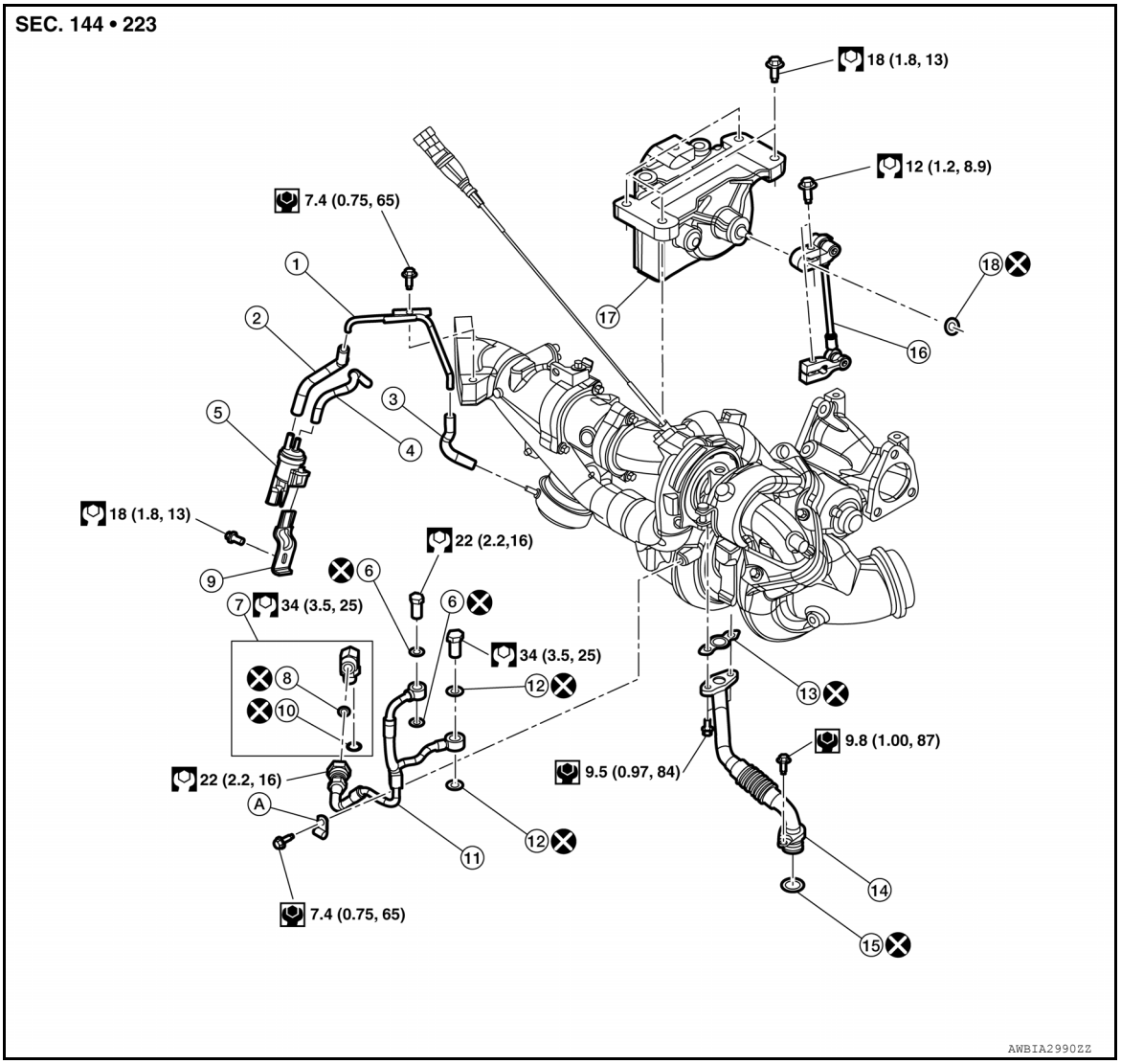
INFOID:0000000014418694

The turbocharger compressor outlet connection is serviced as part of the turbocharger assembly. Refer to EM-399, "Removal and Installation".

ROTARY TURBINE CONTROL VALVE ACTUATOR

Exploded View

INFOID:0000000014418695



1. Vacuum tube
2. Vacuum hose
3. Vacuum hose
4. Vacuum hose
5. Turbocharger compressor bypass solenoid
6. Copper sealing washer
7. Turbocharger oil supply cylinder block fitting
8. O-ring
9. Turbocharger compressor bypass solenoid bracket.
10. O-ring
11. Turbocharger oil supply line
12. Copper sealing washer
13. Turbocharger oil drain line gasket
14. Turbocharger oil drain line
15. O-ring
16. Rotary turbine control valve linkage
17. Rotary turbine control valve actuator
18. Rotary turbine control valve linkage retaining clip

A. Clip

CAUTION:

If the rotary turbine control valve linkage was only removed from the actuator side, the rotary turbine control valve linkage can be reattached to the actuator and reused. If the rotary turbine control valve linkage was removed from the turbine valve shaft, the rotary turbine control valve linkage must be replaced.

Removal and Installation

INFOID:0000000014418696

GENERAL INFORMATION

The rotary turbine control valve actuator is used to control the rotary turbine control valve by moving the rotary turbine control valve linkage.

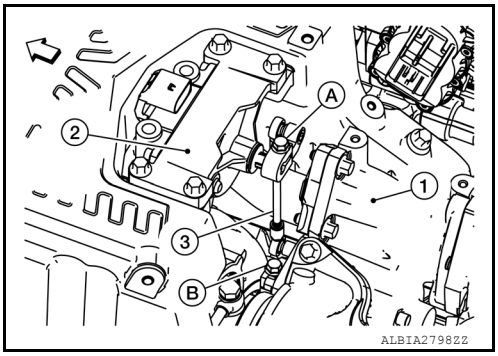
REMOVAL

WARNING:

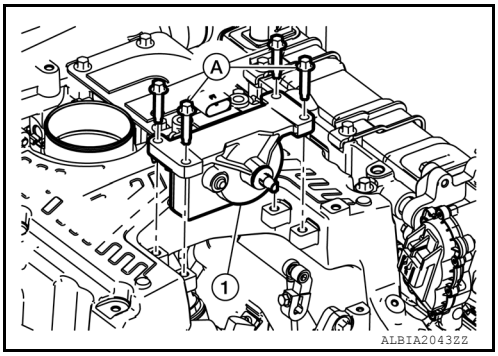
When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:

- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**

1. Clean the area around the turbocharger actuator and dry with compressed air.
2. Loosen the bolt (A) that connects the rotary turbine control valve linkage (3) to the rotary turbine control valve actuator (2).
   NOTE:
   - It is not necessary to remove the rotary turbine control valve linkage bolt (B) to remove the rotary turbine control valve linkage.
   - If the turbine valve side of the rotary turbine control valve linkage is disconnected from the turbine valve shaft, the rotary turbine control valve linkage must be replaced.



3. Remove bolts (A) from the rotary turbine control valve actuator (1) and remove the rotary turbine control valve actuator.



INSPECTION AFTER REMOVAL

- Wipe the area of the actuator with a clean cloth.
- Inspect the actuator connector pins for signs of corrosion or other damage.
- Inspect the drain hole on the bottom of the actuator for signs of any debris. Remove debris, if present.
- Inspect the actuator shaft for signs of damage. Replace the actuator, if the shaft is damaged

INSTALLATION

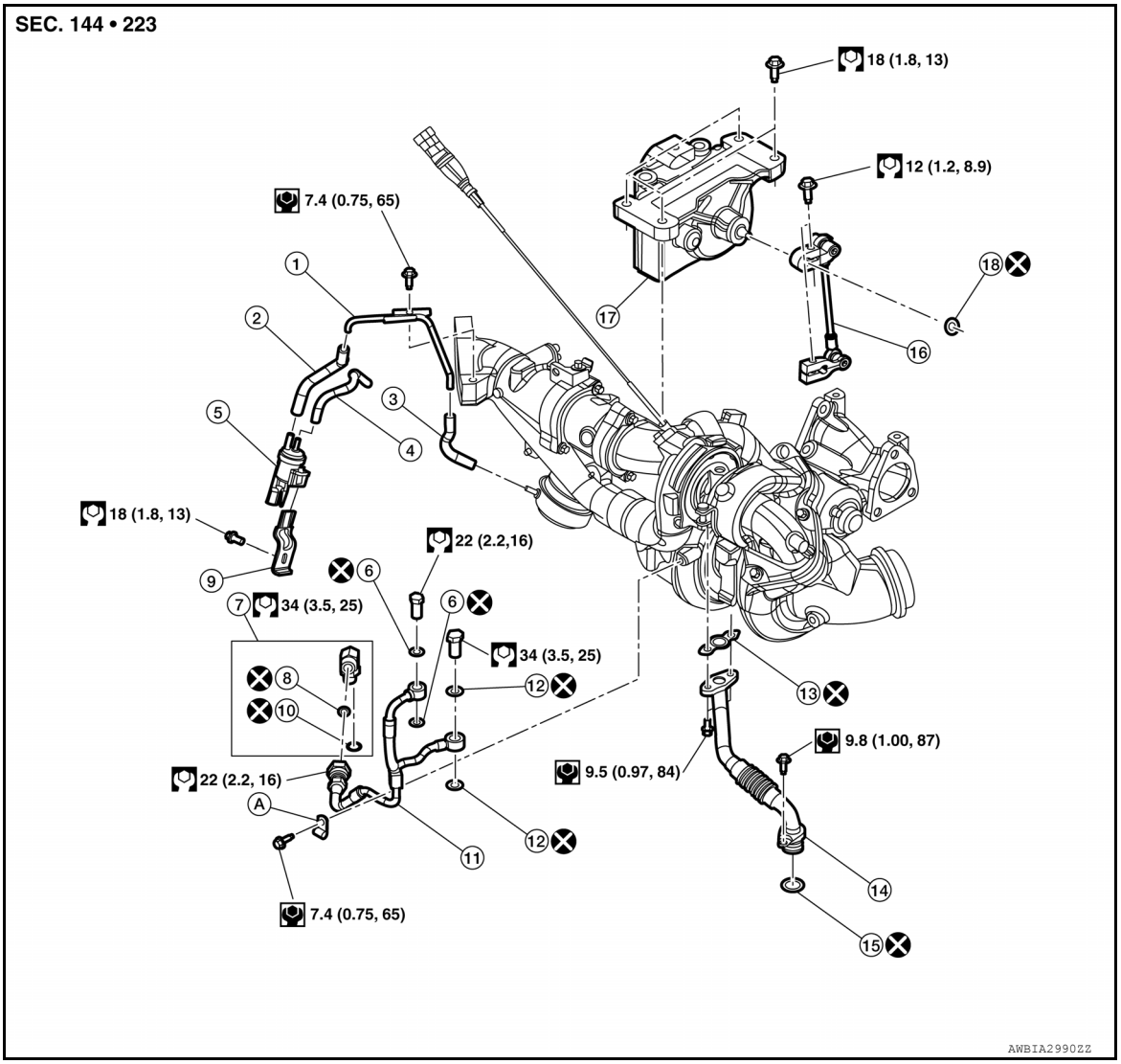
Installation is in the reverse order of removal.

- Use CONSULT work support item RTCV Actuator Calibration to calibrate the rotary turbine control valve actuator. Refer to EC-902, "Description".

ROTARY TURBINE CONTROL VALVE LINKAGE

Exploded View

INFOID:0000000014418697



1. Vacuum tube	2. Vacuum hose	3. Vacuum hose
4. Vacuum hose	5. Turbocharger compressor bypass solenoid	6. Copper sealing washer
7. Turbocharger oil supply cylinder block fitting	8. O-ring	9. Turbocharger compressor bypass solenoid bracket.
10. O-ring	11. Turbocharger oil supply line	12. Copper sealing washer
13. Turbocharger oil drain line gasket	14. Turbocharger oil drain line	15. O-ring
16. Rotary turbine control valve linkage	17. Rotary turbine control valve actuator	18. Rotary turbine control valve linkage retaining clip

A. Clip

CAUTION:

If the rotary turbine control valve linkage was only removed from the actuator side, the rotary turbine control valve linkage can be reattached to the actuator and reused. If the rotary turbine control valve linkage was removed from the turbine valve shaft, the rotary turbine control valve linkage must be replaced.

Removal and Installation

INFOID:0000000014418698

REMOVAL

WARNING:

When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:

- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**

CAUTION:

The rotary turbine control valve must be disconnected from the wiring harness or component damage can result.

1. Clean the area around the rotary turbine control valve linkage and dry with compressed air.
2. Loosen the bolt (A) that connects the rotary turbine control valve linkage (3) to the rotary turbine control valve actuator (2).

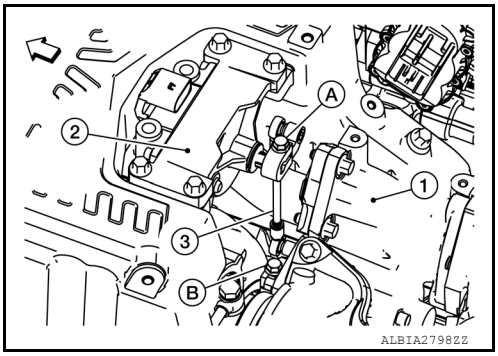
   CAUTION:

   Use care while removing the linkage as damage can result.

   ⇦ : Front

   NOTE:

   It is **not** necessary to completely remove the rotary turbine control valve linkage bolts to remove the rotary turbine control valve actuator linkage.



3. Loosen bolt (B) that connects the rotary turbine control valve linkage (3) to the turbocharger assembly (1).

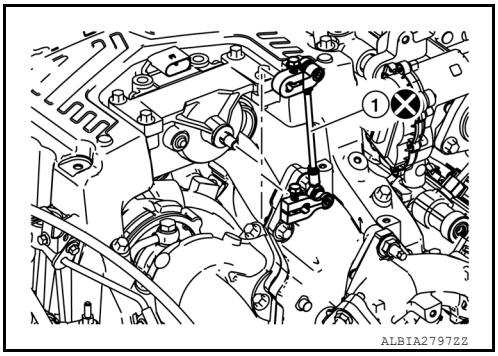
   NOTE:

   If the turbine valve side of the rotary turbine control valve linkage is disconnected from the turbine valve shaft, the rotary turbine control valve linkage **must** be replaced.

4. Remove the rotary turbine control valve linkage (1).

   CAUTION:

   Do not reuse the rotary turbine control valve linkage.



INSPECTION AFTER REMOVAL

- Inspect the rotary turbine control valve linkage bolts and threaded rod for damaged threads.
- Check the threaded rod for cracking, bending, and loose fit with the spherical housing.
- Replace any damaged components.
- Inspect the ball joint race for damage and loose fit.
- Inspect the ball joint rivets for loose fit with the levers. The ball stud **must not** be loose with the lever.

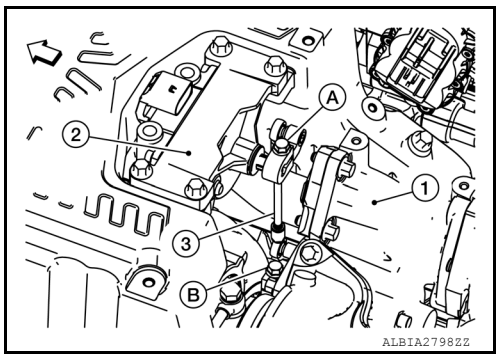
  NOTE:

  If the rotary turbine control valve linkage was **only** removed from the actuator side, the rotary turbine control valve linkage can be reattached to the actuator and reused. If the rotary turbine control valve linkage was removed from the turbine valve shaft, the rotary turbine control valve linkage **must** be replaced.

INSTALLATION

- Installation is in the reverse order of removal.
  NOTE:
  The rotary turbine control valve linkage (3) **must** be oriented as shown with bolts (A) and (B) facing up. The rod is positioned to the right and both levers pointing toward the left as viewed from the flywheel end of the engine.

Rotary turbine control valve bolts : 12 N·m (1.2 kg-m, 8.9 ft-lb)



(1) : Turbocharger
(2) : Rotary turbine control valve actuator
⇦ : Front

- The rotary turbine control valve linkage levers are installed correctly if the bolt heads are facing upward.
- Rotate the rotary turbine control valve linkage levers to verify the shaft on the actuator moves from end-to-end.

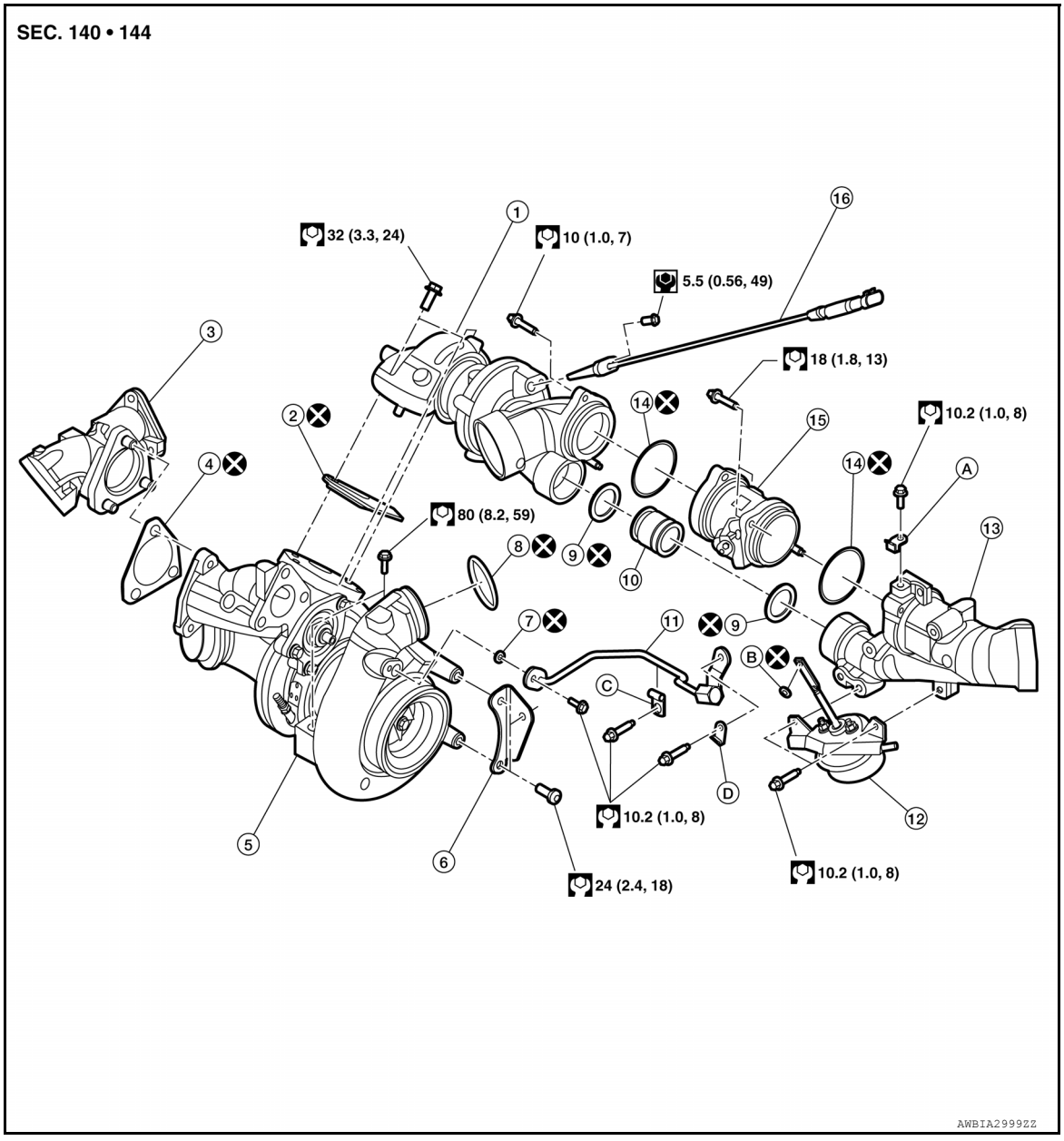
INSPECTION AFTER INSTALLATION

- Use CONSLT work support item RTCV Actuator Calibration to calibrate the rotary turbine control valve linkage. Refer to EC-902, "Description".
- Operate the engine to be sure the turbocharger actuator operates correctly and all turbocharger actuator fault codes are inactive.
  NOTE:
  - All rotary turbine control actuator fault codes should be inactive.
  - Use CONSULT to clear all fault codes.

TURBOCHARGER COMPRESSOR BYPASS VALVE

Exploded View

INFOID:0000000014418699



1. High-pressure turbocharger*
2. High-pressure turbocharger gasket*
3. Exhaust manifold collector pipe
4. Exhaust manifold collector pipe gasket
5. Low-pressure turbocharger*
6. Support bracket*
7. O-ring*
8. O-ring*
9. O-ring*
10. Jumper tube*
11. Low-pressure turbocharger boost pressure sensor tube*
12. Turbocharger compressor bypass valve actuator*
13. Turbocharger compressor outlet connection*
14. O-ring*
15. Turbocharger compressor bypass valve*
16. Turbocharger speed sensor
A. Clip*
B. Retaining clip*
C. Clip*
D. Clip*

*: Always check with parts department for the latest parts information.

Removal and Installation

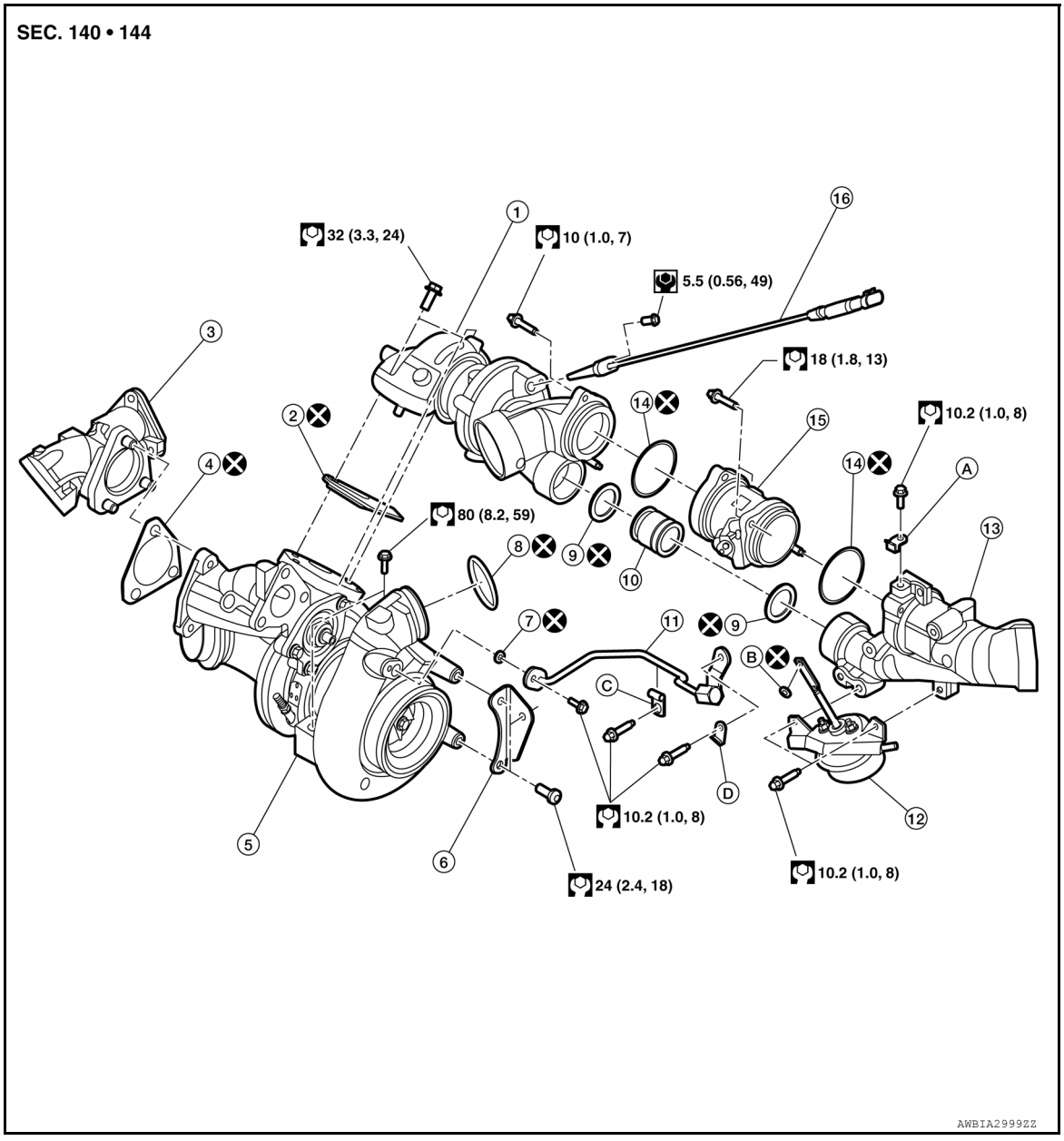
INFOID:0000000014418700

The turbocharger compressor bypass valve is serviced as part of the turbocharger assembly. Refer to EM-399, "Removal and Installation".

TURBOCHARGER COMPRESSOR BYPASS ACTUATOR

Exploded View

INFOID:0000000014418701



1. High-pressure turbocharger*
2. High-pressure turbocharger gasket*
3. Exhaust manifold collector pipe
4. Exhaust manifold collector pipe gasket
5. Low-pressure turbocharger*
6. Support bracket*
7. O-ring*
8. O-ring*
9. O-ring*
10. Jumper tube*
11. Low-pressure turbocharger boost pressure sensor tube*
12. Turbocharger compressor bypass valve actuator*
13. Turbocharger compressor outlet connection*
14. O-ring*
15. Turbocharger compressor bypass valve*
16. Turbocharger speed sensor
A. Clip*
B. Retaining clip*
C. Clip*
D. Clip*

*: Always check with parts department for the latest parts information.

Removal and Installation

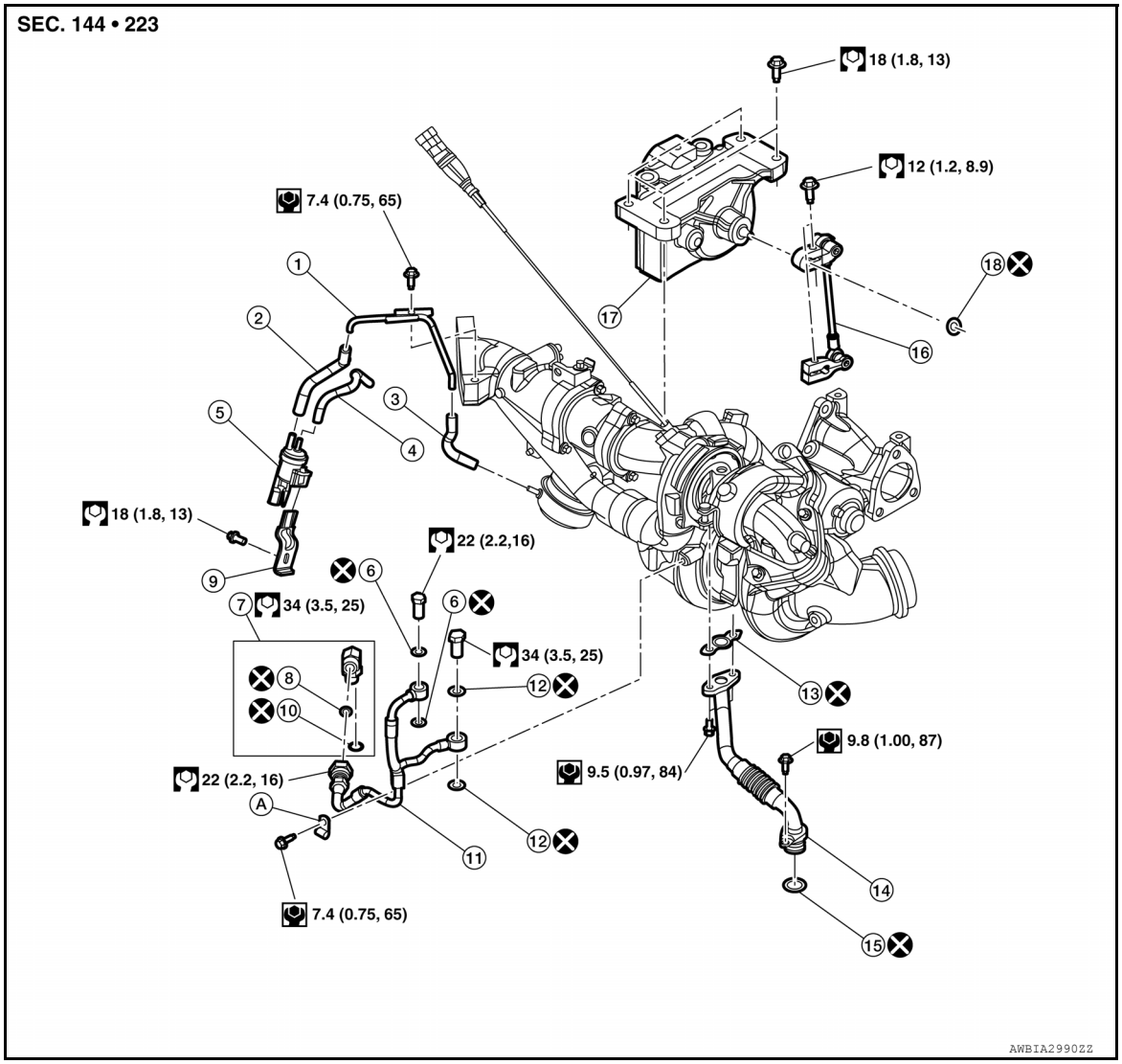
INFOID:0000000014418702

The turbocharger compressor bypass actuator is serviced as part of the turbocharger assembly. Refer to EM-399, "Removal and Installation".

TURBOCHARGER COMPRESSOR BYPASS SOLENOID

Exploded View

INFOID:0000000014418703



1. Vacuum tube
2. Vacuum hose
3. Vacuum hose
4. Vacuum hose
5. Turbocharger compressor bypass solenoid
6. Copper sealing washer
7. Turbocharger oil supply cylinder block fitting
8. O-ring
9. Turbocharger compressor bypass solenoid bracket.
10. O-ring
11. Turbocharger oil supply line
12. Copper sealing washer
13. Turbocharger oil drain line gasket
14. Turbocharger oil drain line
15. O-ring
16. Rotary turbine control valve linkage
17. Rotary turbine control valve actuator
18. Rotary turbine control valve linkage retaining clip

A. Clip

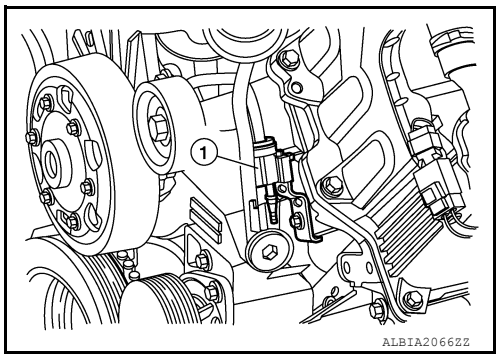
CAUTION:

If the rotary turbine control valve linkage was only removed from the actuator side, the rotary turbine control valve linkage can be reattached to the actuator and reused. If the rotary turbine control valve linkage was removed from the turbine valve shaft, the rotary turbine control valve linkage must be replaced.

Removal and Installation

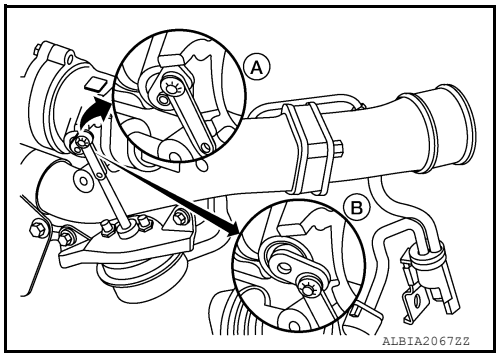
INFOID:0000000014418704

GENERAL INFORMATION



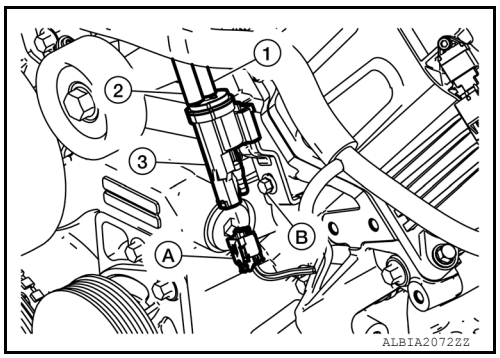
- The turbocharger compressor bypass solenoid (1) allows the vacuum produced by the vacuum pump to pass through to turbocharger compressor bypass actuator when the engine control module (ECM) applies a pulse width modulation (PWM) duty cycle to the turbocharger compressor bypass solenoid.
- The ECM commands a duty cycle of 100 percent to the turbocharger compressor bypass solenoid when the engine speed and load is such that is required for the turbocharger compressor bypass valve to open. This allows vacuum to pass through to actuate the turbocharger compressor bypass valve.
- When the ECM does **not** command the turbocharger compressor bypass valve to open, no vacuum is allowed from the vacuum pump to the turbocharger compressor bypass valve canister.
- The turbocharger compressor bypass solenoid is located at the front cover of the engine near the power steering pump.

INSPECTION BEFORE REMOVAL



- Use CONSULT to override the turbocharger compressor bypass valve command when the engine is at idle. When the command is OFF, the turbocharger compressor bypass valve linkage will be in the default state (A). Refer to EC-806, "CONSULT Function".
- Command the turbocharger compressor bypass solenoid to ON. The turbocharger compressor bypass valve linkage will move downward (B), as demonstrated in the illustration.
- If the turbocharger compressor bypass valve linkage does **not** move, test the resistance of the turbocharger compressor bypass solenoid as specified in this procedure. Replace the turbocharger compressor bypass solenoid if it does **not** meet the resistance specification.
- If the turbocharger compressor bypass solenoid meets the resistance specification, use the following procedure to diagnose the turbocharger compressor bypass system. Refer to EC-806, "CONSULT Function".

REMOVAL



1. Disconnect the harness connector (A) from the turbocharger compressor bypass solenoid (3).
2. Remove the vacuum hoses (1) and (2) from the turbocharger compressor bypass solenoid.
3. Remove bolt (B) and remove the turbocharger compressor bypass solenoid.

INSPECTION AFTER REMOVAL

- Inspect the engine harness connector and the turbocharger compressor bypass solenoid for the following:
- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Repair or replace the engine harness connector as needed.
- Inspect the turbocharger compressor bypass solenoid for the following:
- Bent or broken ports at the turbocharger compressor bypass solenoid. Replace the turbocharger compressor bypass solenoid if damage is found.
- Using a suitable tool, measure the resistance across both pins of the turbocharger compressor bypass solenoid coil.

INSTALLATION

Installation is in the reverse order of removal.

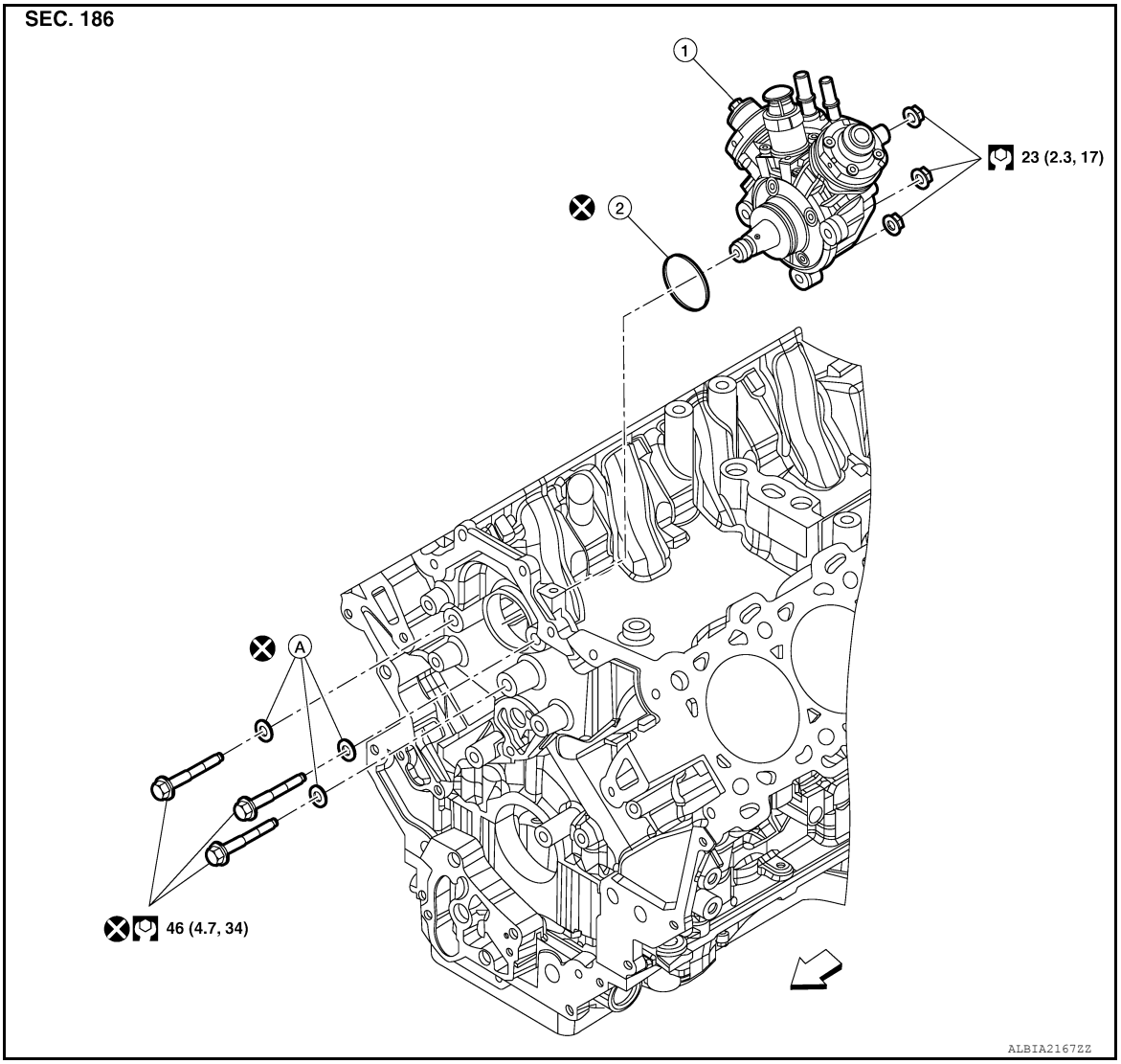
NOTE:

Operate the engine and check for vacuum leaks.

FUEL PUMP

Exploded View

INFOID:0000000014418705



1. Fuel pump
2. O-ring
A. Washer

⇦ Front

Removal and Installation

INFOID:0000000014418706

REMOVAL

WARNING:

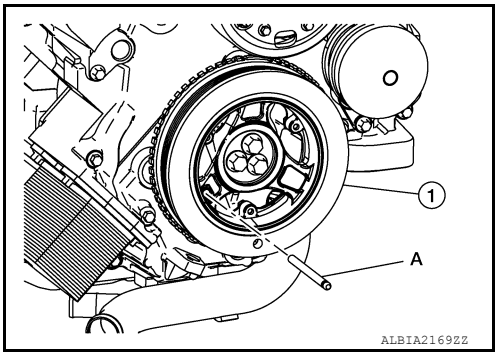
- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **To avoid the risk of personal injury or fire, drain diesel fuel into an approved container and safely dispose of in accordance with local environmental regulations.**

CAUTION:
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

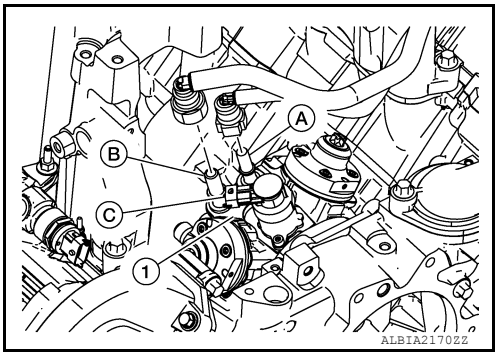
1. Remove the fuel rail supply lines. Refer to EM-468, "Removal and Installation".
2. Remove the vacuum pump. Refer to EM-486, "Removal and Installation".
3. Use Tool (B) on the vibration damper. Bar the engine over until cylinder number 1 top dead center (TDC) has been located.
   NOTE:
   Locate cylinder number 1 TDC by barring the engine until the timing mark on the vibration damper (1) and front cover are aligned. After TDC is located, insert Tool (A).

   Tool A : — (J-54404)
   Tool B : — (J-54424)



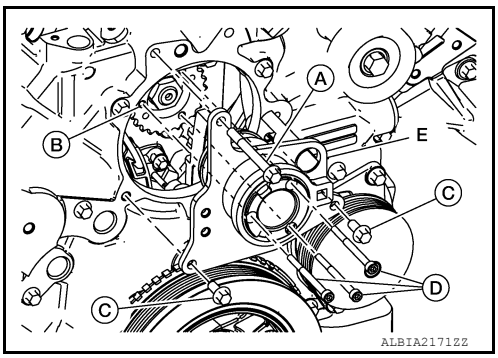
4. Disconnect the harness connector (C) from the high-pressure fuel pump (1).
5. Disconnect the two-button fuel supply line fitting (B) that connects the fuel filter (Stage 2) to the high-pressure fuel pump.
6. Disconnect the two-button fuel drain line fitting (A) that connects the high-pressure fuel pump to fuel filter (Stage 2).
   NOTE:
   When removing and fuel system components, cap all fuel system openings with Tool.

   Tool : — (J-54427)



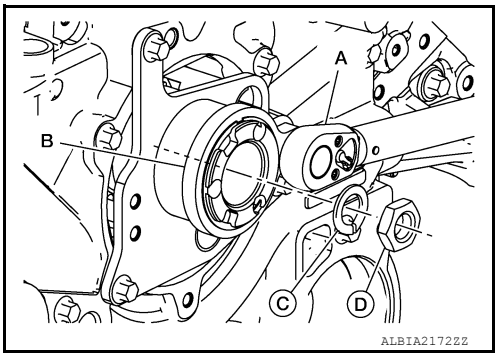
7. Install Tool (E) onto the front cover. Install the bolts (C) (included with the tool) into the lower holes and bolt (A) (from the cover) into the upper hole. Install the sprocket retainer bolts (D) into the pilot holes (B) of the fuel pump sprocket and tighten the bolts.
   CAUTION:
   Fuel pump removal tool must be used to remove the pump. Severe damage can occur if the approved tool is not used.
   NOTE:
   - The fuel pump removal tool should be installed without the forcing screw assembly installed on tool.
   - The sprocket retainer rotates to aid in locating the fuel pump tool bolts into the fuel pump sprockets pilot holes.

   Tool : — (J-54411)

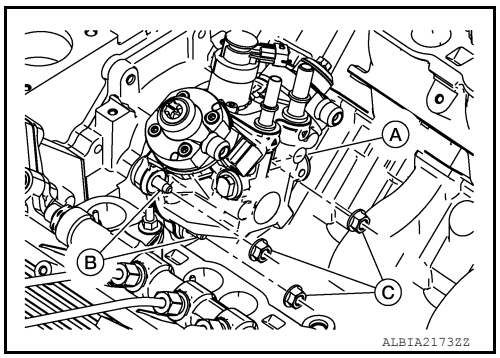


8. Use a suitable tool (A) on the Tool (B) to hold the sprocket in place and remove the nut (D) and lock washer (C).
   CAUTION:
   - **A suitable tool must be used to hold the sprocket in place while turning the fuel pump shaft nut, or severe damage to the engine can result.**
   - **Do not reuse the lock washer.**

   Tool : — (J-54411)



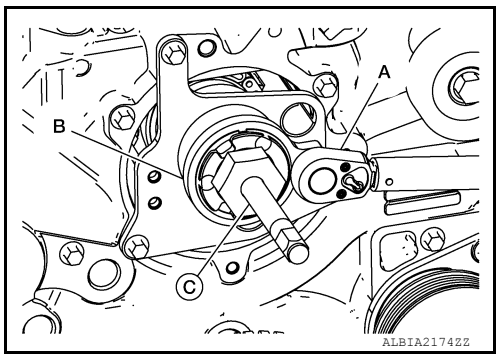
9. Remove the fuel pump nuts (C).
NOTE:
Do not remove the fuel pump bolts (A) and (B) unless they have been damaged. If the fuel pump bolt (A) located on the bank 1 side must be replaced, the front cover and camshaft chain drive must be removed to replace bolt.



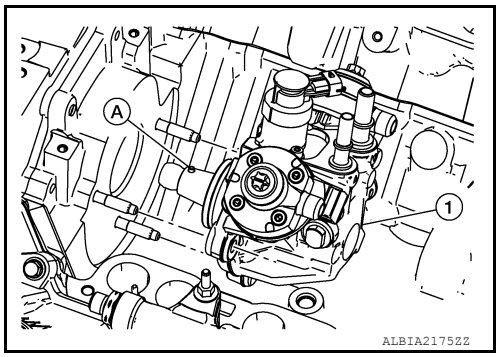
10. Use a suitable tool (A) on Tool (B) to hold the sprocket in place.
CAUTION:
A suitable tool must be used to hold the sprocket in place when using the forcing screw assembly, or severe damage to the engine can result.

Tool : — (J-54411)

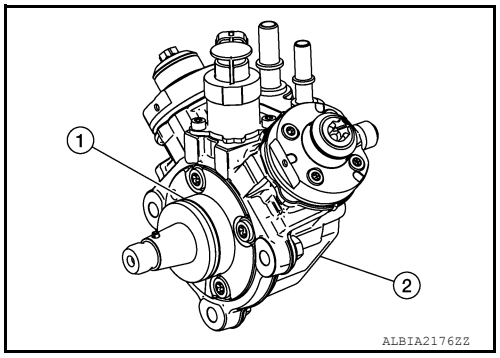
11. Thread the forcing screw assembly (C) into Tool (B).
CAUTION:
Only turn the forcing screw enough to dislodge the shaft from the sprocket, or severe damage to the engine can result.



12. Turn the forcing screw clockwise until the fuel pump shaft is dislodged from the sprocket.
13. Remove the fuel pump (1).
NOTE:
Note the orientation of the fuel pump shaft key (A) to ease in installation.



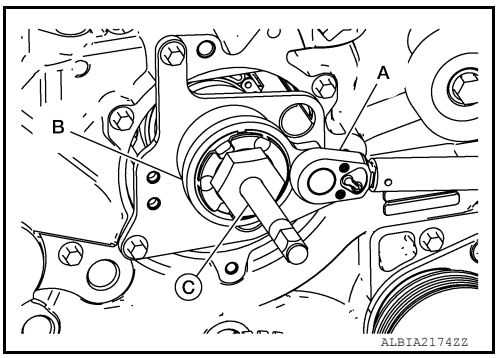
14. Remove and discard O-ring (1) on fuel pump (2).
CAUTION:
Do not reuse O-ring.



15. Remove the forcing screw assembly (C) from the Tool (B).

(A) : Suitable tool

Tool : — (J-54411)



INSPECTION AFTER REMOVAL

WARNING:

- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturers recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**

- Do not exceed 30 psi (207 kPa).
- Wear appropriate eye protection and protective clothing including gloves.

CAUTION:

- **Use solvent or cleaner that will not harm aluminum.**
- **Do not allow the cleaner to enter the fuel fittings. Dirt and debris can damage fuel system.**
- Inspect the fuel pump shaft for damage. Replace if damage is found.
- Inspect the O-ring seal area for damage. Clean and repair any burred surfaces.
- Inspect the fuel pump mounting surfaces at the pump and block mounting flange as well as the pilot bore for nicks, cuts, or other damage.
- Clean the following with a contact cleaner:

- Fuel pump mounting flange.
- Fuel pump shaft machined taper.
- Fuel pump mounting surface on the cylinder block.
- Fuel pump pilot bore in the cylinder block.

- Dry with compressed air.

INSTALLATION

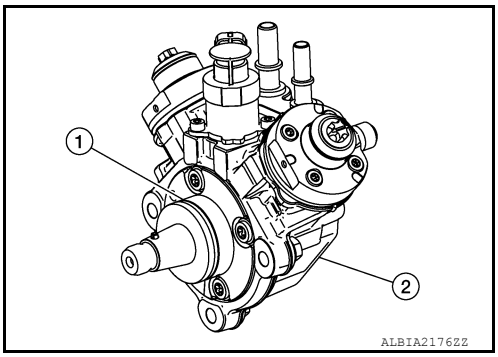
1. Install a new O-ring seal (1) into the machined groove on the fuel pump (2).

   CAUTION:

   Do not reuse the O-ring.

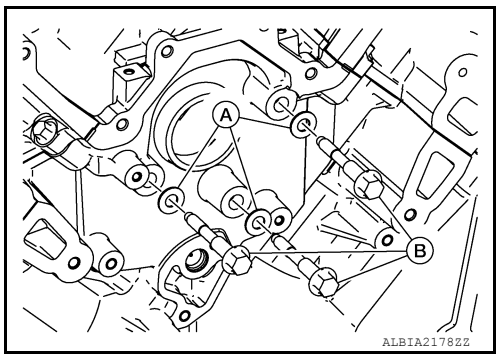
   NOTE:

   Apply a suitable assembly lubricant to the fuel pump O-ring seal and the pilot bore in the cylinder block.

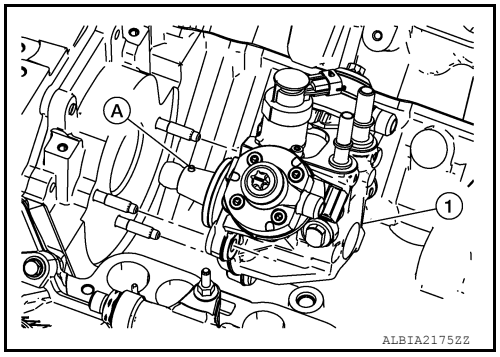


2. If the fuel pump bolts (B) were removed, replace with new bolts and sealing washers (A).

Fuel pump bolts : 46 N·m (4.7 kg-m, 34 ft-lb)



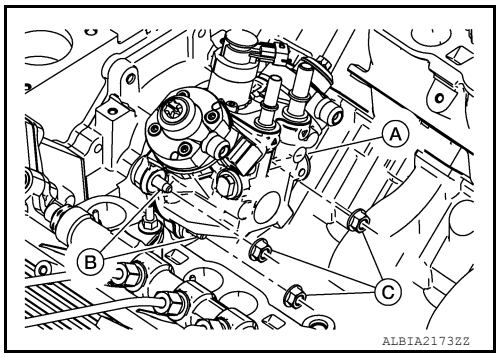
3. Align the fuel pump shaft key (A) in the same location as the fuel pump (1) that was removed.



4. Position the fuel pump in the vee while aligning the fuel pump bolts with the pilot holes on the fuel pump and install the fuel pump.

5. Install the fuel pump nuts (C) onto the fuel pump bolts (A) and (B). Tighten to specification.

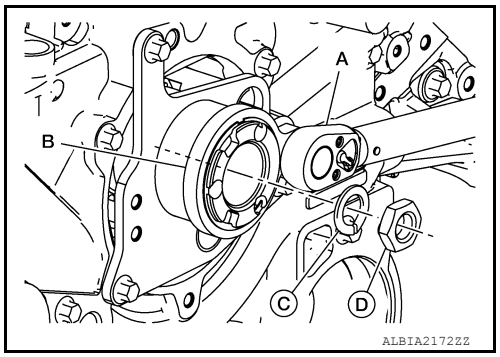
Fuel pump nuts : 23 N·m (2.3 kg-m, 17 ft-lb)



6. Install a new lock washer (C) onto fuel pump shaft. Use a suitable tool (A) on the Tool (B) to hold the sprocket in place and install the nut (D) and tighten to specification.

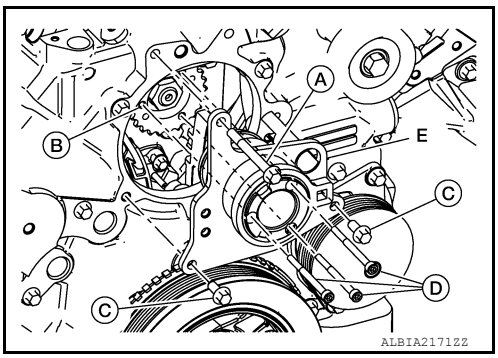
CAUTION:
- **A suitable tool must be used to hold the sprocket in place while turning the fuel pump shaft nut, or severe damage to the engine can result.**
- **Do not reuse the lock washer.**

Tool : — (J-54411)
Fuel pump shaft nut : 80 N·m (8.2 kg-m, 59 ft-lb)



7. Remove bolts (A), (C), and (D), and Tool (E) from the front cover.

Tool : — (J-54411)



8. Installation of the remaining components is in the reverse order of removal.

WARNING:

Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.

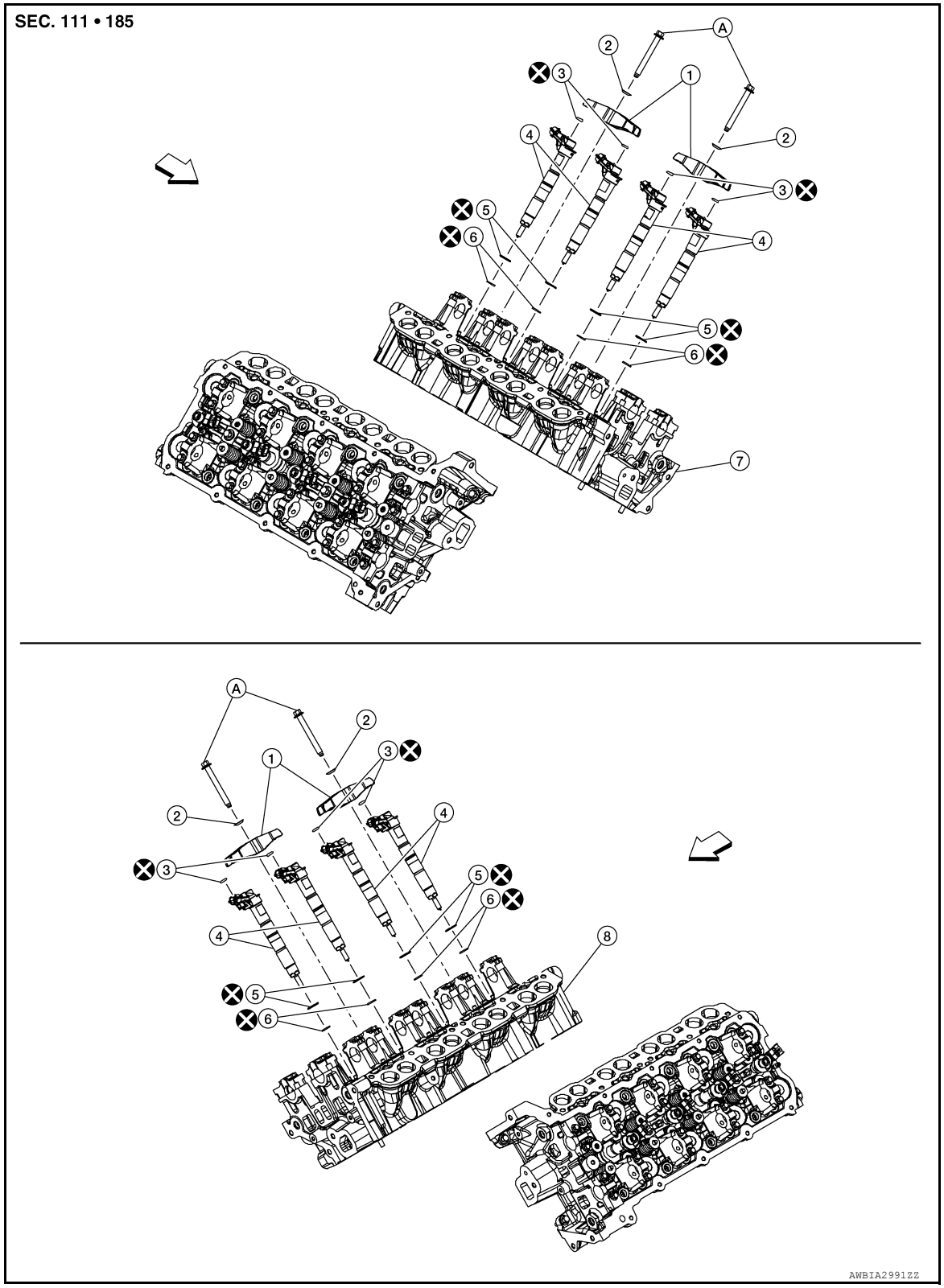
NOTE:

- Prime the fuel system. Refer to EM-219, "Priming".
- Run CONSULT High-Pressure Fuel System Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
- Operate the engine and check for leaks.

FUEL INJECTOR

Exploded View

INFOID:0000000014418707



1. Injector hold down clamp
2. Spherical washer
3. O-ring
4. Fuel injector
5. O-ring
6. Sealing washer

7. Cylinder head (bank 1) 8. Cylinder head (bank 2) A. Refer to INSTALLATION

⇦ Front

Removal and Installation (CYLINDER 1 and CYLINDER 3)

INFOID:0000000014418708

REMOVAL

WARNING:

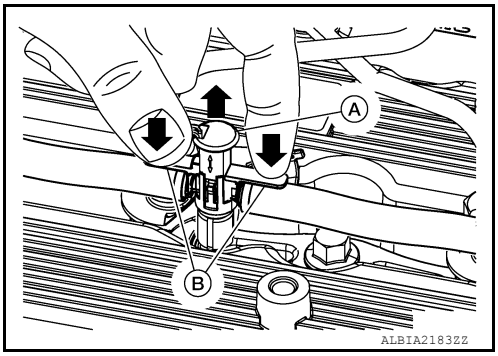
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Never loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

CAUTION:

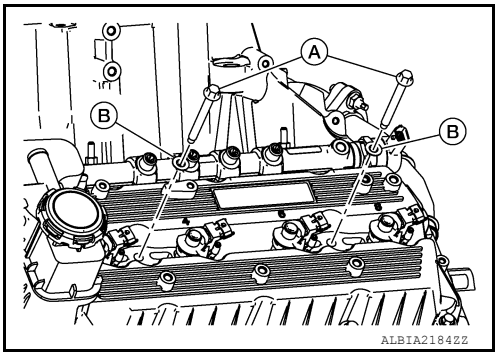
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

1. Remove fuel rail supply line (high pressure). Refer to EM-468, "Removal and Installation".
2. Remove injector supply line (high pressure). Refer to EM-462, "Exploded View".
3. Disconnect the harness connectors from the fuel injectors.
   CAUTION:
   Do not disconnect the fuel injector harness connectors when the engine is running as this could damage the engine.
4. Disconnect the fuel injector drain line quick disconnect connector by pressing down and holding the connector tabs (B), then pulling up on the center button (A) as shown.
   CAUTION:
   Do not reuse the O-rings.
   NOTE:
   When removing the injector drain lines, cap all open fuel system components with Tool.

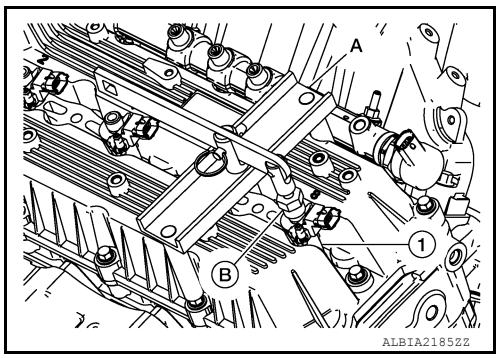
   Tool : — (J-54427)



5. Remove the fuel injector hold-down clamp bolt (A) and washer (B) from hold-down clamp of fuel injector being removed.
   NOTE:
   - Fuel injectors are held down in pairs with one hold-down clamp and bolt between the two injectors.



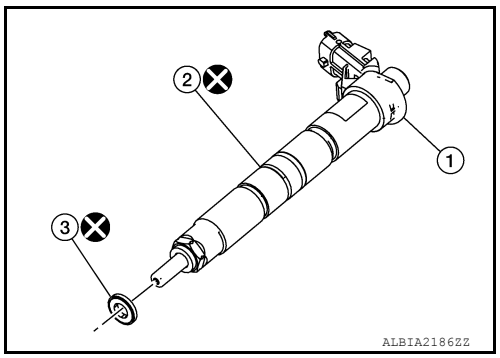
6. Install Tool (A) onto the rocker cover of the injectors to be removed then tighten the nut (B) onto the injector (1).



Tool : — (J-54402)

7. Use a suitable tool on the square drive portion of the Tool to apply constant pressure until fuel injector unseats from bore.
8. Slide fuel injector pairs out of their bores at the same time, along with the hold-down clamp.

9. Make sure the fuel injector sealing washer (3) remained on the tip of the fuel injector (1). If the sealing washer is not on the tip of the fuel injector, remove it from the fuel injector bore in the cylinder head.



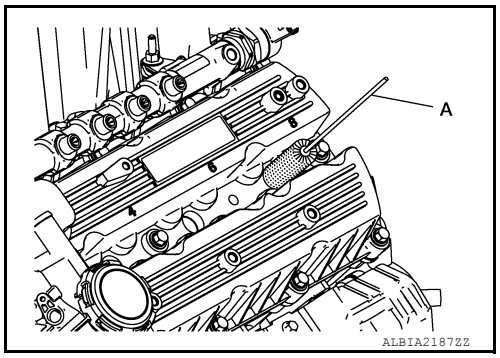
CAUTION:
Do not reuse the O-ring (2) or sealing washer (3).
NOTE:
- A double stacked or incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems because of incorrect fuel injector protrusion.
- When removing the fuel injectors, cap all open fuel system components with Tool.

Tool : — (J-54427)

10. Once the fuel injector has been removed, identify it with the appropriate cylinder number. If the fuel injectors are reused, they must be installed into the correct cylinders.

INSPECTION AFTER REMOVAL

- Clean the injector bores from built up carbon with Tool (A).



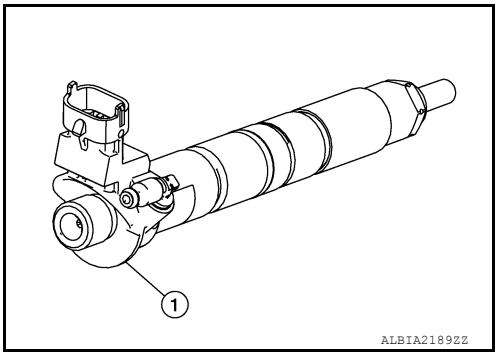
Tool : — (J-54428)

NOTE:
Use suitable tool to clean fuel injector bore prior to installation of fuel injector.

- Inspect the fuel injector tip for carbon deposits or corrosion.
- Check for terminal damage.
- Check the resistance. Resistance should measure between 150 to 210 kOhms.
- Inspect the fuel injector inlet and high-pressure connector tip for damage.
  NOTE:
  Overheating will cause the nozzle to turn a dark yellow/tan or blue color, depending on the degree of overheating.
- Replace any damaged components.
  NOTE:
  Do **not** attempt to clean the fuel injector tip. The fuel injector nozzle could become plugged and cause performance problems.

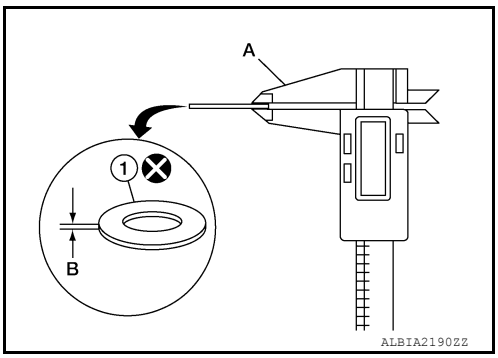
INSTALLATION

1. Record the fuel injector trim codes that are listed on the top of each fuel injector (1) and record the cylinder location where each injector will be installed.
NOTE:
The fuel injector trim codes are seven character alphanumeric codes located the top of the injector.



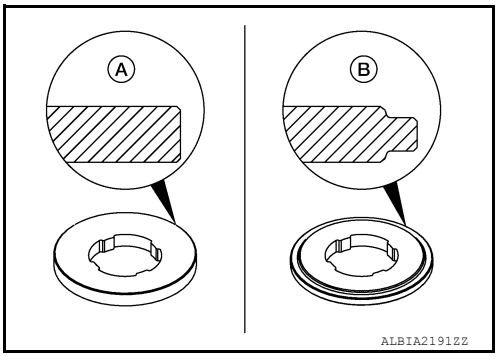
2. Verify that the new injector sealing washer (1) is the correct thickness using a suitable tool (A).
CAUTION:
Use of the incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems because of incorrect injector protrusion.
Do not reuse the sealing washer.

Injector sealing washer thickness (B)	**: 2.5 mm (0.10 in)**

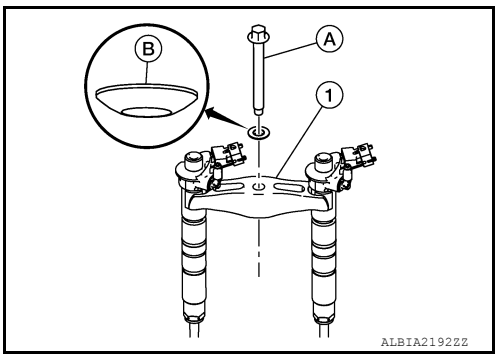


3. Verify a new sealing washer has been installed on the tip of the injector.
NOTE:
A double stacked or incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems because of incorrect injector protrusion.

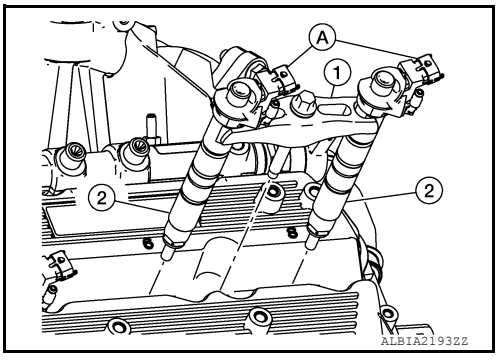
(A) : Good
(B) : NG



4. Position fuel injector pairs into a hold-down clamp (1) and make sure the spherical washer (B) is installed between the bolt (A) and the hold-down clamp with the flat side of the washer mating to the bolt.
CAUTION:
Do not reuse the O-ring.
NOTE:
- Install a new O-ring if reinstalling existing fuel injector.
- Lubricate the injector o-ring with lithium grease and a small amount of clean engine oil.
- The injector hold-down clamp is noted with a "TOP" on the side of the injector clamp that points outward of the engine.
- Make sure the injector bore is clean.



5. Install pairs of injectors (2) into the injector bores in the cylinder heads.
NOTE:
- The Bank 2 injector harness connectors (A) point to the rear of the engine. Bank 1 injector harness connectors (A) point to the front of the engine.
- If reusing the injector, make sure that the number identified on the injector matches the cylinder number.
- Be careful that pressure is not placed on the electrical connectors. The electrical connectors can break off if used to push on the injector.

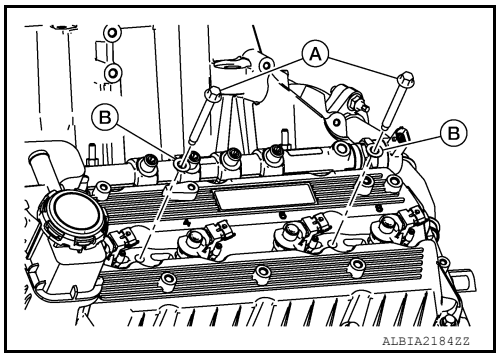


(1) : Injector hold-down clamp

6. Tighten the injector hold-down clamp bolts (A).

Step 1 : 24 N·m (2.4 kg-m, 18 ft-lb)
Step 2 : Tighten 90 degrees

(B) : Spherical washer



7. Installation of the remaining components is in the reverse order of removal.
NOTE:
- If a malfunction resulted in coolant, oil, excessive fuel, or excessive black smoke entering the exhaust system, the aftertreatment system must be inspected. Refer to and EX-21, "Aftertreatment DPF Regeneration Test".
- Prime the fuel system. Refer to EM-219, "Priming" (Fuel system priming).
- Run CONSULT High-Pressure Fuel System Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
- Operate the engine and check for leaks.

Removal and Installation (CYLINDER 2 and CYLINDER 4)

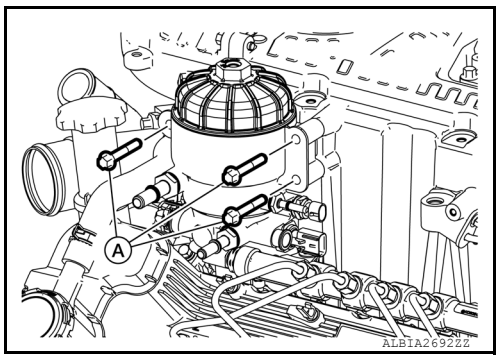
INFOID:0000000014418709

REMOVAL

WARNING:
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Never loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

CAUTION:
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

1. Remove air duct and air cleaner case (upper). Refer to EM-220, "Exploded View".
2. Remove bolts (A) securing the fuel filter housing (Stage 2) to the intake manifold and reposition fuel filter housing (Stage 2).
NOTE:
Fuel supply line, fuel return line, injector drain line, fuel pressure relief valve drain line, fuel pump supply and return lines do not need to be disconnected from fuel filter (Stage 2).

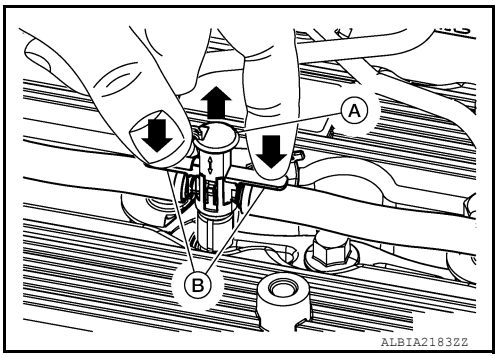


3. Remove injector supply line (high pressure) for cylinders 2 and 4. Refer to EM-462, "Exploded View".
4. Disconnect the harness connector from the fuel injector.
CAUTION:

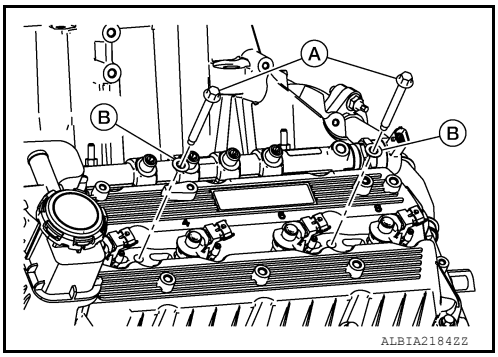
Do not disconnect the fuel injector harness connectors when the engine is running as this could damage the engine.

5. Disconnect the fuel injector drain line quick disconnect connector by pressing down and holding the connector tabs (B), then pulling up on the center button (A) as shown.
CAUTION:
Do not reuse the O-rings.
NOTE:
When removing the injector drain lines, cap all open fuel system components with Tool.

Tool : — (J-54427)



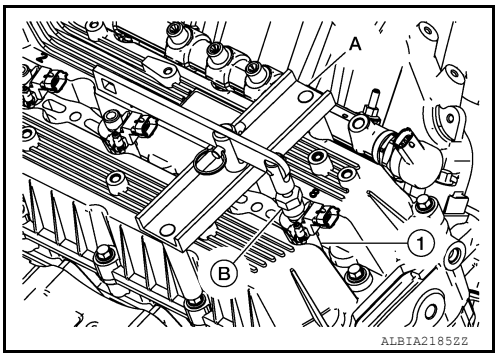
6. Remove the fuel injector hold-down clamp bolt (A) and washer (B) from hold-down clamp of fuel injectors being removed.
NOTE:
- Fuel injectors are held down in pairs with one hold-down clamp and bolt between the two injectors.



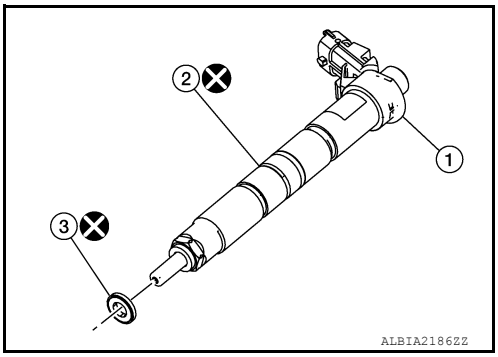
7. Install Tool (A) onto the rocker cover of the injectors to be removed then tighten the nut (B) onto the injector (1).

Tool : — (J-54402)

8. Use a suitable tool on the square drive portion of the Tool to apply constant pressure until fuel injector unseats from bore.
9. Slide fuel injector pairs out of their bores at the same time, along with the hold-down clamp.



10. Make sure the fuel injector sealing washer (3) remained on the tip of the fuel injector (1). If the sealing washer is not on the tip of the fuel injector, remove it from the fuel injector bore in the cylinder head.
CAUTION:
Do not reuse the O-ring (2) or sealing washer (3).
NOTE:
- A double stacked or incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems because of incorrect fuel injector protrusion.
- When removing the fuel injectors, cap all open fuel system components with Tool.



Tool : — (J-54427)

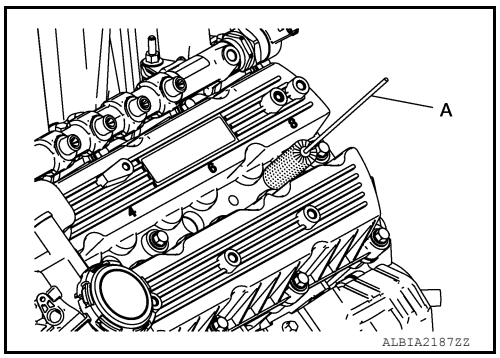
11. Once the fuel injector has been removed, identify it with the appropriate cylinder number. If the fuel injectors are reused, they must be installed into the correct cylinders.

INSPECTION AFTER REMOVAL

- Clean the injector bore from built up carbon with Tool (A).

Tool : — (J-54428)

NOTE:
Use suitable tool to clean fuel injector bore prior to installation of fuel injector.



- Inspect the fuel injector tip for carbon deposits or corrosion.
- Check for terminal damage.
- Check the resistance. Resistance should measure between 150 to 210 kOhms.
- Inspect the fuel injector inlet and high-pressure connector tip for damage.

NOTE:
Overheating will cause the nozzle to turn a dark yellow/tan or blue color, depending on the degree of overheating.

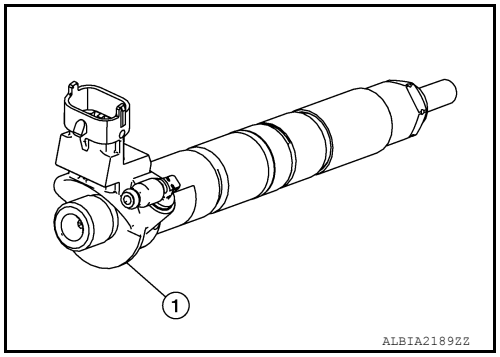
- Replace any damaged components.

NOTE:
Do **not** attempt to clean the fuel injector tip. The fuel injector nozzle could become plugged and cause performance problems.

INSTALLATION

1. Record the fuel injector trim codes that are listed on the top of each fuel injector (1) and record the cylinder location where each injector will be installed.

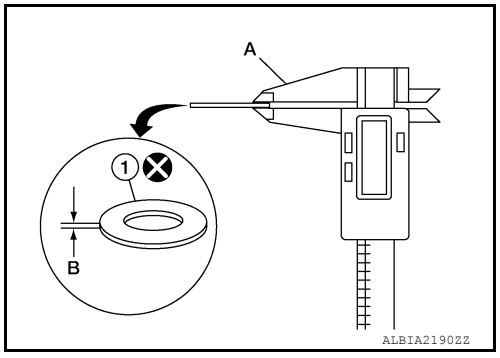
NOTE:
The fuel injector trim codes are seven character alphanumeric codes located the top of the injector.



2. Verify that the new injector sealing washer (1) is the correct thickness using a suitable tool (A).

CAUTION:
- **Use of the incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems because of incorrect injector protrusion.**
- **Do not reuse the sealing washer.**

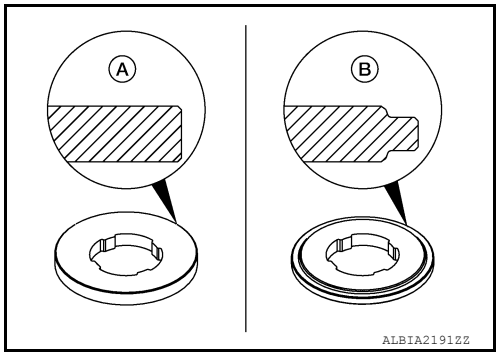
Injector sealing washer thickness (B) : 2.5 mm (0.10 in)



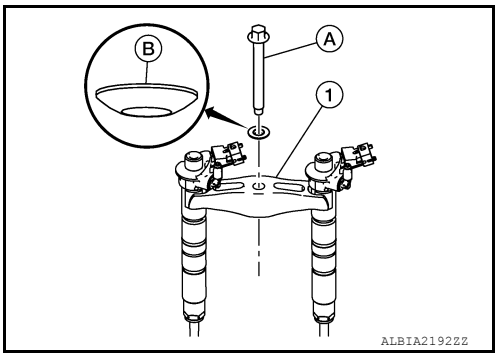
3. Verify a new sealing washer has been installed on the tip of the injector.

NOTE:
A double stacked or incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems because of incorrect injector protrusion.

(A) : Good
(B) : NG

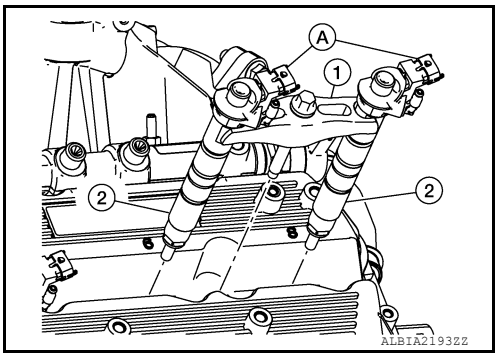


4. Position fuel injector pairs into a hold-down clamp (1) and make sure the spherical washer (B) is installed between the bolt (A) and the hold-down clamp with the flat side of the washer mating to the bolt.



CAUTION:
Do not reuse the O-ring.
NOTE:
- Install a new O-ring if reinstalling existing fuel injector.
- Lubricate the injector o-ring with lithium grease and a small amount of clean engine oil.
- The injector hold-down clamp is noted with a "TOP" on the side of the injector clamp that points outward of the engine.
- Make sure the injector bore is clean.

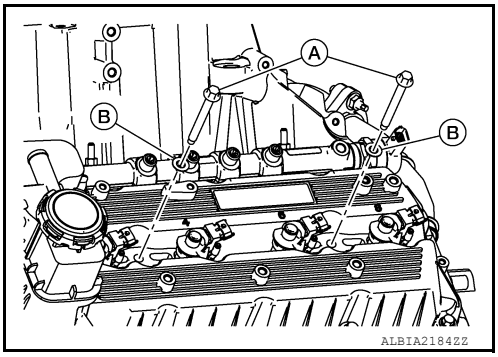
5. Install pairs of injectors (2) into the injector bores in the cylinder heads.



NOTE:
- The Bank 2 injector harness connectors (A) point to the rear of the engine. Bank 1 injector harness connectors (A) point to the front of the engine.
- If reusing the injector, make sure that the number identified on the injector matches the cylinder number.
- Be careful that pressure is not placed on the electrical connectors. The electrical connectors can break off if used to push on the injector.

(1) : Injector hold-down clamp

6. Tighten the injector hold-down clamp bolt (A).



Step 1 : 24 N·m (2.4 kg-m, 18 ft-lb)
Step 2 : Tighten 90 degrees

(B) : Spherical washer

7. Install fuel filter housing (stage 2) onto intake manifold and tighten bolts.

Fuel filter housing (Stage 2) bolts : 18 N·m (1.8 kg-m, 13 ft-lb)

8. Installation of the remaining components is in the reverse order of removal.
NOTE:
- If a malfunction resulted in coolant, oil, excessive fuel, or excessive black smoke entering the exhaust system, the aftertreatment system must be inspected. Refer to and EX-21, "Aftertreatment DPF Regeneration Test".
- Prime the fuel system. Refer to EM-219, "Priming" (Fuel system priming).
- Run CONSULT High-Pressure Fuel System Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
- Operate the engine and check for leaks.

Removal and Installation (CYLINDER 5 and CYLINDER 7)

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REMOVAL

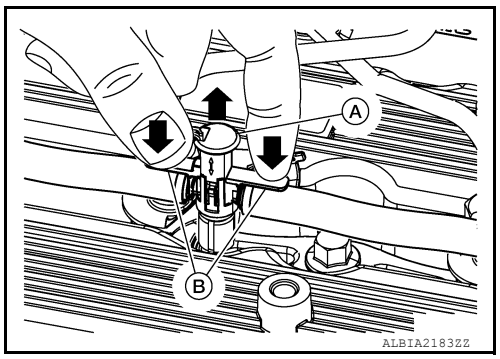
WARNING:
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Never loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

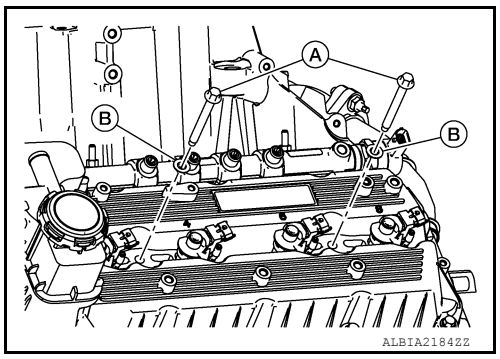
CAUTION:
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

1. Remove injector supply line (high pressure) using a suitable tool. Refer to EM-462, "Exploded View".
2. Disconnect the harness connector from the fuel injector.
   CAUTION:
   Do not disconnect the fuel injector harness connectors when the engine is running as this could damage the engine.
3. Disconnect the fuel injector drain line quick disconnect connector by pressing down and holding the connector tabs (B), then pulling up on the center button (A) as shown.
   CAUTION:
   Do not reuse the O-rings.
   NOTE:
   When removing the injector drain lines, cap all open fuel system components with Tool.

   Tool : — (J-54427)



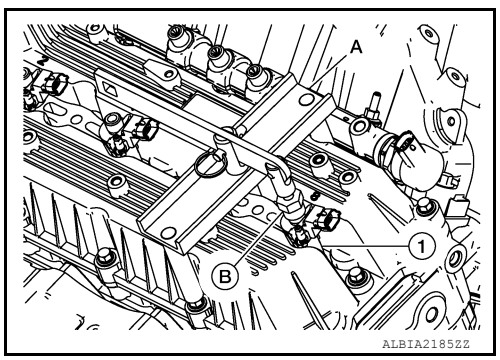
4. Remove the fuel injector hold-down clamp bolt (A) and washer (B) from hold-down clamp of fuel injector being removed.
   NOTE:
   • Fuel injectors are held down in pairs with one hold-down clamp and bolt between the two injectors.



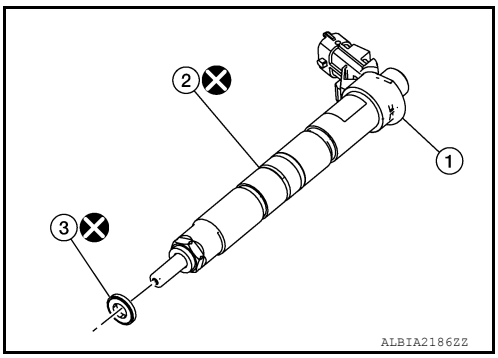
5. Install Tool (A) onto the rocker cover of the injectors to be removed then tighten the nut (B) onto the injector (1).

   Tool : — (J-54402)

6. Use a suitable tool on the square drive portion of the Tool to apply constant pressure until fuel injector unseats from bore.
7. Slide fuel injector pairs out of their bores at the same time, along with the hold-down clamp.



8. Make sure the fuel injector sealing washer (3) remained on the tip of the fuel injector (1). If the sealing washer is not on the tip of the fuel injector, remove it from the fuel injector bore in the cylinder head.
CAUTION:
Do not reuse the O-ring (2) or sealing washer (3).
NOTE:
- A double stacked or incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems because of incorrect fuel injector protrusion.
- When removing the fuel injectors, cap all open fuel system components with Tool.



Tool : — (J-54427)

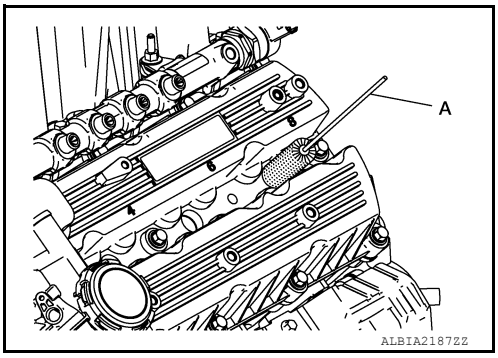
9. Once the fuel injector has been removed, identify it with the appropriate cylinder number. If the fuel injectors are reused, they must be installed into the correct cylinders.

INSPECTION AFTER REMOVAL

- Clean the injector bore from built up carbon with Tool (A).

Tool : — (J-54428)

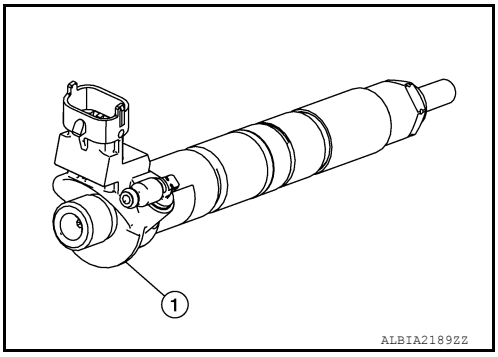
NOTE:
Use suitable tool to clean fuel injector bore prior to installation of fuel injector.



- Inspect the fuel injector tip for carbon deposits or corrosion.
- Check for terminal damage.
- Check the resistance. Resistance should measure between 150 to 210 kOhms.
- Inspect the fuel injector inlet and high-pressure connector tip for damage.
NOTE:
Overheating will cause the nozzle to turn a dark yellow/tan or blue color, depending on the degree of overheating.
- Replace any damaged components.
NOTE:
Do **not** attempt to clean the fuel injector tip. The fuel injector nozzle could become plugged and cause performance problems.

INSTALLATION

1. Record the fuel injector trim codes that are listed on the top of each fuel injector (1) and record the cylinder location where each injector will be installed.
NOTE:
The fuel injector trim codes are seven character alphanumeric codes located the top of the injector.

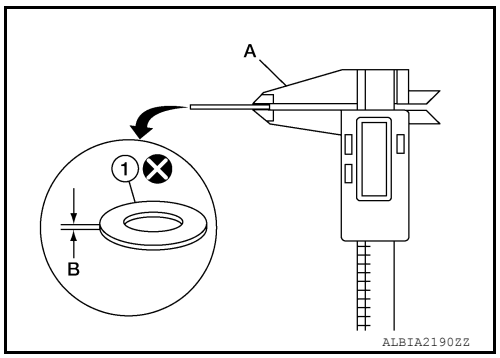


2. Verify that the new injector sealing washer (1) is the correct thickness using a suitable tool (A).

CAUTION:

- **Use of the incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems because of incorrect injector protrusion.**
- **Do not reuse the sealing washer.**

Injector sealing washer thickness (B) : 2.5 mm (0.10 in)

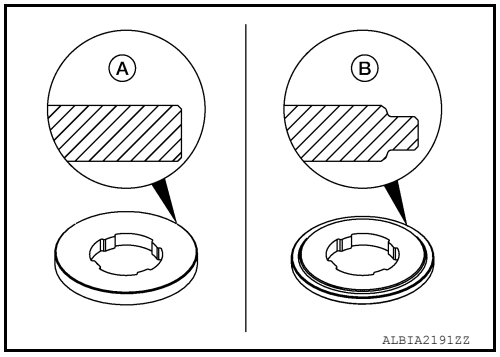


3. Verify a new sealing washer has been installed on the tip of the injector.

NOTE:

A double stacked or incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems because of incorrect injector protrusion.

(A) : Good
(B) : NG



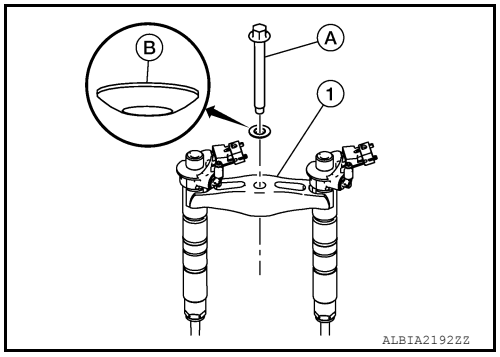
4. Position fuel injector pairs into a hold-down clamp (1) and make sure the spherical washer (B) is installed between the bolt (A) and the hold-down clamp with the flat side of the washer mating to the bolt.

CAUTION:

Do not reuse the O-ring.

NOTE:

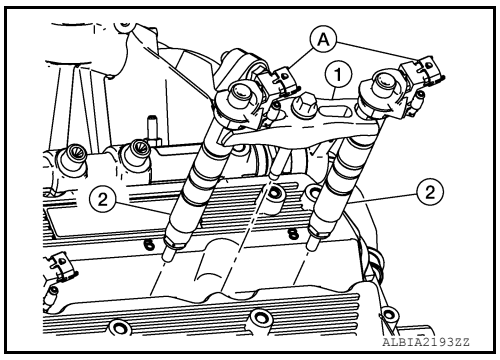
- Install a new O-ring if reinstalling existing fuel injector.
- Lubricate the injector o-ring with lithium grease and a small amount of clean engine oil.
- The injector hold-down clamp is noted with a "TOP" on the side of the injector clamp that points outward of the engine.
- Make sure the injector bore is clean.



5. Install pairs of injectors (2) into the injector bores in the cylinder heads.

NOTE:

- The Bank 2 injector harness connectors (A) point to the rear of the engine. Bank 1 injector harness connectors (A) point to the front of the engine.
- If reusing the injector, make sure that the number identified on the injector matches the cylinder number.
- Be careful that pressure is not placed on the electrical connectors. The electrical connectors can break off if used to push on the injector.

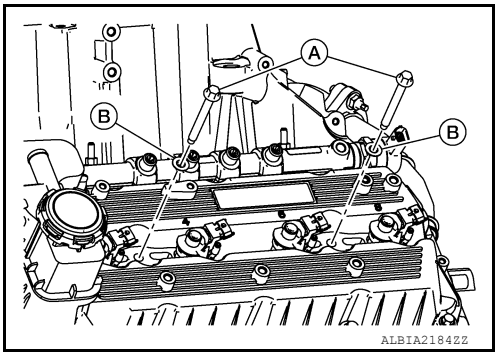


(1) : Injector hold-down clamp

6. Tighten the injector hold-down clamp bolt (A).

Step 1 : 24 N·m (2.4 kg-m, 18 ft-lb)
Step 2 : Tighten 90 degrees

(B) : Spherical washer



7. Installation of the remaining components is in the reverse order of removal.
NOTE:
- If a malfunction resulted in coolant, oil, excessive fuel, or excessive black smoke entering the exhaust system, the aftertreatment system must be inspected. Refer to and EX-21, "Aftertreatment DPF Regeneration Test".
- Prime the fuel system. Refer to EM-219, "Priming" (Fuel system priming).
- Run CONSULT High-Pressure Fuel System Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
- Operate the engine and check for leaks.

Removal and Installation (CYLINDER 6 and CYLINDER 8)

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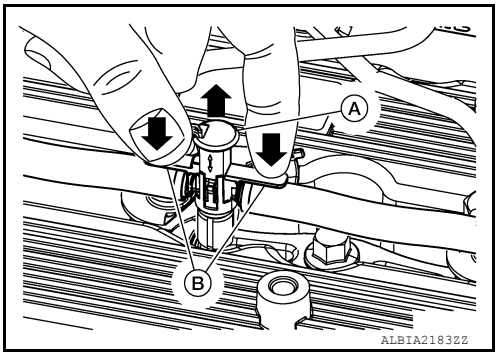
REMOVAL

WARNING:
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Never loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

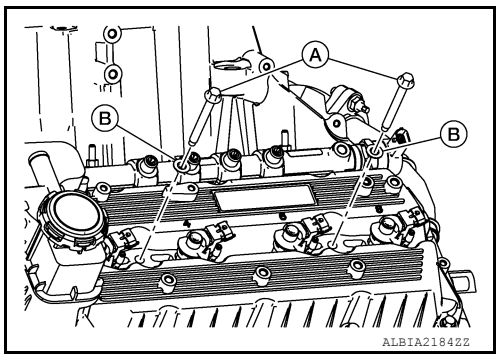
CAUTION:
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

1. Remove hydraulic booster assembly. Refer to BR-33, "Removal and Installation".
2. Remove injector supply lines (high pressure) for cylinders 6 and 8. Refer to EM-462, "Exploded View".
3. Disconnect the harness connector from the fuel injector.
CAUTION:
Do not disconnect the fuel injector harness connectors when the engine is running as this could damage the engine.
4. Disconnect the fuel injector drain line quick disconnect connector by pressing down and holding the connector tabs (B), then pulling up on the center button (A) as shown.
CAUTION:
Do not reuse the O-rings.
NOTE:
When removing the injector drain lines, cap all open fuel system components with Tool.

Tool : — (J-54427)



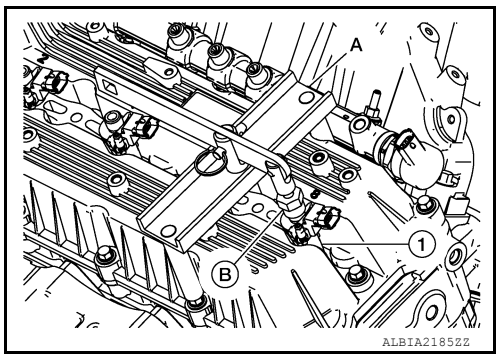
5. Remove the fuel injector hold-down clamp bolt (A) and washer (B) from hold-down clamp of fuel injector being removed.
NOTE:
• Fuel injectors are held down in pairs with one hold-down clamp and bolt between the two injectors.



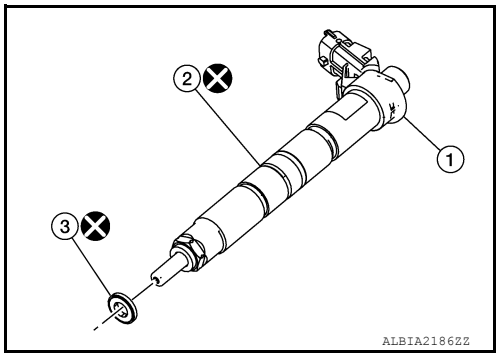
6. Install Tool (A) onto the rocker cover of the injectors to be removed then tighten the nut (B) onto the injector (1).

Tool : — (J-54402)

7. Use a suitable tool on the square drive portion of the Tool to apply constant pressure until fuel injector unseats from bore.
8. Slide fuel injector pairs out of their bores at the same time, along with the hold-down clamp.



9. Make sure the fuel injector sealing washer (3) remained on the tip of the fuel injector (1). If the sealing washer is not on the tip of the fuel injector, remove it from the fuel injector bore in the cylinder head.
CAUTION:
Do not reuse the O-ring (2) or sealing washer (3).
NOTE:
• A double stacked or incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems because of incorrect fuel injector protrusion.
• When removing the fuel injectors, cap all open fuel system components with Tool.



Tool : — (J-54427)

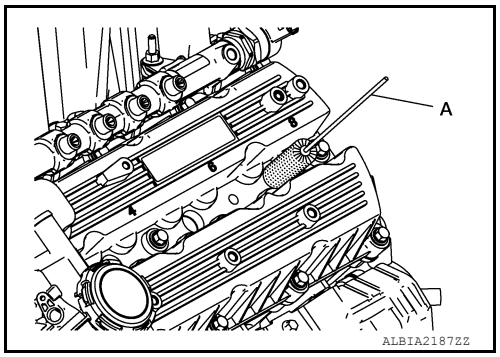
10. Once the fuel injector has been removed, identify it with the appropriate cylinder number. If the fuel injectors are reused, they must be installed into the correct cylinders.

INSPECTION AFTER REMOVAL

• Clean the injector bores from built up carbon with Tool (A).

Tool : — (J-54428)

NOTE:
Use suitable tool to clean fuel injector bore prior to installation of fuel injector.



• Inspect the fuel injector tip for carbon deposits or corrosion.
• Check for terminal damage.
• Check the resistance. Resistance should measure between 150 to 210 kOhms.
• Inspect the fuel injector inlet and high-pressure connector tip for damage.
NOTE:

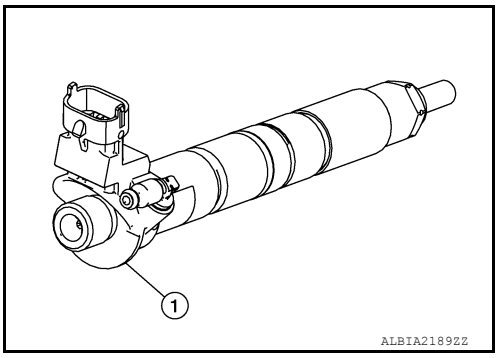
Overheating will cause the nozzle to turn a dark yellow/tan or blue color, depending on the degree of overheating.

- Replace any damaged components.

NOTE:
Do **not** attempt to clean the fuel injector tip. The fuel injector nozzle could become plugged and cause performance problems.

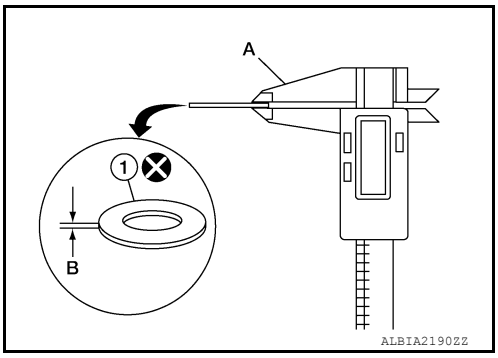
INSTALLATION

1. Record the fuel injector trim codes that are listed on the top of each fuel injector (1) and record the cylinder location where each injector will be installed.
   NOTE:
   The fuel injector trim codes are seven character alphanumeric codes located the top of the injector.



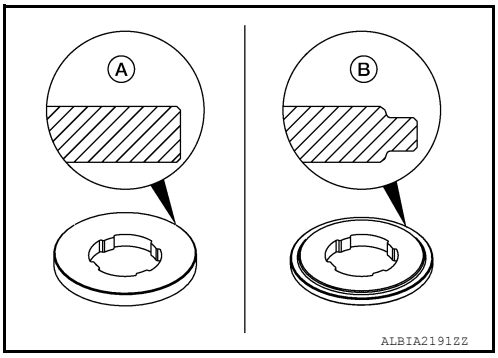
2. Verify that the new injector sealing washer (1) is the correct thickness using a suitable tool (A).
   CAUTION:
   - **Use of the incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems because of incorrect injector protrusion.**
   - **Do not reuse the sealing washer.**

   Injector sealing washer thickness (B) : 2.5 mm (0.10 in)

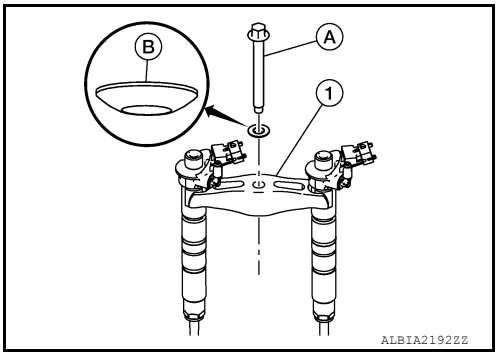


3. Verify a new sealing washer has been installed on the tip of the injector.
   NOTE:
   A double stacked or incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems because of incorrect injector protrusion.

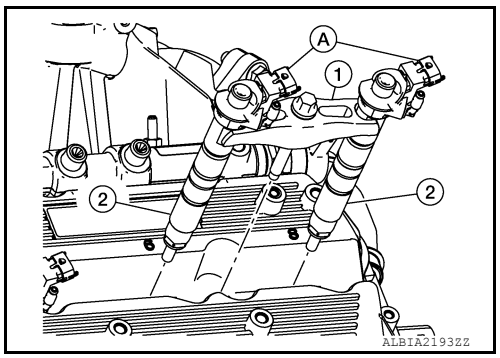
   (A) : Good
   (B) : NG



4. Position fuel injector pairs into a hold-down clamp (1) and make sure the spherical washer (B) is installed between the bolt (A) and the hold-down clamp with the flat side of the washer mating to the bolt.
   CAUTION:
   Do not reuse the O-ring.
   NOTE:
   - Install a new O-ring if reinstalling existing fuel injector.
   - Lubricate the injector o-ring with lithium grease and a small amount of clean engine oil.
   - The injector hold-down clamp is noted with a "TOP" on the side of the injector clamp that points outward of the engine.
   - Make sure the injector bore is clean.



5. Install pairs of injectors (2) into the injector bores in the cylinder heads.
NOTE:
- The Bank 2 injector harness connectors (A) point to the rear of the engine. Bank 1 injector harness connectors (A) point to the front of the engine.
- If reusing the injector, make sure that the number identified on the injector matches the cylinder number.
- Be careful that pressure is not placed on the electrical connectors. The electrical connectors can break off if used to push on the injector.

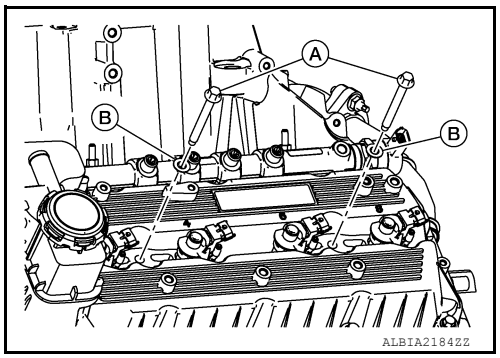


(1) : Injector hold-down clamp

6. Tighten the injector hold-down clamp bolt (A).

Step 1 : 24 N·m (2.4 kg-m, 18 ft-lb)
Step 2 : Tighten 90 degrees

(B) : Spherical washer

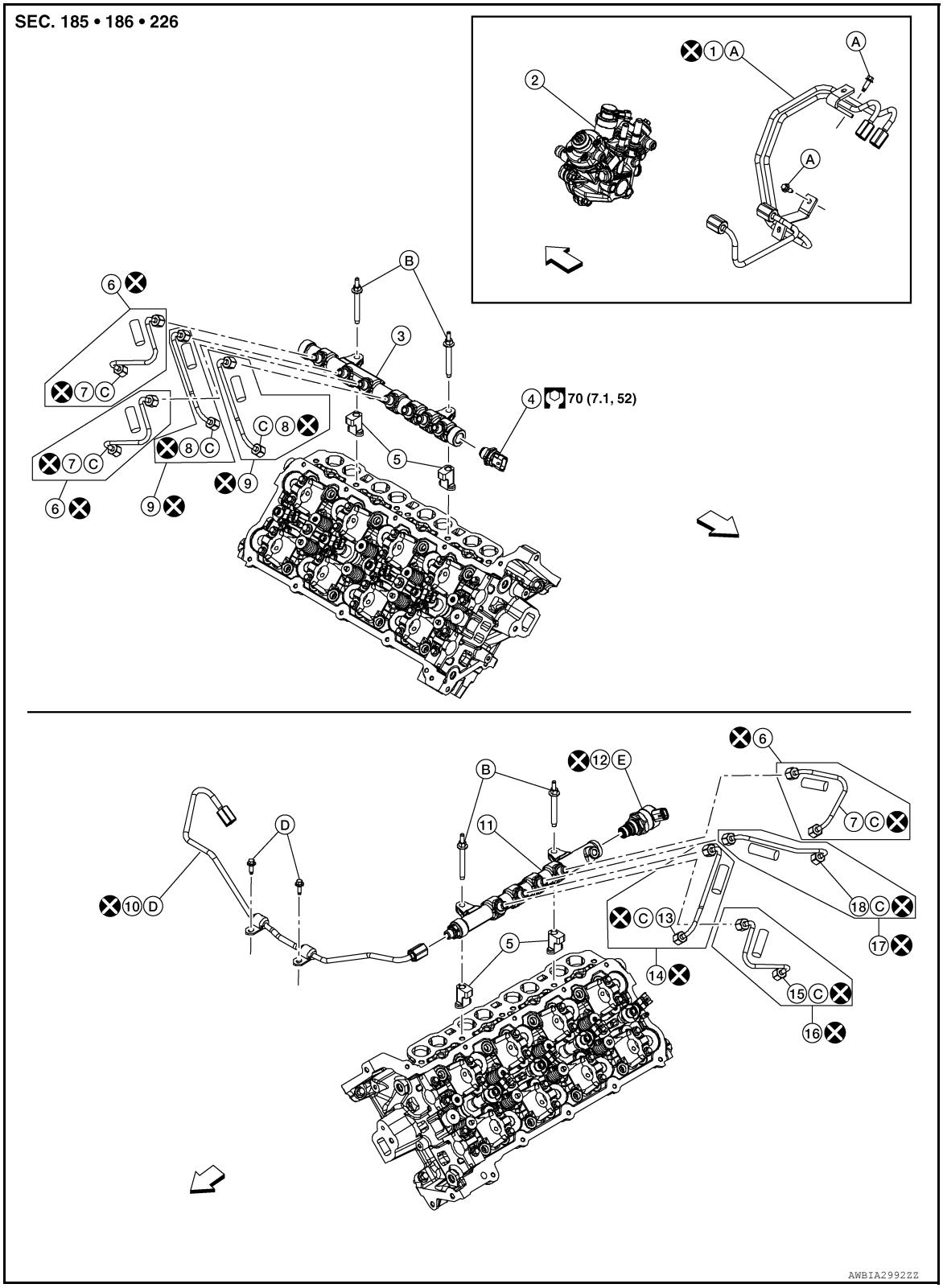


7. Installation of the remaining components is in the reverse order of removal.
NOTE:
- If a malfunction resulted in coolant, oil, excessive fuel, or excessive black smoke entering the exhaust system, the aftertreatment system must be inspected. Refer to and EX-21, "Aftertreatment DPF Regeneration Test".
- Prime the fuel system. Refer to EM-219, "Priming" (Fuel system priming).
- Run CONSULT High-Pressure Fuel System Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
- Operate the engine and check for leaks.

FUEL RAIL

Exploded View

INFOID:0000000014418712



1. Fuel rail supply line
2. Fuel pump
3. Fuel rail (bank 1)
4. Fuel Rail pressure sensor
5. Mounting bracket
6. Injector supply line assembly (high pressure)

7. Injector supply line (high pressure)	8. Injector supply line (high pressure)	9. Injector supply line assembly (high pressure)
10. Fuel rail to fuel rail supply line	11. Fuel rail (bank 2)	12. Fuel rail pressure relief valve
13. Injector supply line (high pressure)	14. Injector supply line assembly (high pressure)	15. Injector supply line (high pressure)
16. Injector supply line assembly (high pressure)	17. Injector supply line assembly (high pressure)	18. Injector supply line (high pressure)
A. Refer to EM-468, "Removal and Installation".	B. Refer to EM-451, "Removal and Installation".	C. Refer to EM-463, "Removal and Installation".
D. Refer to EM-472, "Removal and Installation".	E. Refer to EM-482, "Removal and Installation".	⇦ Front

Removal and Installation

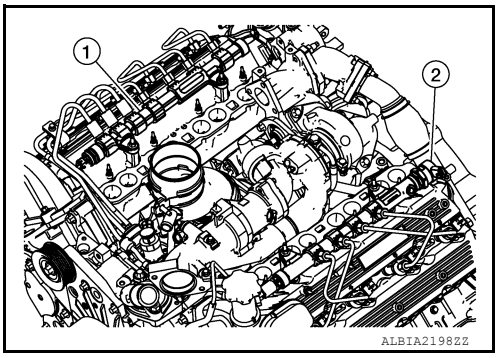
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FUEL RAIL (BANK 2)

General Information

The fuel rails transfer high-pressure fuel to the injectors from the high pressure fuel pump.

- Bank 1 fuel rail (1).
- Bank 2 fuel rail (2).



WARNING:

The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:

- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

Inspection Before Removal

Check the fuel rail for leaks, loose bolts, or any other problems.

WARNING:

Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.

Removal

WARNING:

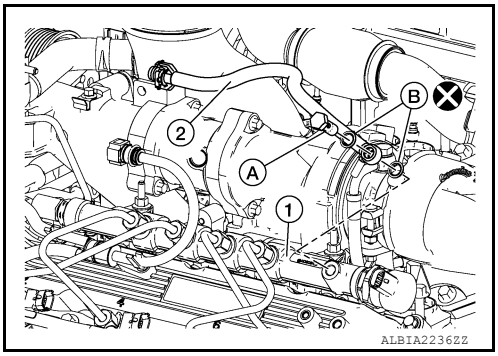
- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

CAUTION:

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

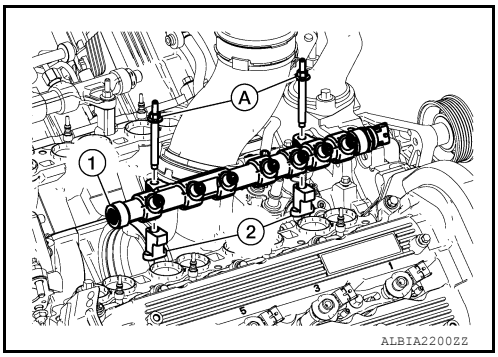
1. Remove the injector supply lines [high pressure (bank 2)]. Refer to EM-463, "Removal and Installation".
   CAUTION:
   Do not reuse the injector supply lines (high pressure).

2. Remove the fuel rail-to-fuel rail supply line (high pressure). Refer to EM-472, "Removal and Installation".
   CAUTION:
   Do not reuse the fuel rail-to-fuel rail supply line (high pressure).
3. Remove the banjo bolt (A) and washers (B) from the fuel rail [bank 2 (1)].
   CAUTION:
   Do not reuse the washers.
4. Remove the fuel pressure relief valve drain line (2) from the engine.
   CAUTION:
   Do not reuse the washers.
   NOTE:
   After removing the fuel pressure relief valve drain line, cap all of the open fuel system components with Tool.



Tool : — (J-54427)

5. Disconnect the harness connector from the fuel pressure relief valve.
6. Remove fuel pressure relief valve (if necessary).
7. Remove the fuel rail bolts (A) and remove the fuel rail [bank 2 (1)] and mounting spacers (2) from the engine.
   NOTE:
   - Bank 1 shown, Bank 2 similar.
   - When removing the fuel rail, cap all of the open fuel system components with Tool.



Tool : — (J-54427)

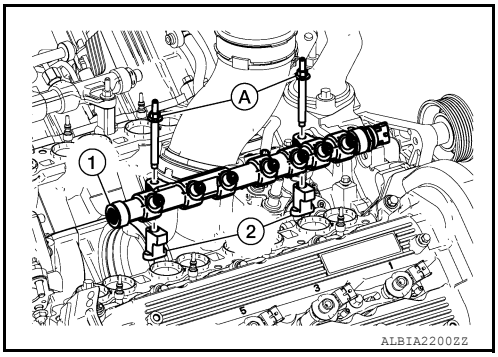
Inspection After Removal

CAUTION:
Internal passages of the fuel rail may only be cleaned with contact cleaner. Do not use a parts washer to clean the fuel rail. Dirt and contaminants can damage the fuel system.

- Inspect the fuel line connections at the fuel rail for cracks or scratches.
- Check for a loose or damaged fuel pressure sensor and/or pressure relief valve. Replace parts if necessary.
  NOTE:
  When replacing a fuel rail, the bank 2 fuel rail will be installed with a fuel pressure relief valve and the bank 1 will be installed with a fuel rail pressure sensor.

Installation

1. Install the fuel rail [bank 2 (1)], mounting spacers (2), and bolts (A).
   NOTE:
   - Make sure the mounting spacers are installed correctly under the fuel rail (bank 2). The fuel rail (bank 2) will not seat properly without these spacers. The tops of the spacers have an arrow pointing outward from the engine.
   - Do not torque the fuel rail bolts at this time.
   - Bank 1 shown, Bank 2 similar.

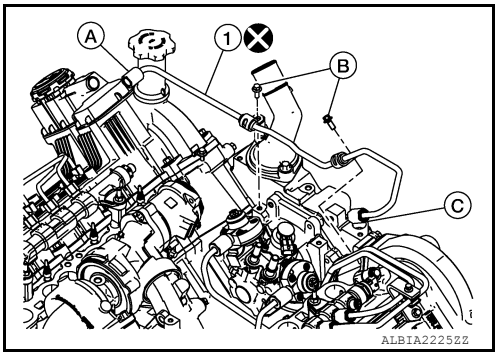


Tool : — (J-54427)

2. Install the fuel rail to fuel rail supply line [high-pressure (1)].

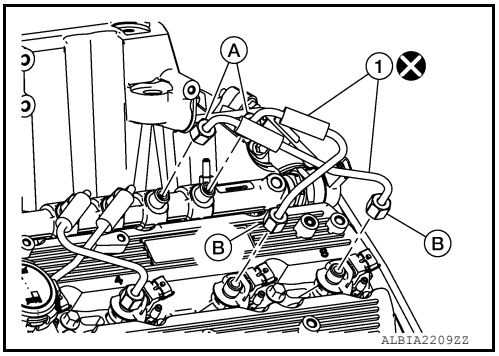
CAUTION:
Do not reuse the fuel rail-to-fuel rail supply line (high pressure).
NOTE:
Hand-tighten nuts and bolts first and then tighten the nuts and bolts to specification.

Supply line nuts (A) and (C)	**: 30 N·m (3.1 kg-m, 22 ft-lb)**
Bolts (B)	**: 7 N·m (0.7 kg-m, 62 in-lb)**



3. Position injector supply line to proper injector on engine and tighten the nuts (A) and (B) hand-tight.

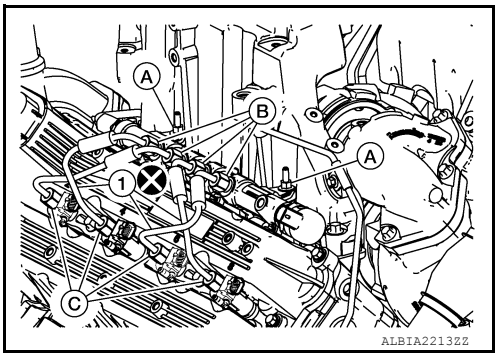
CAUTION:
Do not reuse injector supply line (high-pressure).
NOTE:
Injector numbering is noted on nut at injector side of line. Numbering refers to cylinder number. Cylinder numbering is denoted on the rocker covers. Injector side nuts (B) are colored black.



4. Tighten the injector supply line nut (C), then tighten injector supply line nut (B) then tighten fuel rail bolts (A)

CAUTION:
To reduce the possibility of damaging the fuel rails, the injector supply lines, fuel rail to fuel rail supply line, and the fuel rail supply line must be tightened prior to tightening the fuel rail bolts.

Fuel rail bolts (A)	**: 18 N·m (1.8 kg-m, 13 ft-lb)**
Injector supply line nut (B)	**: 38 N·m (3.9 kg-m, 28 ft-lb)**
Injector supply line nut (C)	**: 38 N·m (3.9 kg-m, 28 ft-lb)**



5. Installation of the remaining components is in the reverse order of removal.

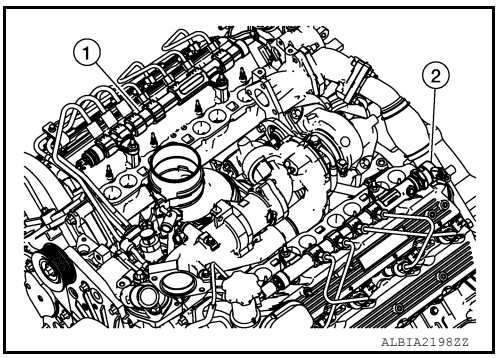
NOTE:
- Prime the fuel system. Refer to EM-219, "Priming".
- Perform the CONSULT High-Pressure Fuel System Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
- If the fuel rail (bank 2) was replaced, in CONSULT click the relief valve button in the Fuel or Timing System Table Reset in Work Support. Refer to EC-806, "CONSULT Function".
- Operate the engine and check for leaks.

FUEL RAIL (BANK 1)

General Information

The fuel rails transfer high-pressure fuel to the injectors from the high pressure fuel pump.
- Bank 1 fuel rail (1).
- Bank 2 fuel rail (2).

WARNING:
The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**



- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

Inspection Before Removal

Check the fuel rail for leaks, loose bolts, or any other problems.

WARNING:

Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.

Removal

WARNING:

- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

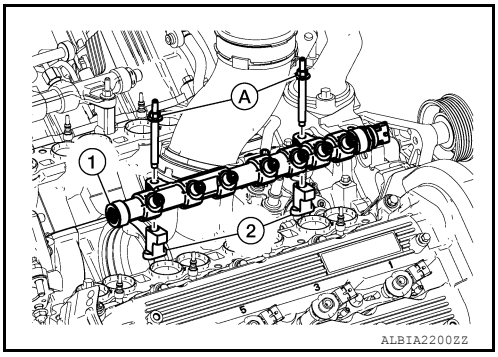
CAUTION:

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

1. Remove the fuel rail supply lines [high pressure (bank 1)]. Refer to EM-468, "Removal and Installation".
   CAUTION:
   Do not reuse the fuel rail supply lines (high pressure).
2. Remove the injector supply lines [high pressure (bank 1)]. Refer to EM-463, "Removal and Installation".
   CAUTION:
   - **Any open fuel ports must be closed immediately with Tool to avoid contamination.**
   - **Do not reuse the injector supply lines (high-pressure).**

   Tool : — (J-54427)
3. Disconnect the harness connector from the fuel rail pressure sensor.
4. Remove the fuel rail bolts (A) and remove the fuel rail [bank 2 (1)] and mounting spacers (2) from the engine.
   NOTE:
   When removing the fuel rail, cap all of the open fuel system components with Tool.

   Tool : — (J-54427)



Inspection After Removal

CAUTION:

Internal passages of the fuel rail may only be cleaned with contact cleaner. Do not use a parts washer to clean the fuel rail. Dirt and contaminants can damage the fuel system.

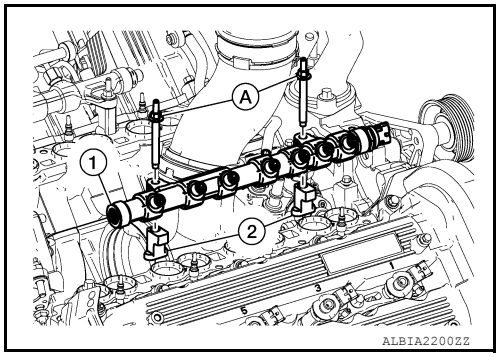
- Inspect the fuel line connections at the fuel rail for cracks or scratches.
- Check for a loose or damaged fuel pressure sensor and/or pressure relief valve. Replace parts if necessary.

NOTE:

When replacing a fuel rail, the bank 2 fuel rail will be installed with a fuel pressure relief valve and the bank 1 will be installed with a fuel rail pressure sensor.

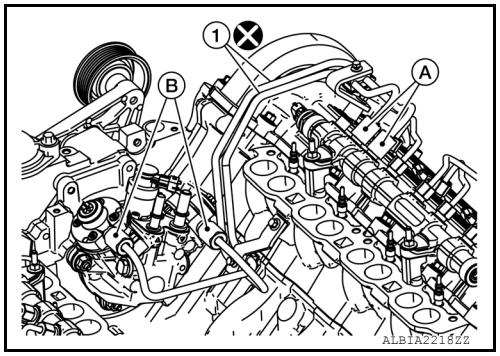
Installation

1. Install the mounting spacers (2), fuel rail [bank 1 (1)] and bolts (A) onto the engine.
CAUTION:
Make sure no dirt or debris enters the fuel rail line fittings to prevent the passing of contaminants to the high-pressure fuel rail and injectors. Small amounts of dirt and debris can cause a malfunction of these components.
NOTE:
• Make sure the spacers are installed correctly under the fuel rail. The rail will **not** seat properly without these spacers. The tops of the spacers have an arrow pointing outward from the engine.
• Do **not** torque the fuel rail bolts at this time.



2. Install the fuel rail supply line (high-pressure) and tighten nuts.
CAUTION:
Do not reuse fuel rail supply line (high-pressure).

Supply line nuts (A) : 33 N·m (3.4 kg-m, 24 ft-lb)
Supply line nuts (B) : 37 N·m (3.8 kg-m, 27 ft-lb)

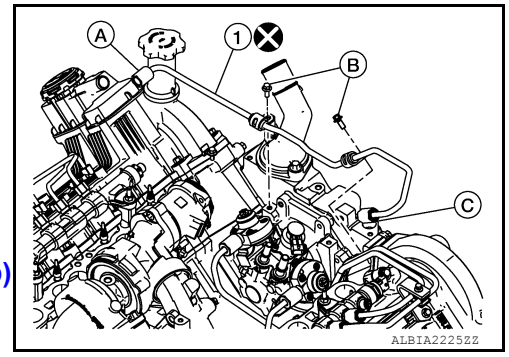


3. Tighten the fuel rail supply line (high pressure) bolts.

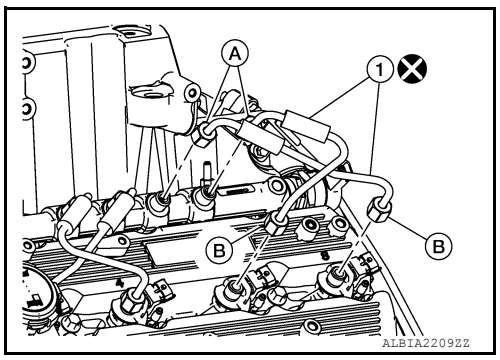
Fuel rail supply line bolts : 7.4 N·m (0.75 kg-m, 65 in-lb)

4. Install the fuel rail to fuel rail supply line.
CAUTION:
Do not reuse fuel rail-to-fuel rail supply line (high-pressure).
NOTE:
Hand-tighten nuts and bolts first and then tighten the nuts and bolts to specification.

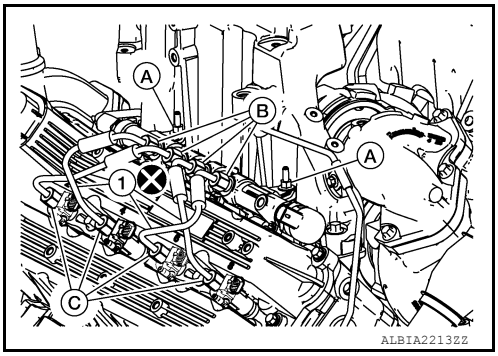
Supply line nuts (A) and (C) : 33 N·m (3.4 kg-m, 24 ft-lb)
Bolts (B) : 7.4 N·m (0.75 kg-m, 65 in-lb)



5. Position injector supply line [high-pressure) (1)] to proper injector on engine and tighten the nuts (A) and (B) hand-tight.
CAUTION:
Do not reuse injector supply line (high-pressure).
NOTE:
• Injector numbering is noted on nut at injector side of line. Numbering refers to cylinder number. Cylinder numbering is denoted on the rocker covers. Injector side nuts (B) are colored black.
• Bank 2 shown, Bank 1 similar



6. Tighten the injector supply line nut (C), then tighten injector supply line nut (B) then tighten fuel rail bolts (A)



CAUTION:
To reduce the possibility of damaging the fuel rails, the injector supply lines, fuel rail to fuel rail supply line, and the fuel rail supply line must be tightened prior to tightening the fuel rail bolts.
NOTE:
Bank 2 shown, Bank 1 similar

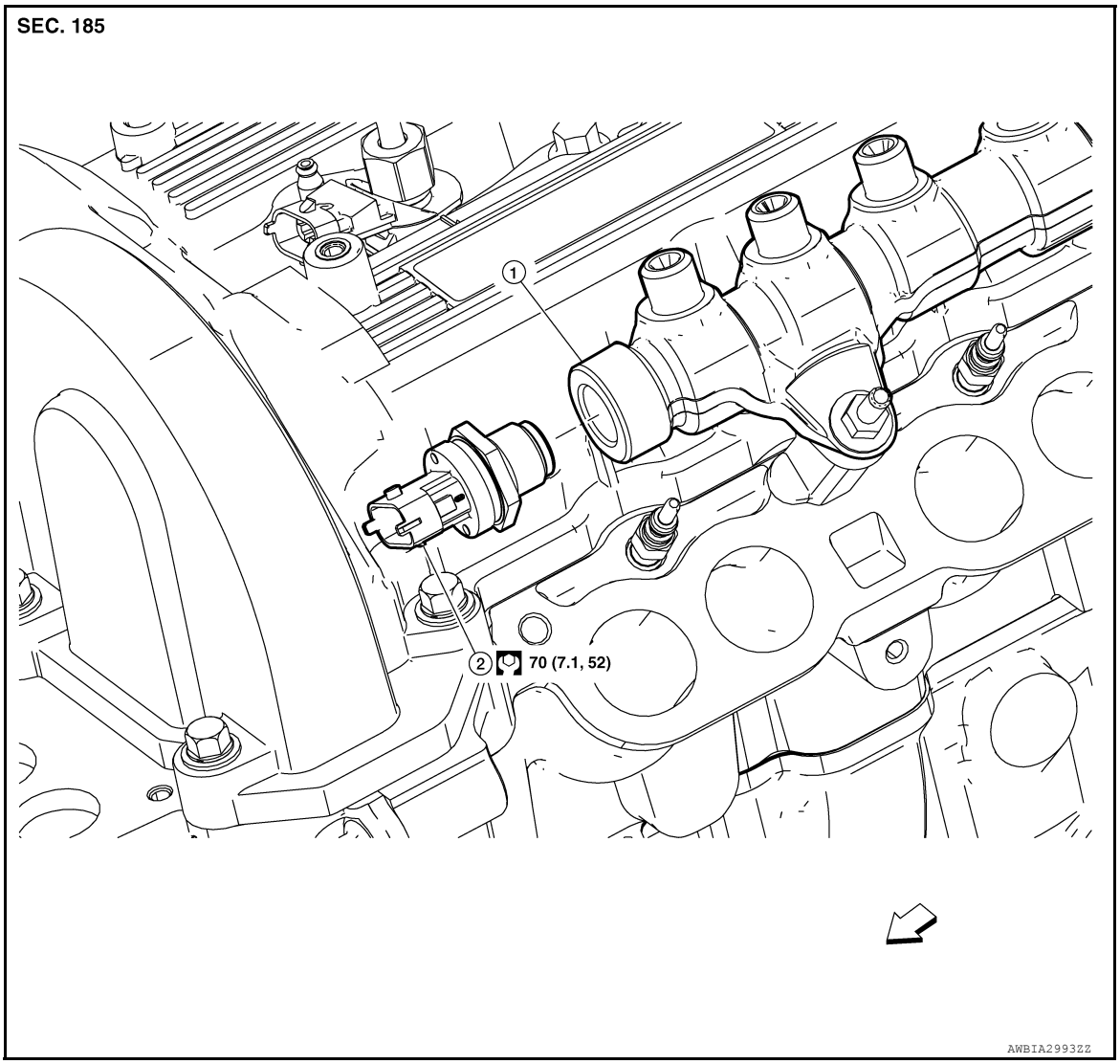
Fuel rail bolts (A)	**: 18 N·m (1.8 kg-m, 13 ft-lb)**
Injector supply line nut (B)	**: 38 N·m (3.9 kg-m, 28 ft-lb)**
Injector supply line nut (C)	**: 38 N·m (3.9 kg-m, 28 ft-lb)**

7. Installation of the remaining components is in the reverse order of removal.
NOTE:
- Prime the fuel system. Refer to EM-219, "Priming".
- Perform the CONSULT High-Pressure Fuel System Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
- If the fuel rail (bank 1) was replaced, in CONSULT click the rail pres button on the Fuel or Timing System Table Reset in Work Support. Refer to EC-806, "CONSULT Function".
- Operate the engine and check for leaks.

FUEL RAIL PRESSURE SENSOR

Exploded View

INFOID:0000000014418714



1. Fuel rail (bank 1)
2. Fuel rail pressure sensor
⇦ Front

Removal and Installation

INFOID:0000000014418715

GENERAL INFORMATION

The rail fuel pressure sensor is located on the fuel rail (bank 1).
Use the following procedure for a detailed component location view. Refer to EM-190, "FUEL SYSTEM : Description".

REMOVAL

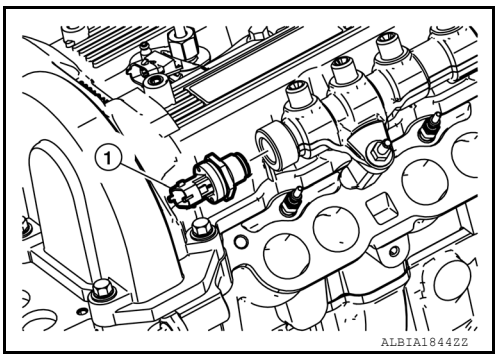
WARNING:
The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**

- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

NOTE:
When removing components such as hoses, tubes/lines, etc., cap or plug openings to prevent fluid from spilling.

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".

   WARNING:
   Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:
   - **Wear appropriate goggles and protective clothing.**
   - **Always properly ventilate the area where the service is being performed.**
   - **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
   - **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
   - **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**
2. Remove the exhaust gas recirculation (EGR) cooler. Refer to EM-276, "Removal and Installation".
3. Clean the area around the rail fuel pressure sensor.
4. Disconnect the fuel rail pressure sensor harness connector and remove the fuel rail pressure sensor (1).

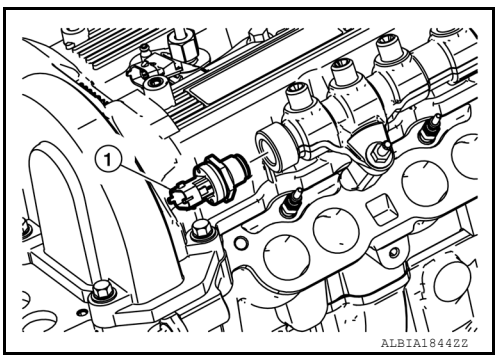


INSPECTION AFTER REMOVAL

- Inspect the engine harness connector and the rail fuel pressure sensor for the following:
  - Cracked or broken connector shell
  - Missing or damaged connector seals
  - Dirt, debris, or moisture in or on the connector pins
  - Corroded, bent, broken, pushed back, or expanded pins.
- Repair or replace the engine harness connector or rail fuel pressure sensor, as needed.
- Inspect the rail fuel pressure sensor and fuel rail for the following:
  - Damaged seal surface in the rail
  - Damaged seal surface on the sensor
  - Thread damage.
- **Only** concentric grooves are allowed. No cuts in radial direction are tolerable.
- Replace the rail fuel pressure sensor if damage is found.
- See the following procedure for fuel rail replacement. Refer to EM-451, "Removal and Installation".

INSTALLATION

1. Install the rail fuel pressure sensor (1).
   NOTE:
   Lubricate the threads of the rail fuel pressure sensor with Bosch Lubricant FT1-V27 or equivalent..



2. Connect the rail fuel pressure sensor to the engine harness.
NOTE:
Make sure the electrical harness is **not** under tension.
3. Install the EGR cooler. Refer to EM-276, "Removal and Installation".
4. Connect the battery or batteries. Refer to PG-185, "Battery Disconnect".

WARNING:
Warning: Battery acid and battery acid fumes are extremely dangerous and can cause server burns and explosion. To help reduce the risk of personal injury:
- **Wear appropriate goggles and protective clothing.**
- **Always properly ventilate the area where the service is being performed.**
- **ever allow battery fluid to come in contact with skin, eyes, fabrics, or painted surfaces.**
- **To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**
- **If acid contacts eyes, skin or clothing, immediately flush with water for 15 minutes and seek medical attention.**

5. Operate the engine and check for leaks.
NOTE:
- Prime the fuel system. Refer to EM-219, "Priming".
- Run CONSULT High-Pressure Fuel System Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
- If the fuel rail pressure sensor has been replaced, in CONSULT click the Rail Pres button on the Fuel or Timing System Table Reset in Work Support. Refer EC-806, "CONSULT Function".

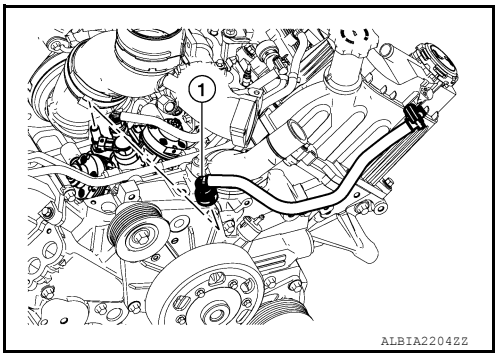
FUEL SUPPLY PIPE

Removal and Installation

INFOID:0000000014418716

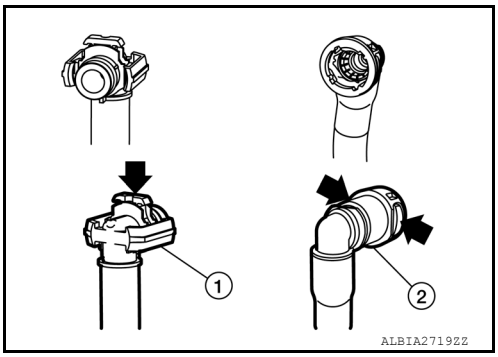
GENERAL INFORMATION

- This procedure addresses the service of the fuel supply line (1) between the Stage 2 fuel filter and the fuel pump. Reference the following list for other fuel supply line procedures.



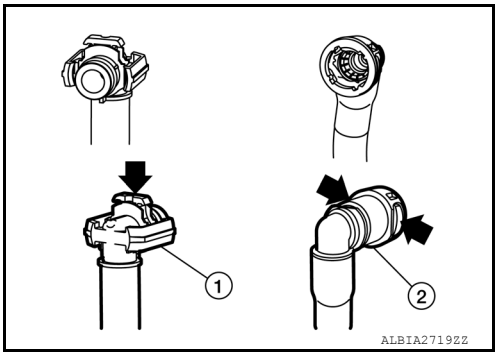
Directions for service of a one-button quick disconnect connector (1):

- Disconnect the one-button quick-disconnect connector by pressing in the raised section of the clip on the connector.
- With the clip fully depressed, the fuel line can be removed from the mating female port.
- Connect the one-button quick-disconnect connector by pushing the connector into the female mating port until it clicks.



Directions for service of a two-button quick-disconnect connector (2):

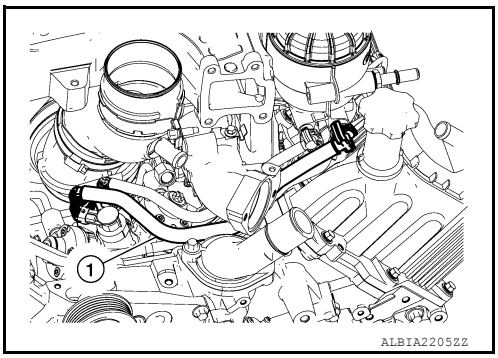
- Disconnect the two-button quick-disconnect connector by pressing in the locking tangs on both sides of the connector.
- After pressing the opposing locking tangs, the quick-disconnect connector can be removed from the male fuel fitting.
- Connect the two-button quick-disconnect connector by pushing the quick-disconnect connector onto the male fuel fitting until it clicks.



INSPECTION BEFORE REMOVAL

Inspect the lines for signs of leaks, cracks, chafing, or loose or broken connectors. Make sure the fuel lines are **not** rubbing on any components.

(1) : Fuel supply line



REMOVAL

WARNING:

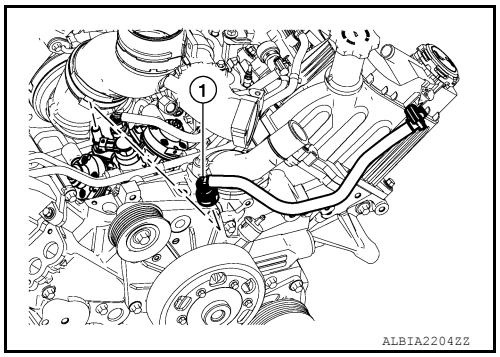
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **The fuel system (fuel pump, high-pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **Fuel can be returned at highly elevated temperatures. Wear safety glasses and protective gloves and clothing when performing this test. Avoid any contact with returned fuel.**
- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufactures recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
- **Wear appropriate eye protection and protective clothing including gloves and a face shield.**

CAUTION:

Clean all connectors before disassembly. Dirt or contaminants can damage the fuel system.

1. Remove intake manifold assembly. Refer to EM-239, "Removal and Installation".
2. Disconnect the two-button quick-disconnect connector from the high-pressure fuel pump inlet and remove the fuel supply line (1).

   NOTE:
   - Mark the routing of the fuel supply line to be sure that it is installed in the correct location during assembly.
   - Do **not** bend, pry, or kink the fuel supply line during removal.
   - When removing the fuel supply line, cap all fuel openings with Tool.



Tool : — (J-54427)

INSPECTION AFTER REMOVAL

- Inspect the fuel supply line for clogging and pinched areas.
- Inspect the connections on each end of the fuel line for damage.
- Replace any damaged fuel lines.

INSTALLATION

Installation is in the reverse order of removal.

CAUTION:

To avoid damage, do not kink or bend fuel, lubrication, air intake, and exhaust tubing or lines. Ensure all tubes and lines are routed and installed properly and care is given during the disassembly and assembly process. Failure to do so can result in damage to the tubes, lines or surrounding components.

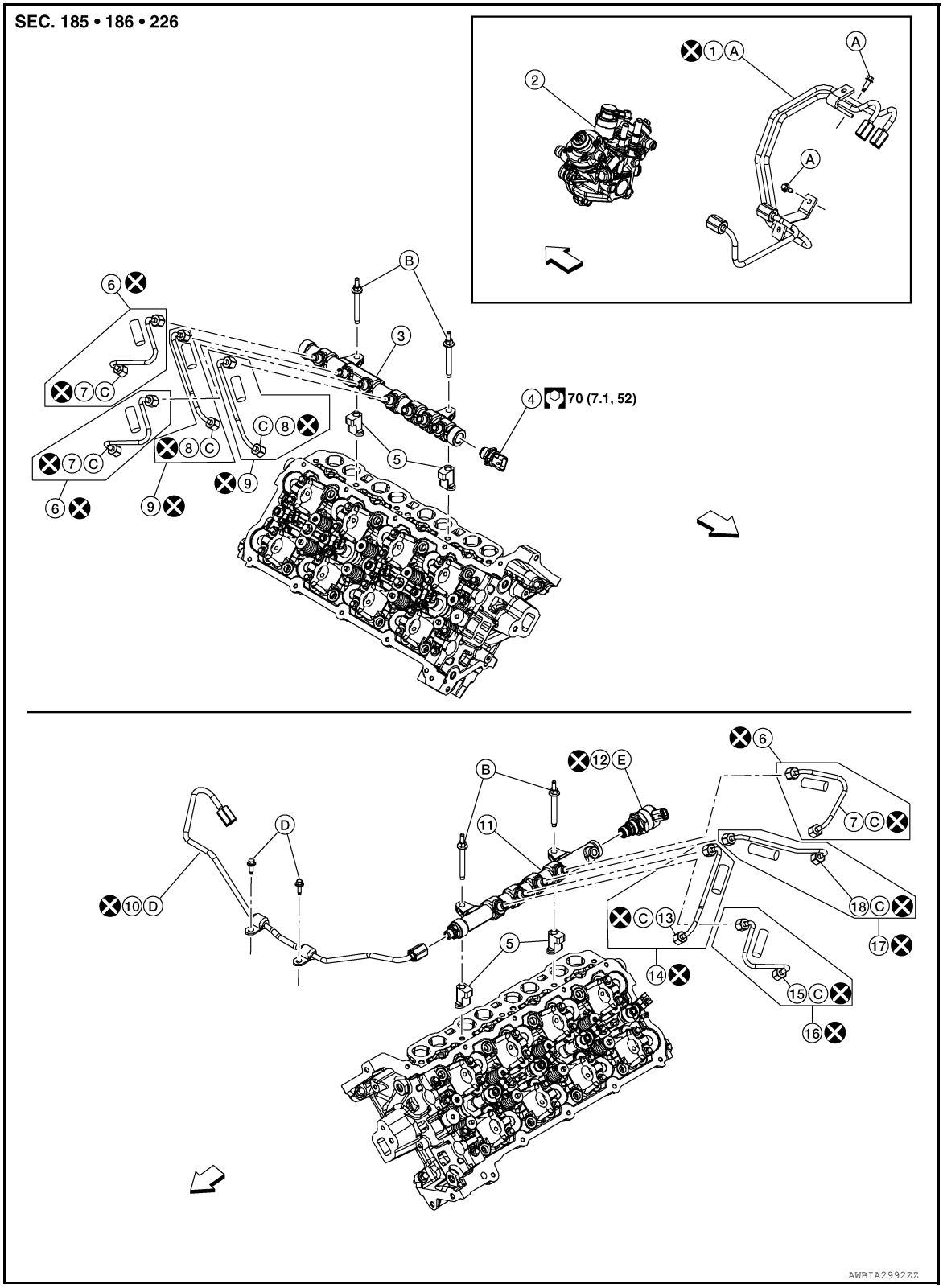
NOTE:

- Prime the fuel system. Refer to EM-219, "Priming".
- Operate the engine and check for leaks.

INJECTOR SUPPLY LINES (HIGH PRESSURE)

Exploded View

INFOID:0000000014418717



1. Fuel rail supply line
2. Fuel pump
3. Fuel rail (bank 1)
4. Fuel Rail pressure sensor
5. Mounting bracket
6. Injector supply line assembly (high pressure)

7. Injector supply line (high pressure)	8. Injector supply line (high pressure)	9. Injector supply line assembly (high pressure)
10. Fuel rail to fuel rail supply line	11. Fuel rail (bank 2)	12. Fuel rail pressure relief valve
13. Injector supply line (high pressure)	14. Injector supply line assembly (high pressure)	15. Injector supply line (high pressure)
16. Injector supply line assembly (high pressure)	17. Injector supply line assembly (high pressure)	18. Injector supply line (high pressure)
A. Refer to EM-468, "Removal and Installation".	B. Refer to EM-451, "Removal and Installation".	C. Refer to EM-463, "Removal and Installation".
D. Refer to EM-472, "Removal and Installation".	E. Refer to EM-482, "Removal and Installation".	⇦ Front

Removal and Installation

INFOID:0000000014418718

WARNING:
- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

CAUTION:
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

INSPECTION BEFORE REMOVAL

- Inspect the injector supply lines (high-pressure) for leaks, cracks, damage, loose connections, chafing, or deterioration. If necessary, replace the damaged components.
- If the injector supply lines (high-pressure) have a visible red/orange corrosion associated with rust after rinsing debris, replace the component.

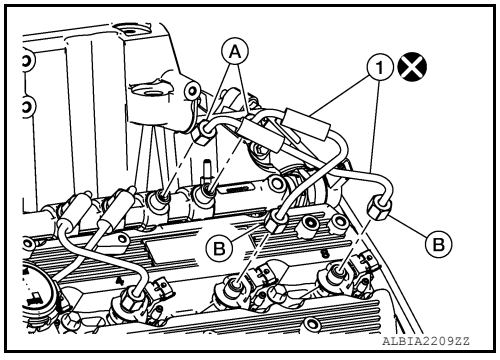
Injector Supply Lines [high-pressure (Bank 1)]

REMOVAL

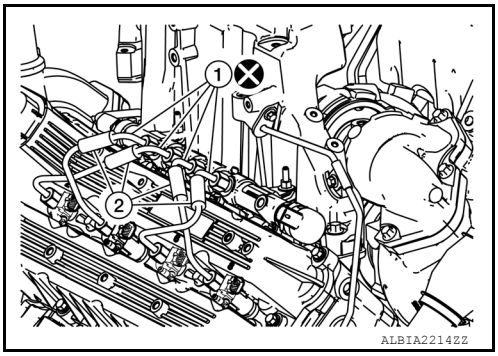
1. Remove the EGR cooler assembly. Refer to EM-276, "Removal and Installation".
2. Loosen the injector supply line [high-pressure (1)] nuts (B) at fuel injectors and nuts (A) at the fuel rail and remove the injector supply lines (high-pressure).
   CAUTION:
   - **Do not reuse the injector supply lines (high-pressure).**
   - **Any open fuel ports must be closed immediately with clean care caps to avoid contamination.**

   NOTE:
   Bank 2 shown, bank 1 similar.

   Tool : — (J-54427)



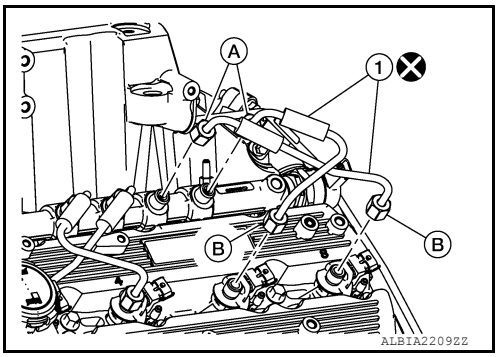
3. Remove the injector supply lines (high-pressure) vibration isolators (2) from each injector supply line [high-pressure (1)].
NOTE:
Bank 2 shown, bank 1 similar.
CAUTION:
Do not reuse the injector supply lines (high-pressure).



INSPECTION AFTER REMOVAL
- Inspect the fuel rails and fuel injectors for damaged sealing surfaces. Replace any damaged component.
- Check the injector supply lines (high-pressure) for cracks, wear, or pinched areas. Replace if necessary.

INSTALLATION

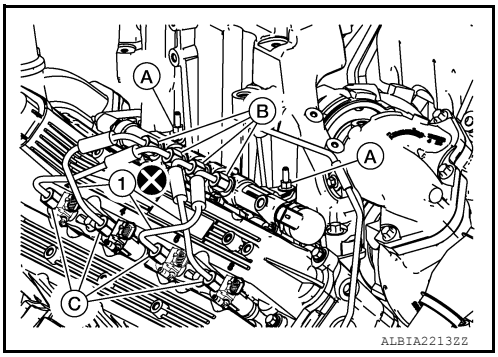
1. Position injector supply lines (high-pressure) (1) to proper fuel injector on engine and tighten the nuts (A) and (B) hand-tight.
CAUTION:
Do not reuse the injector supply lines (high-pressure).
NOTE:
- Bank 2 shown, Bank 1 similar.
- Fuel injector numbering is noted on nut at fuel injector side of line. Numbering refers to cylinder number. Cylinder numbering is denoted on the rocker covers. Injector side nuts (B) are colored black.



2. Tighten the injector supply line [high-pressure (1)] nuts (C), then tighten injector supply line (high-pressure) nuts (B).
CAUTION:
Do not reuse the injector supply lines (high-pressure).
NOTE:
Bank 2 shown, Bank 1 similar.

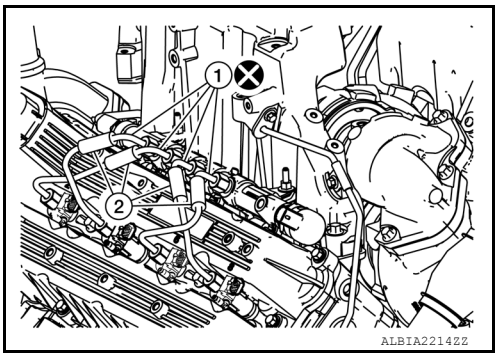
Injector supply line nut (B) : 38 N·m (3.9 kg-m, 28 ft-lb)
Injector supply line nut (C) : 38 N·m (3.9 kg-m, 28 ft-lb)

(A) : Fuel rail bolts



3. Install the injector supply line (high-pressure) vibration isolators (2) on each injector supply line [high-pressure (1)].
CAUTION:
- **Make sure the vibration isolators are installed on each high-pressure injector supply line. Failure to install the isolators can cause high vibration on the injector electrical connector which can cause engine and after-treatment progressive damage.**
- **Do not reuse the injector supply lines (high-pressure).**

NOTE:
Bank 2 shown, Bank 1 similar.



4. Installation of the remaining components is in the reverse order of removal.
NOTE:
- It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Keying on/cranking the engine will prime the fuel system. Refer to EM-219, "Priming".

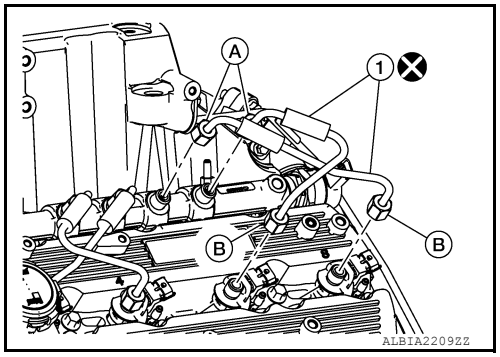
- Perform the CONSULT High-Pressure Fuel System Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
- Operate the engine and check for leaks.

Injector Supply Lines [high-pressure (Bank 2)]

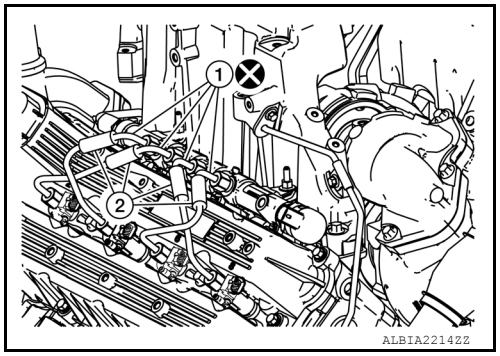
REMOVAL

1. Remove the air duct. Refer to EM-220, "Exploded View".
2. Remove the fuel filter housing (Stage 2). Refer to FL-46, "Removal and Installation".
3. Loosen the injector supply line (high-pressure) nuts (B) at fuel injectors and injector supply line (high-pressure) nuts (A) at the fuel rail and remove the injector supply lines [high-pressure (1)].
   CAUTION:
   - **Do not reuse the injector supply lines (high-pressure).**
   - **Any open fuel ports must be closed immediately with clean care caps to avoid contamination.**

   Tool : — (J-54427)



4. Remove the injector supply lines (high-pressure) vibration isolators (2) from each injector supply line [high-pressure (1)].
   CAUTION:
   Do not reuse the injector supply lines (high-pressure).

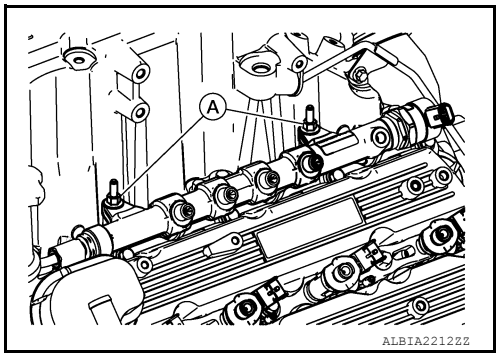


INSPECTION AFTER REMOVAL

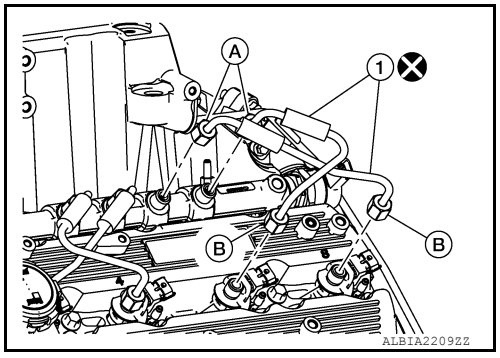
- Inspect the fuel rails and fuel injectors for damaged sealing surfaces. Replace any damaged component.

INSTALLATION

1. Loosen the fuel rail bolts (A). Hand-tighten the fuel rail bolts. Do **not** remove the fuel rail (bank 2). The bolts should be loosened to allow proper alignment of the fuel rail (bank 2) while installing the new injector supply lines (high-pressure).

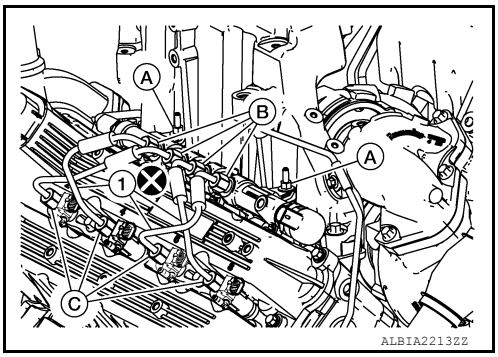


2. Position new injector supply line [high-pressure (1)] to proper injector on engine and tighten the nuts (A) and (B) hand-tight.
   CAUTION:
   Do not reuse the injector supply lines (high-pressure).
   NOTE:
   Fuel injector numbering is noted on nut at fuel injector side of line. Numbering refers to cylinder number. Cylinder numbering is denoted on the rocker covers. Injector side nuts (B) are colored black.



3. Tighten the injector supply line [high-pressure (1)] nuts (C), then tighten injector supply line (high-pressure) nuts (B) then tighten fuel rail bolts (A).
CAUTION:
Do not reuse the injector supply lines (high-pressure).

Fuel rail bolts (A)	**: 18 N·m (1.8 kg-m, 13 ft-lb)**
Injector supply line nut (B)	**: 38 N·m (3.9 kg-m, 28 ft-lb)**
Injector supply line nut (C)	**: 38 N·m (3.9 kg-m, 28 ft-lb)**

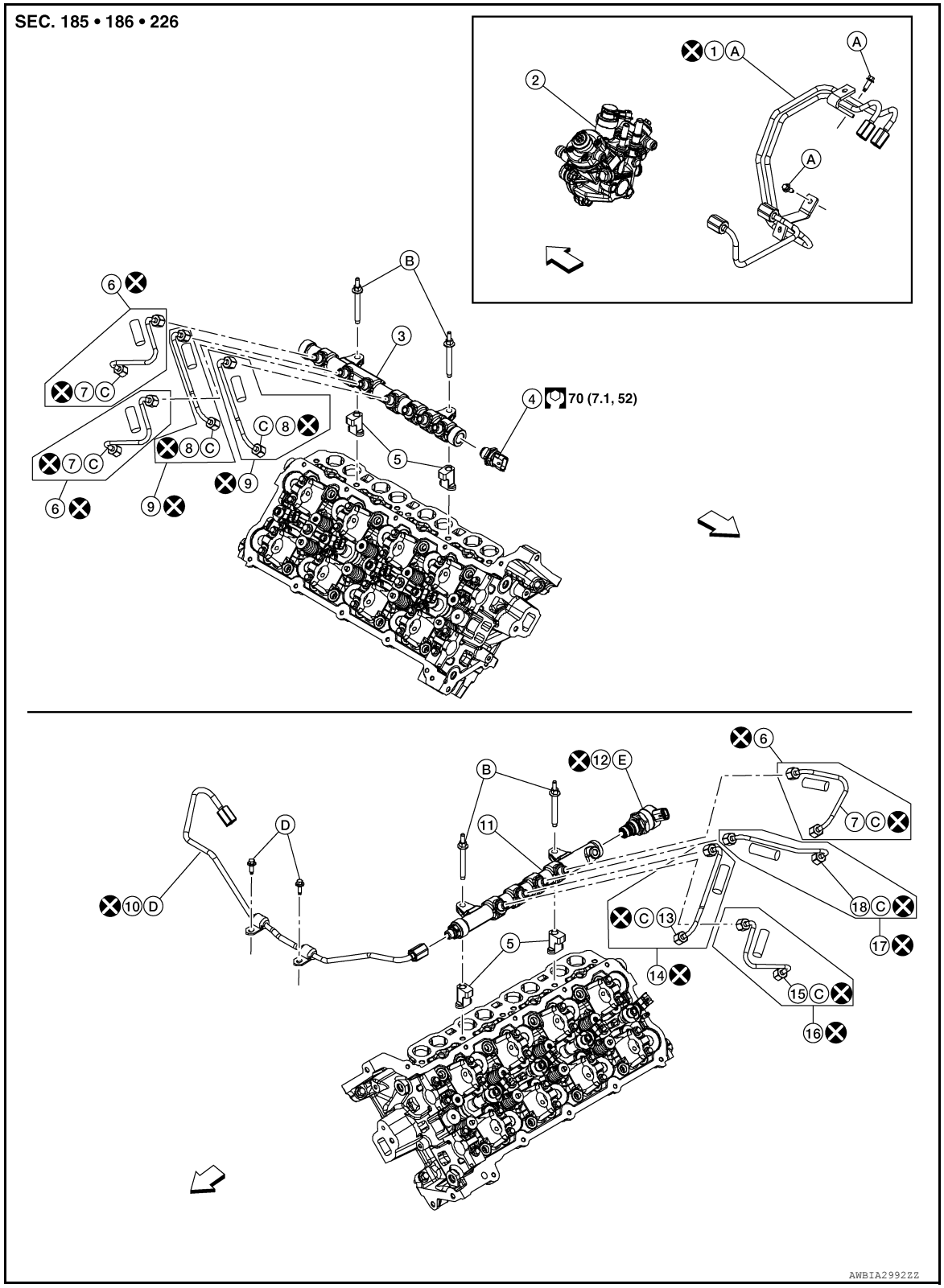


4. Install the vibration isolators on each injector supply line (high pressure).
CAUTION:
Make sure the vibration isolators are installed on each injector supply line (high pressure). Failure to install the vibration isolators can cause high vibration on the injector harness connector which can cause engine and aftertreatment damage.
5. Installation of the remaining components is in the reverse order of removal.
NOTE:
- It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Keying on/cranking the engine will prime the fuel system. Refer to EM-219, "Priming".
- Perform the CONSULT High-Pressure Fuel System Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
- Operate the engine and check for leaks.

FUEL RAIL SUPPLY LINE (HIGH PRESSURE)

Exploded View

INFOID:0000000014418719



1. Fuel rail supply line
2. Fuel pump
3. Fuel rail (bank 1)
4. Fuel Rail pressure sensor
5. Mounting bracket
6. Injector supply line assembly (high pressure)

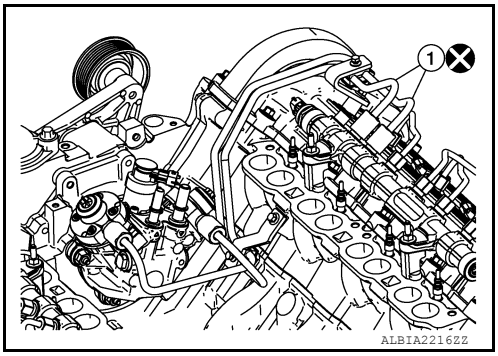
7. Injector supply line (high pressure)	8. Injector supply line (high pressure)	9. Injector supply line assembly (high pressure)
10. Fuel rail to fuel rail supply line	11. Fuel rail (bank 2)	12. Fuel rail pressure relief valve
13. Injector supply line (high pressure)	14. Injector supply line assembly (high pressure)	15. Injector supply line (high pressure)
16. Injector supply line assembly (high pressure)	17. Injector supply line assembly (high pressure)	18. Injector supply line (high pressure)
A. Refer to EM-468, "Removal and Installation".	B. Refer to EM-451, "Removal and Installation".	C. Refer to EM-463, "Removal and Installation".
D. Refer to EM-472, "Removal and Installation".	E. Refer to EM-482, "Removal and Installation".	⇦ Front

Removal and Installation

INFOID:0000000014418720

GENERAL INFORMATION

The fuel rail supply line [high pressure (1)] connects the fuel pump to the fuel rail (bank 1), containing high-pressure fuel.



WARNING:

The fuel system (fuel pump, fuel rail supply line (high-pressure), fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:

- **Do not loosen any fittings while engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

CAUTION:

Do not reuse fuel rail supply lines [high-pressure) (1)].

INSPECTION BEFORE REMOVAL

WARNING:

The fuel system (fuel pump, fuel rail supply line (high-pressure), fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:

- **Do not loosen any fittings while engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **To avoid the risk of personal injury or fire, drain diesel fuel into an approved container and safely dispose of in accordance with local environmental regulations.**
- Inspect the high-pressure fuel rail supply lines for leaks, cracks, damage, loose connections, chafing, or deterioration. If necessary, replace damaged parts.

  NOTE:

  Make sure the fuel line is **not** rubbing on any other components.
- If the fuel rail supply lines (high pressure) have a visible red/orange corrosion associated with rust after rinsing debris, replace the component.

REMOVAL

WARNING:

- **Do not loosen any fittings while engine is running.**

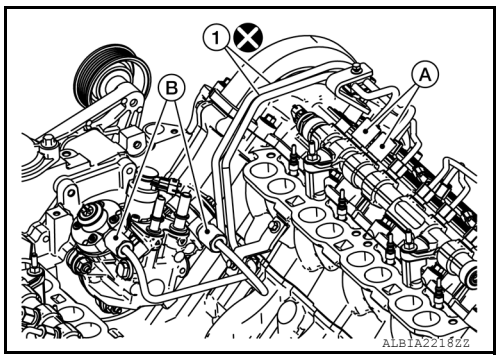
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**

- Do not exceed 30 psi (207 kPa).

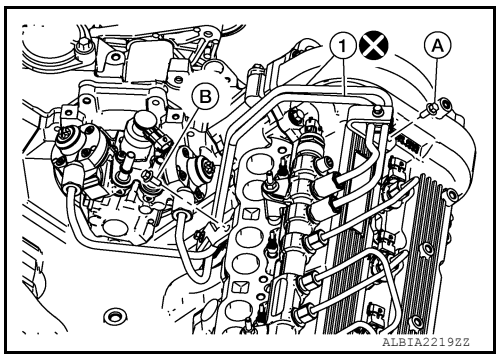
CAUTION:

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

1. Remove the fuel rail-to-fuel rail supply line (high pressure). Refer to EM-472, "Removal and Installation".
2. Remove the air inlet connection. Refer to EM-227, "Removal and Installation".
3. Loosen the fuel rail supply line nuts (A) at the fuel rail (bank 1).
4. Loosen the fuel rail supply line nuts (B) at the fuel pump.
   NOTE:
   Mark the location and routing of the fuel rail supply lines and clips to make sure it is replaced in the correct location during assembly.



5. Remove the bolts (A) and (B) that secure the fuel rail supply line (1) to the cylinder head (bank 1) and rocker cover (bank 1).



6. Remove the fuel rail supply lines from the engine.
   CAUTION:
   Do not reuse fuel rail supply lines (high-pressure).
   NOTE:
   After removing the fuel rail supply line, install Tool on all open fuel system components

Tool : — (J-54427)

INSPECTION AFTER REMOVAL

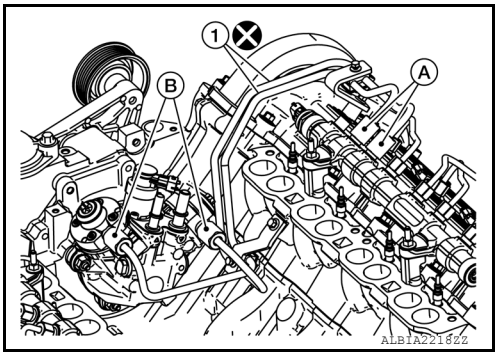
- Check for cracks, wear, or pinched areas along the rail to rail supply line (including the mounting braces). Replace as necessary.

INSTALLATION

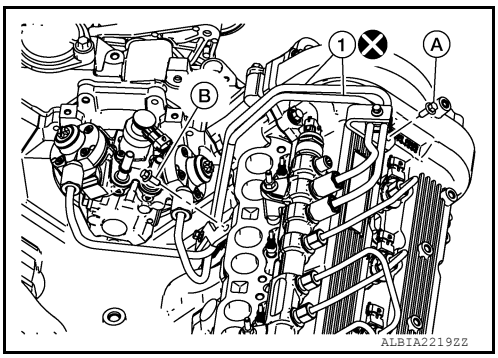
CAUTION:

Make sure that no dirt or debris enters the fuel rail supply line to prevent passing of contaminants to the high-pressure fuel rail and injectors. Small amounts of dirt or debris can cause a malfunction of these components.

1. Install the fuel rail supply lines (1) on the engine. Tighten nuts (A) and (B) hand-tight at each end of line.
CAUTION:
Do not reuse fuel rail supply lines [high-pressure) (1)]
NOTE:
Make sure that the fuel line is **not** rubbing on any other components.

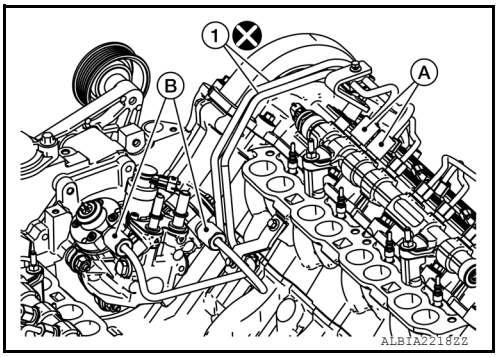


2. Hand-tighten bolts (A) and (B) that secures the fuel rail supply lines (1) to the cylinder head (bank 1) and rocker cover (bank 1).



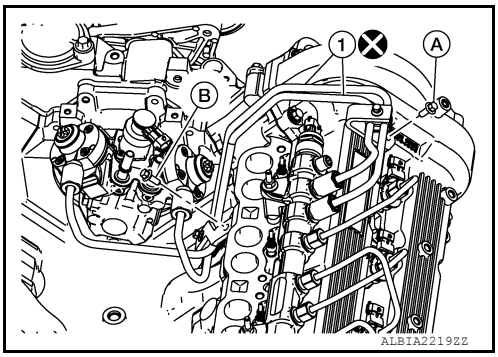
3. Tighten the fuel rail supply line (1) nuts (B), then tighten fuel rail supply line nuts (A).
CAUTION:
High-pressure line leaks may result if the nuts are not torqued to the proper specification.
NOTE:
When tightening high-pressure fuel lines, make sure there is no interference between the wrench and adjacent nuts.

Supply line nuts (A)	**: 33 N·m (3.4 kg-m, 24 ft-lb)**
Supply line nuts (B)	**: 37 N·m (3.8 kg-m, 27 ft-lb)**



4. Tighten the bolts (A) and (B) that secure the fuel rail supply line to the cylinder head (bank 1) and rocker cover (bank 1).

Bolts (A) and (B)	**: 7.4 N·m (0.75 kg-m, 65 in-lb)**

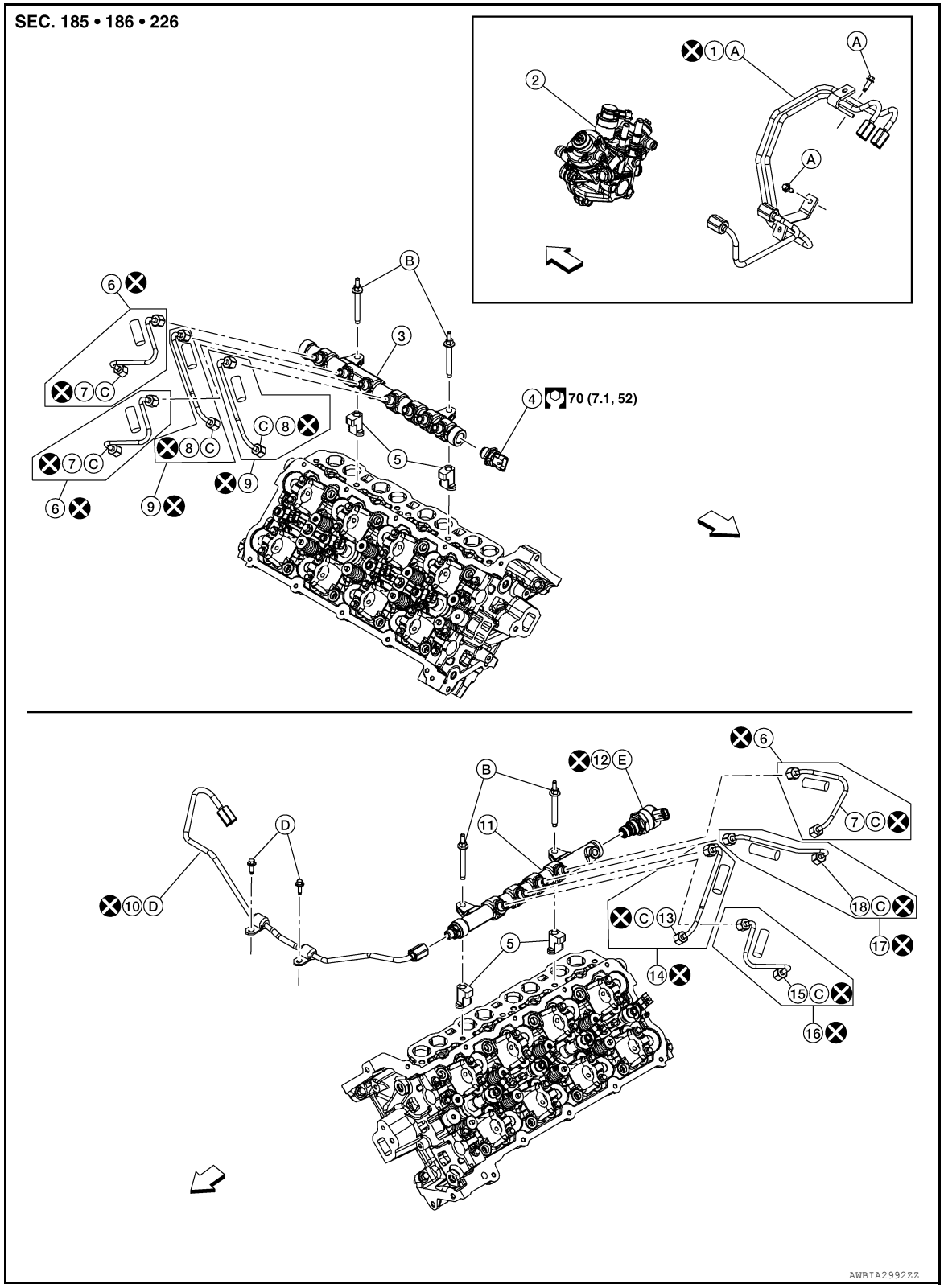


5. Install the fuel rail-to-fuel rail supply line (high pressure). Refer to EM-472, "Removal and Installation".
6. Install the air inlet connection. Refer to EM-227, "Exploded View".
7. Installation of the remaining components is in the reverse order of removal.
   - Prime the fuel system. Refer to EM-219, "Priming".
     NOTE:
     It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Turning the keyswitch ON/cranking the engine primes the fuel system.
   - Run CONSULT High-Pressure Fuel System Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
   - Operate the engine and check for leaks.

FUEL RAIL TO FUEL RAIL SUPPLY LINE (HIGH PRESSURE)

Exploded View

INFOID:0000000014418721



1. Fuel rail supply line
2. Fuel pump
3. Fuel rail (bank 1)
4. Fuel Rail pressure sensor
5. Mounting bracket
6. Injector supply line assembly (high pressure)

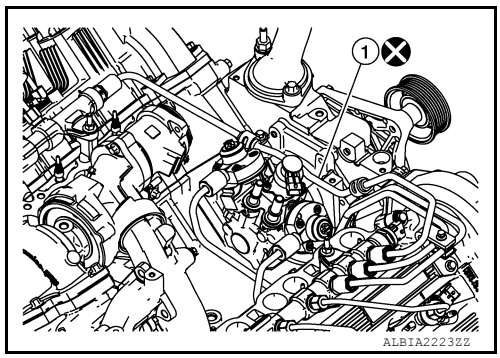
7. Injector supply line (high pressure)	8. Injector supply line (high pressure)	9. Injector supply line assembly (high pressure)
10. Fuel rail to fuel rail supply line	11. Fuel rail (bank 2)	12. Fuel rail pressure relief valve
13. Injector supply line (high pressure)	14. Injector supply line assembly (high pressure)	15. Injector supply line (high pressure)
16. Injector supply line assembly (high pressure)	17. Injector supply line assembly (high pressure)	18. Injector supply line (high pressure)
A. Refer to EM-468, "Removal and Installation".	B. Refer to EM-451, "Removal and Installation".	C. Refer to EM-463, "Removal and Installation".
D. Refer to EM-472, "Removal and Installation".	E. Refer to EM-482, "Removal and Installation".	⇦ Front

Removal and Installation

INFOID:0000000014418722

GENERAL INFORMATION

The fuel rail to fuel rail supply line [high-pressure (1)] supplies high-pressure fuel from the fuel rail (bank 1) to the fuel rail (bank 2).



INSPECTION BEFORE REMOVAL

WARNING:

- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **To avoid the risk of personal injury or fire, drain the diesel fuel into an approved container and safely dispose of in accordance with local environment regulations.**
- **the fuel system (fuel pump, high-pressure fuel lines, fuel rail, injectors) contain very high-pressure fuel. To avoid the risk of personal injury or fire;**

- Do not loosen any fittings while the engine is running.
- wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.
- Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate skin.
- Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Do not allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.

- Inspect the high-pressure fuel rail to rail supply lines for leaks, cracks, damage, loose connection, chafing, or deterioration. if necessary, replace damaged parts. If the high pressure fuel rail to fuel rail supply line has visible red/orange corrosion associated with rust after rinsing debris. replace the component.

NOTE:
Make sure the fuel line is **not** rubbing on any other components.

REMOVAL

WARNING:

- **The fuel system (fuel pump, high-pressure fuel lines, fuel rail, injectors) contain very high-pressure fuel. To avoid the risk of personal injury or fire;**

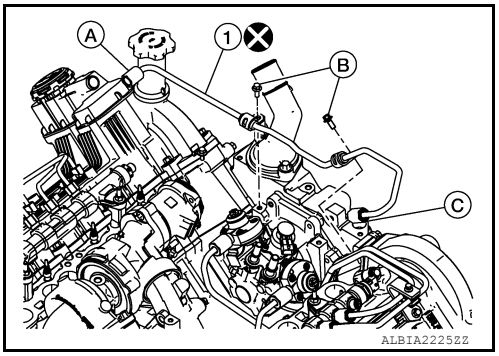
- Do not loosen any fittings while the engine is running.
- wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.
- Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate skin.

- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Do not allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Do not allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
- **Wear appropriate eye protection and protective clothing including gloves and a face shield.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**

CAUTION:

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

1. Remove the intake manifold assembly. Refer to EM-239, "Removal and Installation".
2. Remove bolts (B) that secure the fuel rail to fuel rail supply line (high-pressure) (1).
3. Disconnect the fuel rail to fuel rail supply line (high-pressure) nut (C) at the fuel rail (bank 1).
4. Disconnect the fuel rail to fuel rail supply line (high-pressure) nut (A) at the fuel rail (bank 2) and remove the fuel rail to fuel rail supply line (high-pressure).



CAUTION:

- **Make sure that no dirt or debris enters the fuel rail to prevent the passing of contaminants to the high-pressure fuel rail and injectors. Small amounts dirt or debris can cause a malfunction of these components.**
- **Do not reuse fuel rail to fuel rail supply line (high-pressure).**

NOTE:

- Mark the location and routing of the fuel rail to fuel rail supply line (high-pressure) and clips to make sure it is replaced in the correct location during assembly.
- After removing the fuel rail to fuel rail supply line (high-pressure), install Tool on all open fuel system components

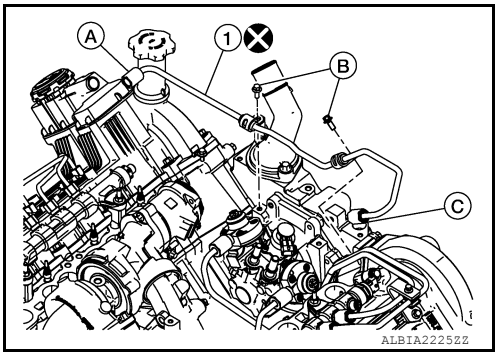
Tool : — (J-54427)

INSPECTION AFTER REMOVAL

- Check for cracks, wear, or pinched areas along the fuel rail to fuel rail supply line (high-pressure) including the mounting braces. Replace if necessary.

INSTALLATION

1. Position new fuel rail to fuel rail supply line (high-pressure) on the engine and hand tighten nuts (A) and (C), then install bolts (B).



CAUTION:

- **Make sure that no dirt or debris enters the fuel rail supply line to prevent the passing of contaminants to the high-pressure fuel rail and injectors. Small amounts dirt or debris can cause a malfunction of these components.**
- **Do not reuse fuel rail to fuel rail supply line (high-pressure).**

2. Tighten the fuel rail to fuel rail supply line (high-pressure) nuts and then the bolts.

CAUTION:

High-pressure line leaks may result if the nuts are not tightened to the proper specifications.

Nuts (A) and (C)	**: 33 N·m (3.4 kg-m, 24 ft-lb)**
Bolts (B)	**: 7.4 N·m (0.75 kg-m, 65 in-lb)**

NOTE:
- Make sure that the fuel rail to fuel rail supply line (high-pressure) is **not** rubbing on any other components.
- When tightening high-pressure fuel lines, make sure there is **no** interference between the wrench and adjacent nuts.

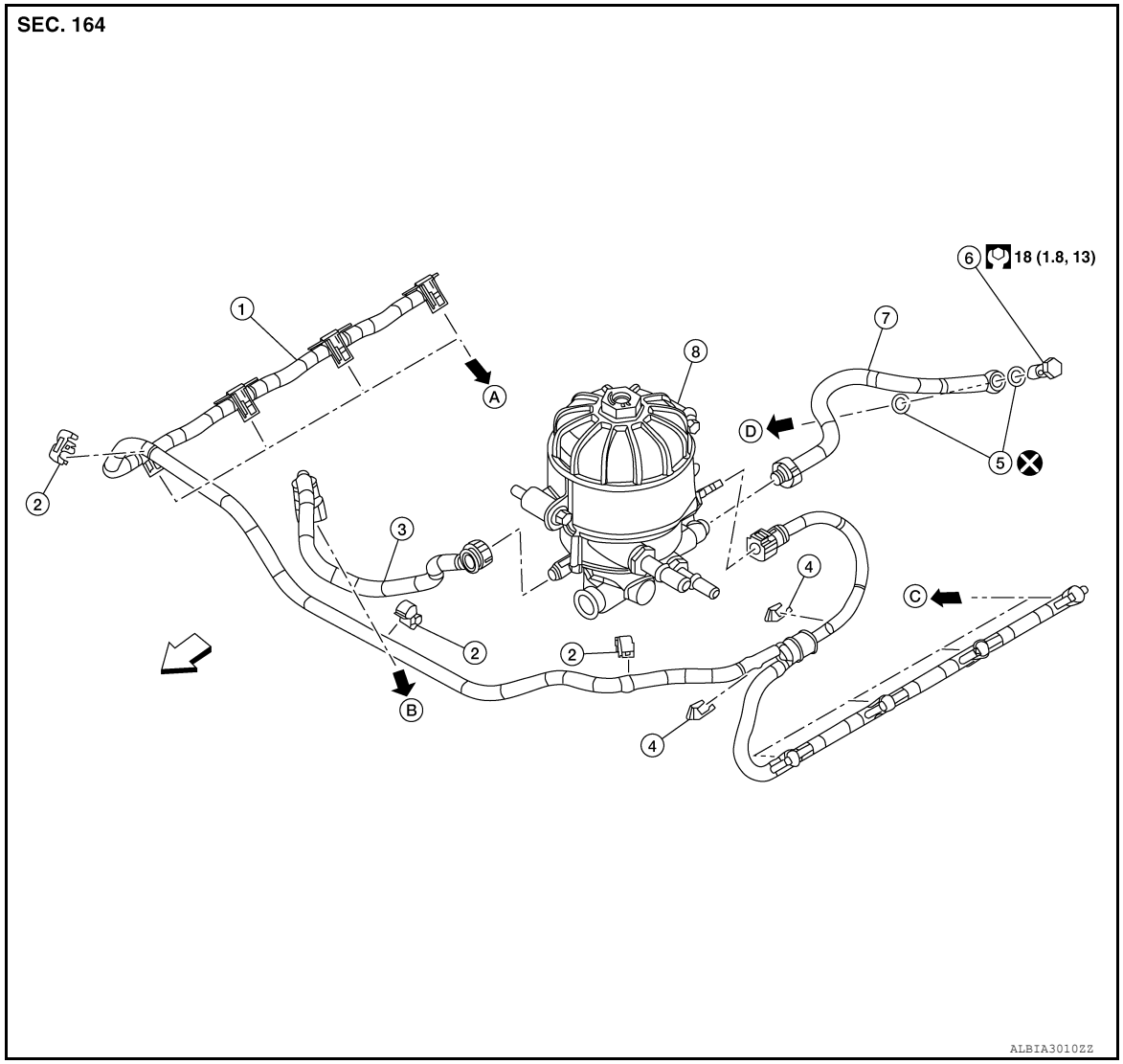
3. Installation of the remaining components is in the reverse order of removal.

NOTE:
- Perform the CONSULT High-Pressure Leakage Test. EM-218, "High-Pressure Fuel System Leak Test".
- Operate the engine and check for leaks.

FUEL DRAIN LINES

Exploded View

INFOID:0000000014418723



1. Injector drain line
2. Clip
3. Fuel pump drain line
4. Clip
5. Sealing washer
6. Banjo bolt
7. Fuel pressure relief valve drain line
8. Fuel filter
A. To injectors (bank 1)
B. To fuel pump
C. To injectors (bank 2)
D. To fuel rail (bank 2)

⇦ Front

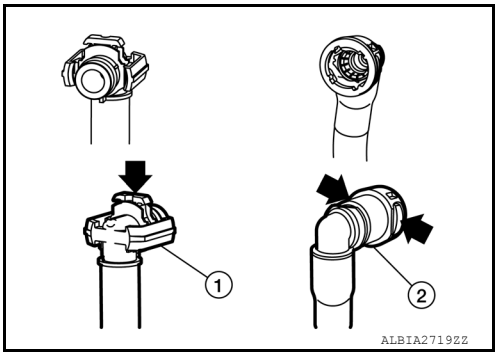
Removal and Installation

INFOID:0000000014418724

GENERAL INFORMATION

Directions for service of a one-button quick-disconnect connector (1):

- Disconnect the one-button quick-disconnect connector by pressing in the raised section of the clip on the connector.
- With the clip fully depressed, the fuel line can be removed from the mating female port.
- Connect the one-button quick-disconnect connector by pushing the connector into the female mating port until it clicks.

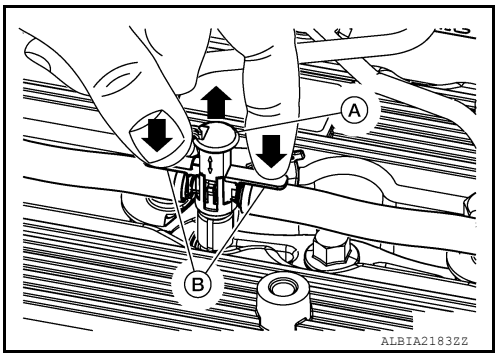


Direction for service of a two-button quick disconnect connector (2):

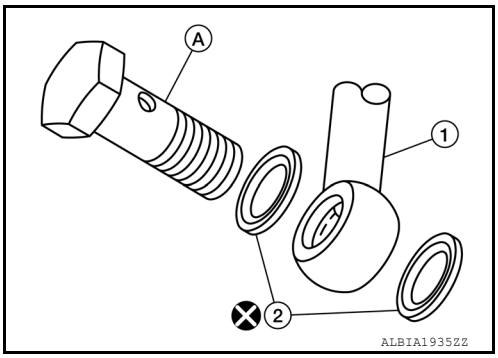
- Disconnect the two-button quick-disconnect connector by pressing in the locking tangs on both sides of the connector.
- After pressing the opposing locking tangs, the quick-disconnect connector can be removed from the male fuel fitting.
- Connect the two-button quick-disconnect connector by pushing the quick-disconnect connector onto the male fuel fitting until it clicks.
- **CAUTION:**
  Do not use a screwdriver or pliers on the fuel connector locking tabs. This can result in damage to the quick disconnect fitting.

Direction for service of an injector quick disconnect connect:

- Disconnect the injector quick disconnect connector by pressing down and holding the connector tabs (B), then pulling up on the center button (A) as shown in the illustration.
- Be sure the connector is fully disengaged before removing the connector from the injector drain port.
- To connect the injector quick disconnect connector, be sure the quick disconnect connector is in the release position (the button is up).
- Press **only** on the connector tabs to seat the drain line onto the injector drain port. An audible snap sound will be heard when the connector is seated. When the connector snaps into place, press the button to secure the connector.



- Sealing washers (2) are used on each sides of a banjo fitting (1). New sealing washers **must** be used when installing the banjo bolt (A).



INPECTION BEFORE REMOVAL

- Inspect the fuel drain lines for signs of leaks, cracks, chafing, or loose or broken connectors.
- Be sure the fuel lines are **not** rubbing on any components.

REMOVAL

WARNING:

- **The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine**

before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**

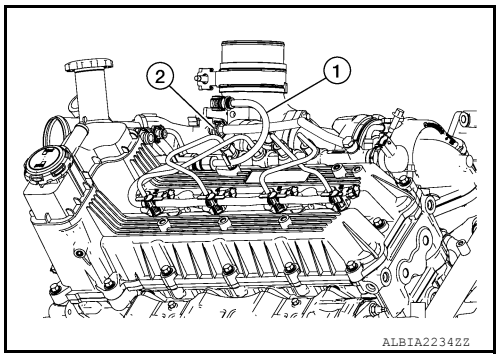
- Wear appropriate eye protection and protective clothing including gloves and a face shield.

CAUTION:

Clean all around the filter area before disassembly. Dirt or contaminants can damage the fuel system.

Fuel Pump Drain Line

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".
2. Mark the location of the drain lines to be sure they are installed in the correct location during assembly.



(1) : Injector drain line
(2) : Fuel pressure relief valve drain line

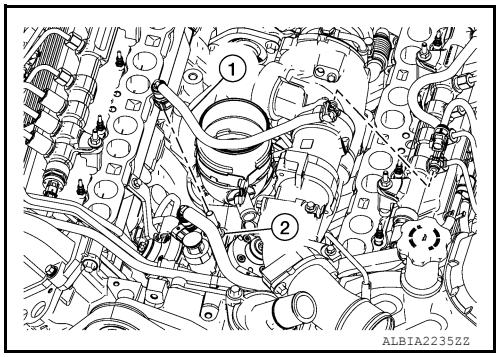
CAUTION:

To avoid damage, do not kink or bend fuel, lubrication, air intake, and exhaust tubing or lines. Ensure all tubes and lines are routed and installed properly and care is given during the disassembly and assembly process. Failure to do so can result in damage to the tubes, lines or surrounding components.

3. Remove the intake manifold. Refer to EM-239, "Removal and Installation".
4. Disconnect the two-button drain connector from high-pressure fuel pump (2) and remove the fuel pump return line (1).

NOTE:

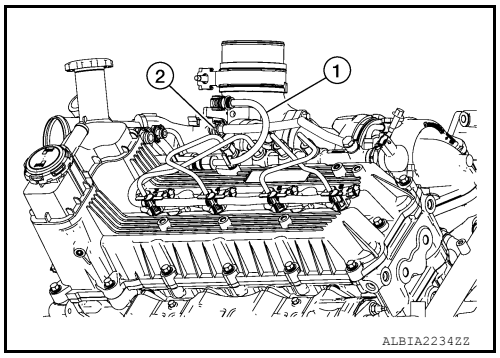
After removing the fuel pump return line, install Tool on all open fuel system components



Tool : — (J-54427)

Injector Drain Line

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".
2. Mark the location of the drain lines to be sure they are installed in the correct location during assembly.



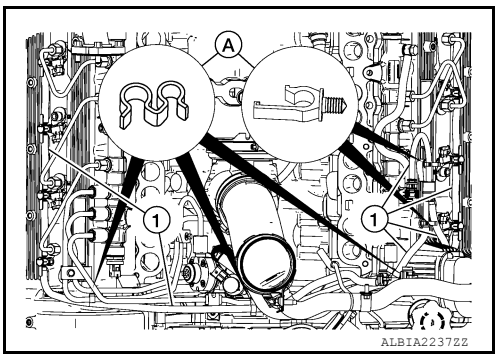
(1) : Injector drain line
(2) : Fuel pressure relief valve drain line

CAUTION:

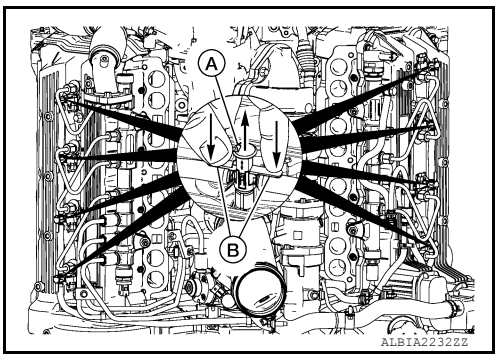
To avoid damage, do not kink or bend fuel, lubrication, air intake, and exhaust tubing or lines. Ensure all tubes and lines are routed and installed properly and care is given during the disassembly and assembly process. Failure to do so can result in damage to the tubes, lines or surrounding components.

3. Remove the intake manifold. Refer to EM-239, "Removal and Installation".
4. Disconnect the harness connector from the injector to allow adequate room to access the injector drain line.

5. Disconnect or remove any clips (A) securing the injector drain lines.
NOTE:
Mark the location of all clips and the routing of the injector drain line (1) to be sure it is replaced in the correct location during assembly.

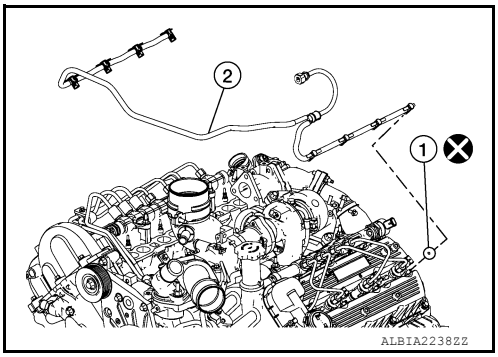


6. Press down on the tabs (B) and pull up on the center button (A) to disconnect the eight quick disconnect connectors from the injector drain ports.



7. Remove the injector drain line (2) from the engine.
CAUTION:
Do not reuse the O-ring (1).
NOTE:
After removing the injector drain line, install Tool on all open fuel system components

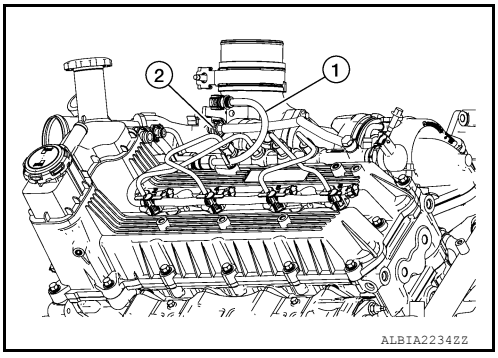
Tool number : — (J-54427)



CAUTION:
To avoid damage, do not kink or bend fuel, lubrication, air intake, and exhaust tubing or lines. Ensure all tubes and lines are routed and installed properly and care is given during the disassembly and assembly process. Failure to do so can result in damage to the tubes, lines or surrounding components.

Fuel Pressure Relief Valve Drain Line

1. Disconnect the battery. Refer to PG-185, "Battery Disconnect".
2. Relieve the fuel pressure.
3. Remove the air duct. Refer to EM-220, "Exploded View".
4. Mark the location of the drain lines to be sure they are installed in the correct location during assembly.

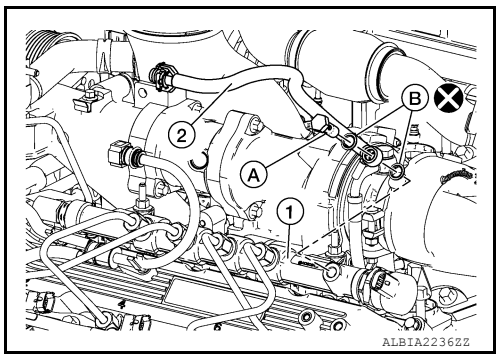


(1) : Injector drain line
(2) : Fuel pressure relief valve drain line

CAUTION:
To avoid damage, do not kink or bend fuel, lubrication, air intake, and exhaust tubing or lines. Ensure all tubes and lines are routed and installed properly and care is given during the disassembly and assembly process. Failure to do so can result in damage to the tubes, lines or surrounding components.

5. Drain the fuel filter housing (Stage 2). Refer to FL-46, "Removal and Installation".

6. Remove the banjo bolt (A) and washers (B) from the fuel rail [bank 2 (1)].
7. Remove the fuel pressure relief valve drain line (2) from the engine.
   CAUTION:
   Do not reuse the washers.
   NOTE:
   After removing the fuel pressure relief valve drain line, install Tool on all open fuel system components.



Tool : — (J-54427)

CAUTION:
To avoid damage, do not kink or bend fuel, lubrication, air intake, and exhaust tubing or lines. Ensure all tubes and lines are routed and installed properly and care is given during the disassembly and assembly process. Failure to do so can result in damage to the tubes, lines or surrounding components.

INSPECTION AFTER REMOVAL

Fuel Pump Drain Line and Fuel Pressure Relief Valve Drain Line
- Inspect the fuel pump drain line and pressure relief valve drain line for clogging and pinched areas.
- Inspect the connectors for cracks, wear, or pinched areas. Replace any damaged fuel lines.
- Inspect the face of the banjo connectors for sealing surface damage. If the fuel rail sealing surface is damaged, replace the left bank fuel rail.
- Replace any damaged fuel lines.

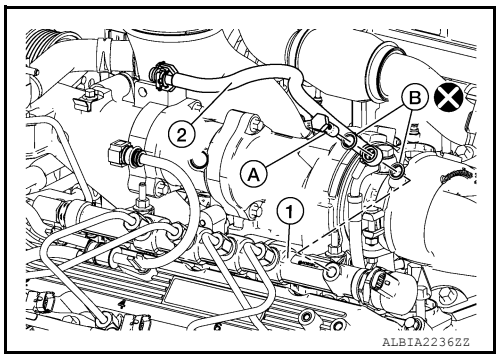
Injector Drain Line
- Inspect the injector drain lines for clogging and pinched areas.
- Inspect the section of the drain line located in the vee for abrasion, overheating, or other damage.
- Inspect the connectors for cracks, wear, or pinched areas.
- Replace the injector drain line if damage is found.

INSTALLATION

Fuel Pump Drain Line:
- Installation is in the reverse order of removal.

Fuel Pressure Relief Valve Drain Line

1. Align the fuel pressure relief valve drain line (2) on the fuel rail [LH (1)] and install the banjo bolt (A) and new washers (B).
   CAUTION:
   Do not reuse the washers.

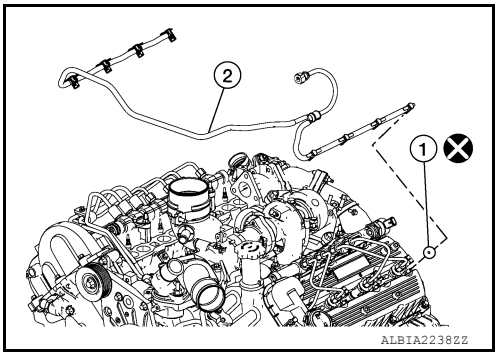


Bolt (A) : 18 N·m (1.8 kg-m, 13 ft-lb)

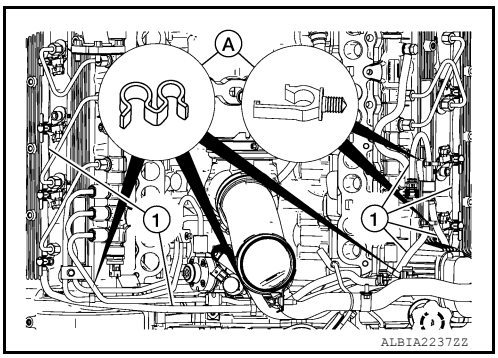
2. Installation is in the reverse order of removal.
   NOTE:
   Operate the engine and check for leaks.

Injector Drain Line

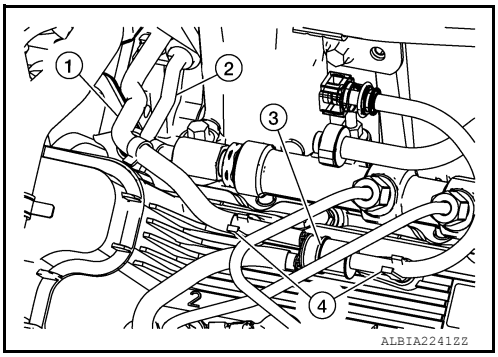
1. Lubricate the o-ring with clean diesel fuel.
2. Position the drain line (2) as previously routed.
   CAUTION:
   Do not reuse the O-ring (1).



3. Install the clips (A) securing the injector drain line (1). Three clips secure the injector drain line to the high-pressure rail to rail high-pressure fuel line and two clips secure the injector drain line to the rocker lever cover (LH).



4. The injector drain line (1) **must** be routed on the front side of the rail to rail high-pressure fuel line (2). (The Stage 2 filter is omitted for clarity.)
5. The constant pressure valve (3) should be flush with locating tab (4) on the rocker lever cover.
   NOTE:
   - Be sure that other components are **not** restricting the injector drain line.
   - Be sure the injector drain line is **not** twisted in the area of the constant pressure valve. This can cause a restriction in the line, resulting in poor performance.
   - The routing of the injector drain line is crucial to prevent other engine components from pinching the fuel return line.

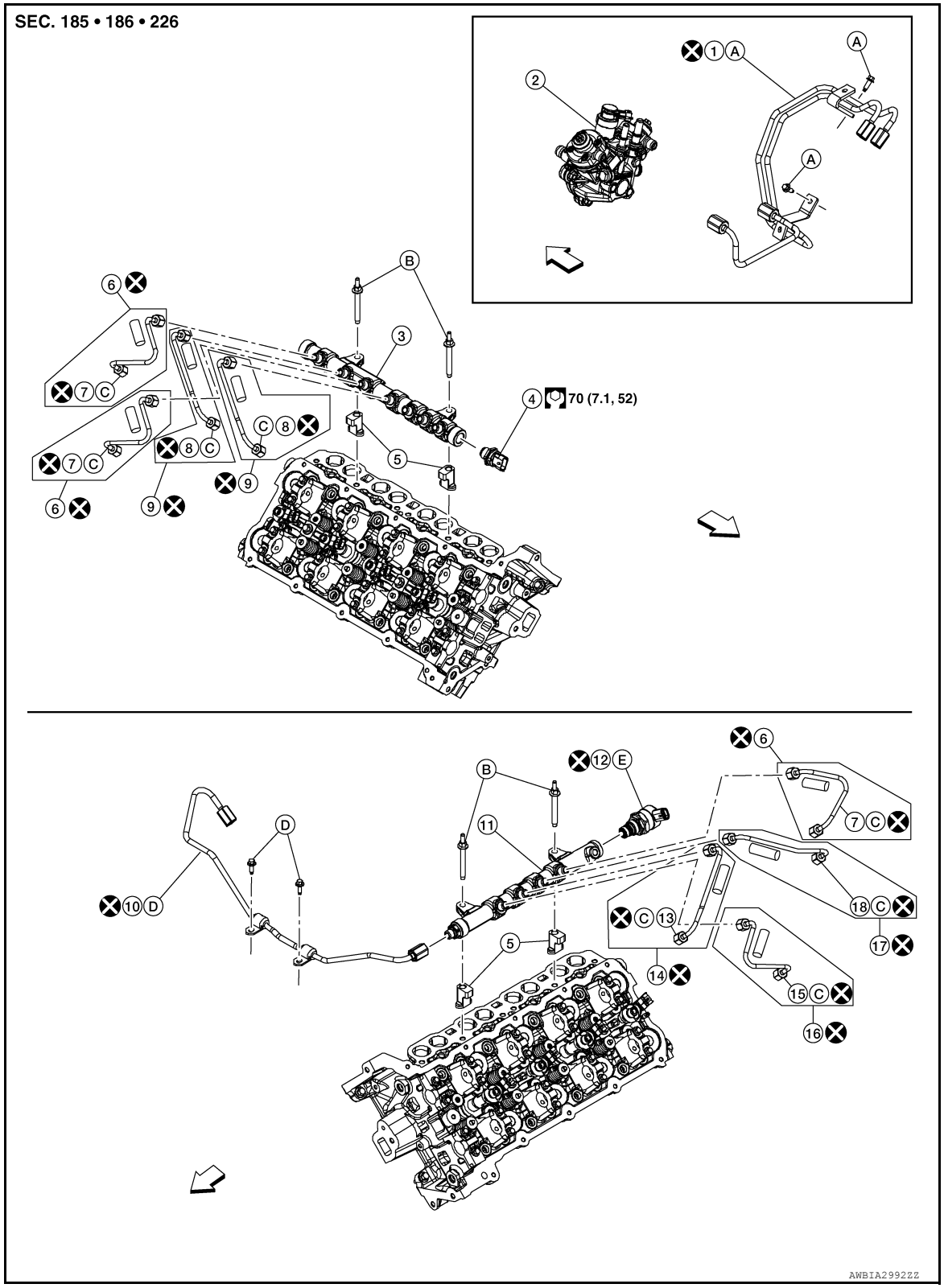


6. Be sure the injector drain line quick disconnect connector is in the release position (the button is up). Press **only** on the connector tabs to seat the drain line onto the injector drain port. An audible snap sound will be heard when the connector is seated.
   When the connector snaps into place, press the center button to secure the connector.
7. Installation of remaining components is in the reverse order of removal.
   NOTE:
   Operate the engine and check for leaks.

FUEL RAIL PRESSURE RELIEF VALVE

Exploded View

INFOID:0000000014418725



1. Fuel rail supply line
2. Fuel pump
3. Fuel rail (bank 1)
4. Fuel Rail pressure sensor
5. Mounting bracket
6. Injector supply line assembly (high pressure)

7. Injector supply line (high pressure)	8. Injector supply line (high pressure)	9. Injector supply line assembly (high pressure)
10. Fuel rail to fuel rail supply line	11. Fuel rail (bank 2)	12. Fuel rail pressure relief valve
13. Injector supply line (high pressure)	14. Injector supply line assembly (high pressure)	15. Injector supply line (high pressure)
16. Injector supply line assembly (high pressure)	17. Injector supply line assembly (high pressure)	18. Injector supply line (high pressure)
A. Refer to EM-468, "Removal and Installation".	B. Refer to EM-451, "Removal and Installation".	C. Refer to EM-463, "Removal and Installation".
D. Refer to EM-472, "Removal and Installation".	E. Refer to EM-482, "Removal and Installation".	⇦ Front

Removal and Installation

INFOID:0000000014418726

GENERAL INFORMATION

The fuel pressure relief valve is located on the fuel rail (bank 2).

REMOVAL

WARNING:

The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire;

- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate the skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

1. Remove the air duct. Refer to EM-220, "Exploded View".
2. Disconnect glow plug harness connector on cylinder number eight and reposition harness.
3. Clean the area around the fuel pressure relief valve.
4. Disconnect harness connector from fuel pressure relief valve.
5. Using a suitable tool, loosen the fuel pressure relief valve inner nut while holding the outer nut and remove the fuel pressure relief valve (1).

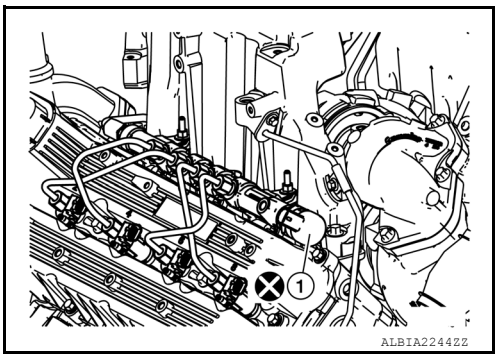
   CAUTION:

   Do not reuse the fuel pressure relief valve.

   NOTE:

   After removing the fuel pressure relief valve, install Tool on all open fuel system components.

   Tool : — (J-54427)



INSPECTION AFTER REMOVAL

Inspect the engine harness connector for the following:

- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Repair or replace the engine harness connector as needed

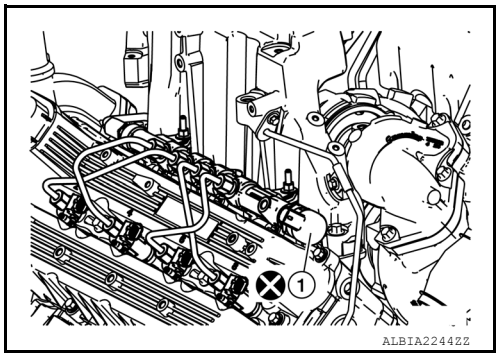
Inspect the fuel rail (bank 2) for the following:

- Damaged seal surface in the rail
- Thread damage
- Corrosion
- Replace the fuel rail (bank 2) if damage is found

INSTALLATION

1. Lubricate the new fuel pressure relief valve O-rings with clean diesel fuel.
2. Install fuel pressure relief valve (1) and orient harness connector to ensure harness will not be under tension.
3. Tighten fuel pressure relief valve (1) as follows:

Step 1 : 60 N·m (6.1 kg-m, 44 ft-lb)
Step 2 : Loosen 90°
Step 3 : 85 N·m (8.7 kg-m, 63 ft-lb)



4. Installation of the remaining components is in the reverse order of removal.

a. Complete the following after installation is complete:
   1. Prime the fuel system. Refer to EM-219, "Priming".
   2. Run CONSULT High-Pressure Fuel System Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
   3. If the fuel rail pressure relief valve has been replaced, in CONSULT click the Relief Val button in the Fuel or Timing System Table Reset in Work Support. Refer to EC-806, "CONSULT Function".
   4. Operate the engine and check for leaks.

FUEL PUMP ACTUATOR

Removal and Installation

INFOID:0000000014418727

REMOVAL

WARNING:

- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
- **Wear appropriate eye protection and protective clothing including gloves and a face shield.**
- **The fuel system (fuel pump, high pressure fuel lines, fuel rail, injectors) contain very high pressure fuel. To avoid the risk of personal injury or fire:**
- **Do not loosen any fittings while the engine is running.**
- **Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.**
- **Wear appropriate eye protection and protective equipment as high-pressure fuel spray can penetrate skin.**
- **Never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**
- **Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.**

CAUTION:

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

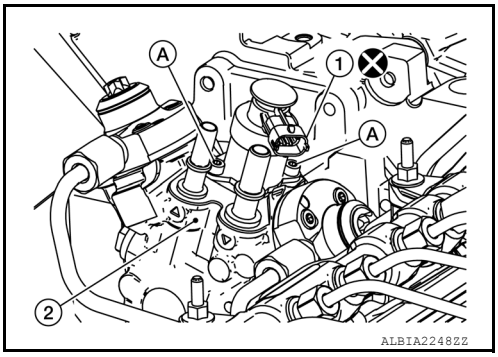
1. Remove the intake manifold assembly. Refer to EM-239, "Removal and Installation".
2. Disconnect the harness connector from fuel pump actuator.
3. Remove bolts (A) securing fuel pump actuator (1) to fuel pump (2).

   CAUTION:

   Do not reuse the fuel pump actuator.

   NOTE:

   - Do **not** use a screwdriver to remove fuel pump actuator.
   - Note the location of the fuel pump actuator to ensure it is installed in the same orientation as removed.



4. Remove fuel pump actuator from the fuel pump by twisting and pulling.

INSPECTION AFTER REMOVAL

CAUTION:

Internal passages of the fuel rail may only be cleaned with electrical contact cleaner. Do not use a parts washer to clean the fuel rail. Dirt and contaminants can damage the fuel system.

- Inspect the hole and seat of the fuel pump housing for damage.
- Remove existing dirt and other particles from the fuel pump actuator bore. Use of a vacuum/suction device can aid in removing debris.
- Replace the fuel pump if damage is present.

INSTALLATION

CAUTION:

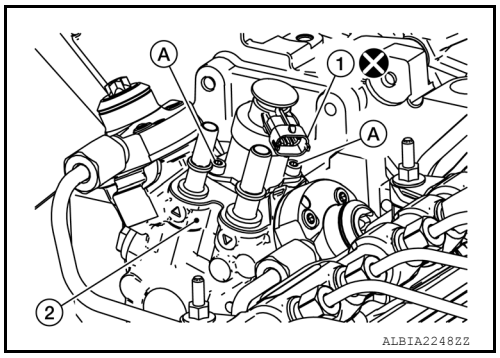
- **Do not reuse the fuel pump actuator.**
- **Make sure no dirt or debris enters the fuel rail line fittings to prevent the passing of contaminants to the high-pressure fuel rails and injectors. Small amounts of dirt and debris can cause a malfunction of these components.**

NOTE:

Lubricate the O-rings with petroleum jelly, or equivalent.

1. Install the fuel pump actuator (1) into the fuel pump (2) by twisting and pushing the fuel pump actuator into the previous orientation.
2. Tighten the bolts (A) as follows.

Step 1	**: 4 N·m (0.4 kg-m, 35 in-lb)**
Step 2	**: 7 N·m (0.7 kg-m, 62 in-lb)**



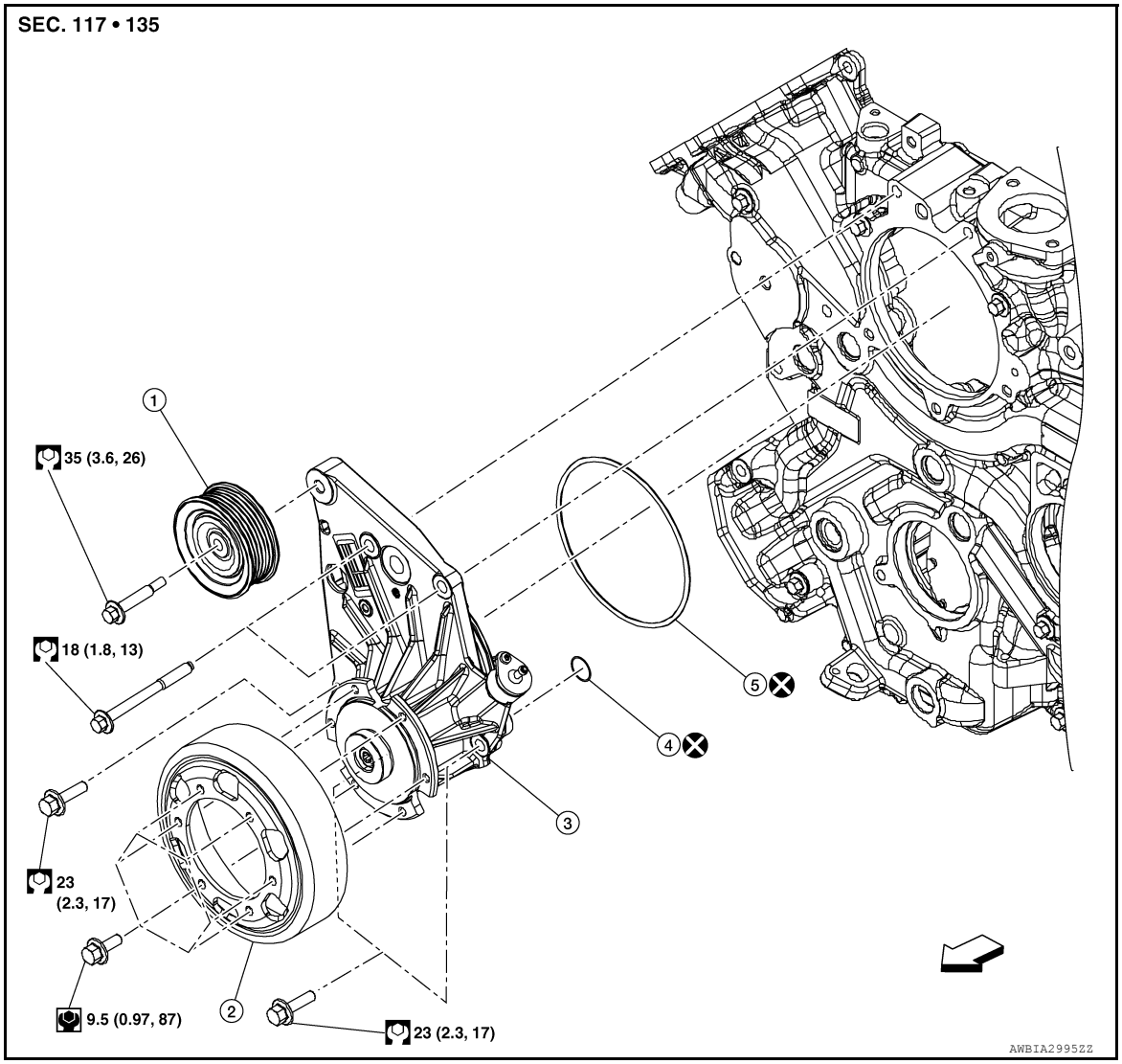
3. Connect the fuel pump actuator harness connector.
4. Installation of the remaining components is in the reverse order of removal.

WARNING:
Diesel fuel and diesel fuel vapor is flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Never allow diesel fuel to spill onto a hot exhaust manifold which can cause a fire.
NOTE:
- Run CONSULT High-Pressure Fuel System Leak Test. Refer to EM-218, "High-Pressure Fuel System Leak Test".
- Operate the engine and check for leaks.

VACUUM PUMP

Exploded View

INFOID:0000000014418728



1. Idler pulley
2. Fan spacer and pulley
3. Vacuum pump
4. O-ring
5. O-ring
⇦ Front

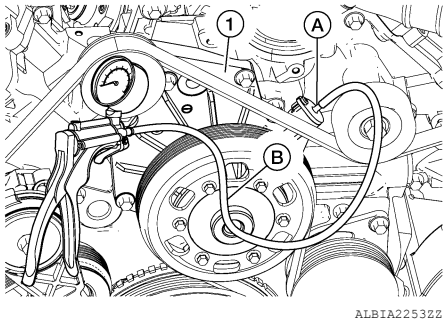
Removal and Installation

INFOID:0000000014418729

INSPECTION BEFORE REMOVAL

- The vacuum pump (1) **must** produce enough vacuum to overcome the compressor bypass valve actuator spring. If the vacuum pump does **not** produce enough vacuum, the compressor bypass valve will **not** open.
- Connect a suitable tool (B) to the vacuum pump inlet (A).
- Start the engine. With the engine running at idle, observe the vacuum produced by the pump.

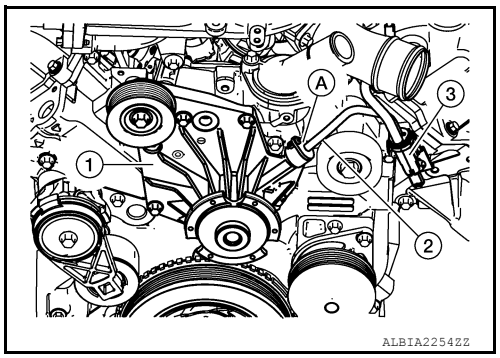
Required Vacuum (minimum) **: 40 kPa (0.41 kg/cm^2, 5.8 psi)**



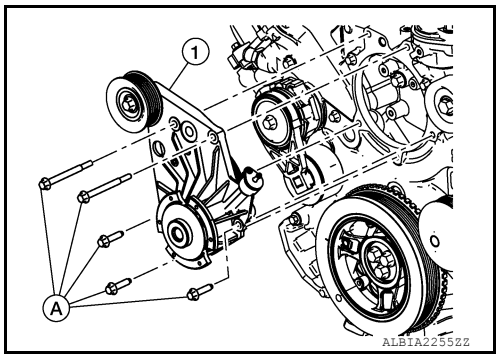
REMOVAL

1. Remove the fan spacer and fan pulley. Refer to CO-55, "Removal and Installation".
2. Disconnect the vacuum hose (2) from the vacuum pump port (A).

   (1) : Vacuum pump assembly



3. If necessary, disconnect the vacuum tube from the turbocharger compressor bypass solenoid (3).
4. Remove the bolts (A) and remove the vacuum pump assembly (1).



5. Remove the idler pulley (if necessary).

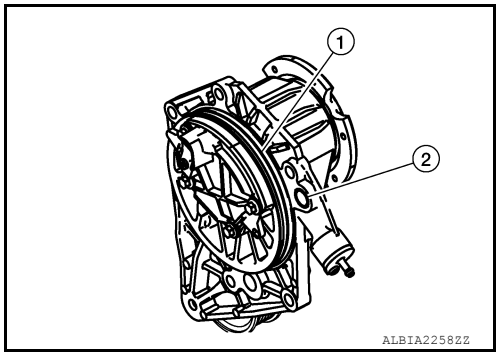
INSPECTION AFTER REMOVAL

WARNING:

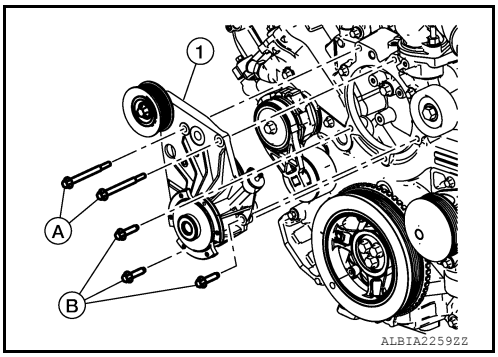
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- **To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturers recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.**
- Check the vacuum pump for cracks, chips, or other damage.
- If damage is found, replace the vacuum pump.
- Check the chain drive for damage if the vacuum pump cover plate bolts have fallen out.
- Inspect the idler pulley for cracks or other damage.
- If damage is found, replace the fan idler pulley.
- Use a suitable tool to clean the bolt hole threads in the front cover.
- Use a suitable tool to clean the vacuum pump bolts.

INSTALLATION

1. Apply clean engine oil to the vacuum pump O-ring (1) and install a new gasket (2).



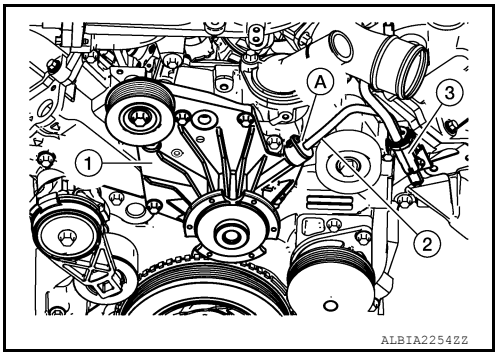
2. Install the vacuum pump (1) into the front cover and hand start the bolts (A and B).



CAUTION:
During installation of vacuum pump assembly, press the pump straight into the bore. Do not allow pump to rock back and forth from side-to-side as this can damage the O-ring.
NOTE:
- Before installing the bolts, apply Loctite 242 or equivalent to the threads of the vacuum pump bolts.

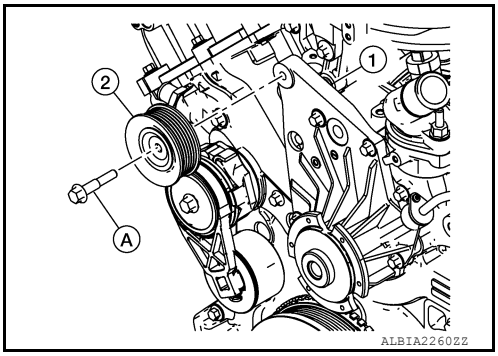
Bolts (A) : 18 N·m (1.8 kg-m, 13 ft-lb)
Bolts (B) : 23 N·m (2.3 kg-m, 17 ft-lb)

3. Connect the vacuum hose (2) to the vacuum pump port (A). Reconnect the vacuum hose to the turbocharger compressor bypass solenoid (3) (if necessary).



(1) : Vacuum pump assembly

4. If the idler pulley (2) was removed, install the idler pulley and bolt (A) onto the vacuum pump assembly (1).



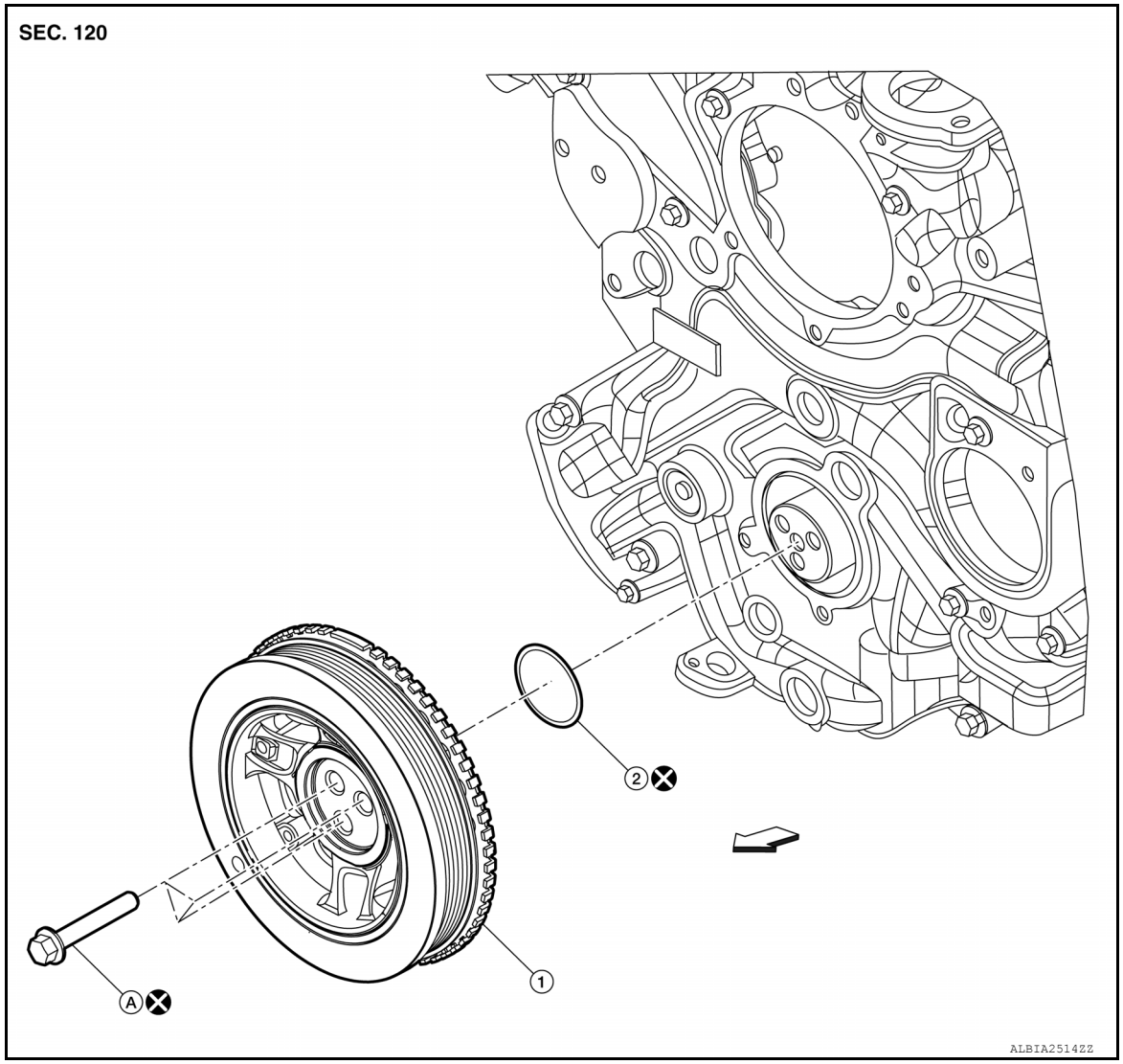
Bolt (A) : 35 N·m (3.6 kg-m, 26 ft-lb)

5. Installation of the remaining components is in the reverse order of removal.

VIBRATION DAMPER

Exploded View

INFOID:0000000014418730



1. Vibration damper
2. O-ring
A. Refer to INSTALLATION
⇦ Front

Removal and Installation

INFOID:0000000014418731

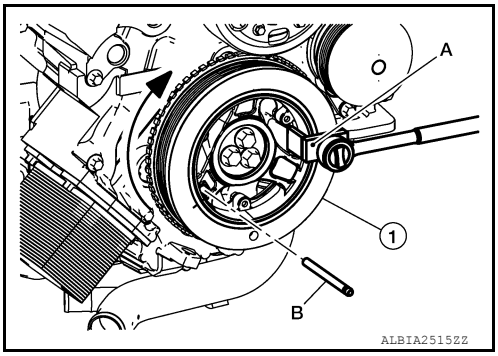
GENERAL INFORMATION

- The vibration damper and crankshaft speed indicator ring (tone wheel) **must** be serviced as an assembly.
  NOTE:
  Do **not** attempt to remove the indicator ring from the vibration damper.

REMOVAL

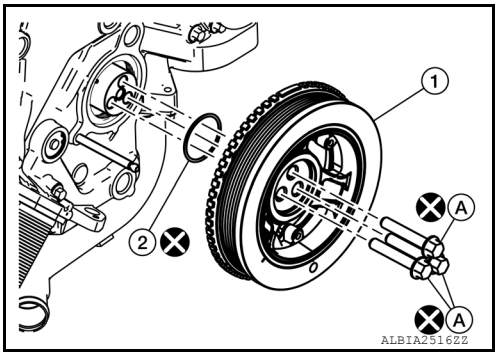
1. Remove the engine cooling fan. Refer to CO-55, "Removal and Installation".

2. Rotate the engine **clockwise** using suitable tool until the timing/alignment pin hole in the damper aligns with the corresponding hole in the front cover.
CAUTION:
Not using the Tool (A) to hold the damper can result in damage to the crankshaft index pin.
Use Tool (A), to hold the damper while the pulley bolts are being loosened or tightened.
3. Insert Tool (B) into the vibration damper hole and then into the front cover.



Tool (A) : — (J-54424)
Tool (B) : — (J-54404)

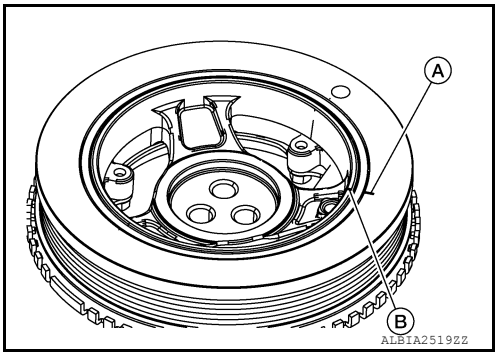
4. Remove the bolts (A) and remove the vibration damper (1) and O-ring (2).
CAUTION:
- **Do not reuse vibration damper bolts.**
- **Do not reuse O-ring.**



INSPECTION AFTER REMOVAL

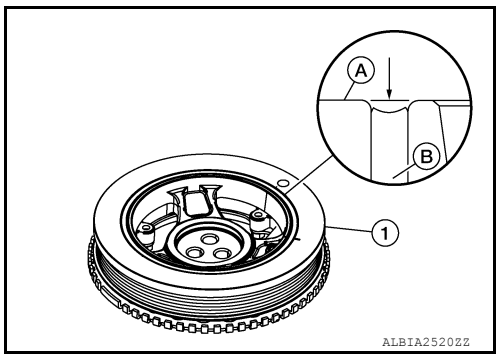
WARNING:
When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:
- **Do not exceed 30psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- **Use soapy water to clean any oil from the crankshaft speed indicator ring and vibration damper.**
- **Dry the crankshaft speed indicator ring and vibration damper with compressed air.**

- Inspect the crankshaft speed indicator ring for missing or bent teeth, cracks, or damaged surfaces.
- If damage is found, the vibration damper **must** be replaced.
- Check the alignment marks (A and B) on the inner and outer rings, if the lines are more than 1.59 mm (0.063 in) out of alignment, replace the vibration damper.



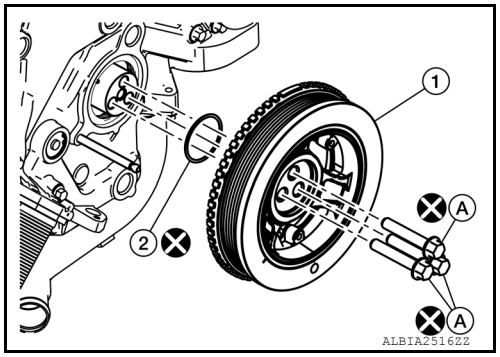
- Check the mounting web for cracks.

- Inspect the rubber member for deterioration.
  If pieces of rubber are missing, or if the elastic member (B) is more than 3.18 mm (0.125 in) below the metal surface (A), replace the vibration damper (1).
  NOTE:
  Look for forward movement of the damper ring on the hub. Replace the damper if movement is detected.



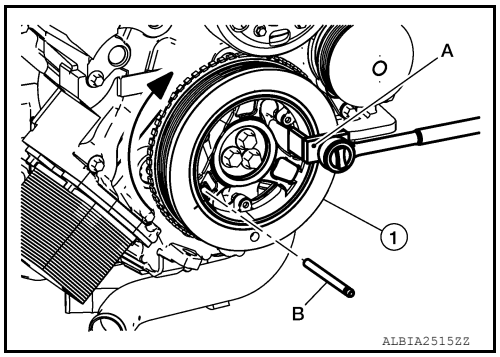
INSTALLATION

1. Install the vibration damper (1).
   CAUTION:
   - **Align the vibration damper with the index pin located on the nose of the crankshaft. Proper alignment will be achieved when the index pin on the crankshaft aligns with the slot in the damper and the alignment pin hole in the damper spoke aligns with the alignment tool hole in the front cover. Failure to achieve this will result in the index pin in the damper being damaged and sheared off the crankshaft. This will result in the replacement of the crankshaft.**
   - **Do not reuse the O-ring.**
   - **Do not reuse vibration damper bolts.**



2. Insert Tool (B) through the vibration damper leg and into the front cover timing pin hole
   NOTE:
   - Use the Tool (A) to hold the damper while the vibration damper bolts are being loosened or tightened.
   - The Tool (B) **must not** be used to prevent the crankshaft from turning while tightening the damper.

   Tool (A) : — (J-54424)
   Tool (B) : — (J-54404)

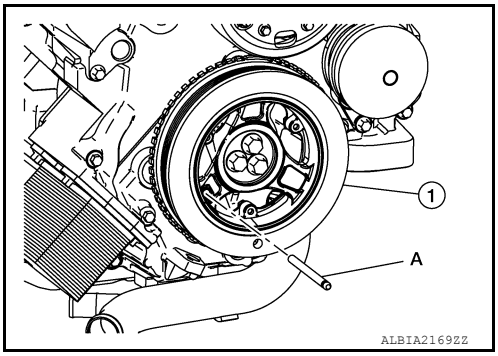


3. Tighten the vibration damper bolts in a **clockwise** pattern.
   NOTE:
   - Use the Tool (A) to hold the damper while the vibration damper bolts are being loosened or tightened.
   - The Tool (B) **must not** be used to prevent the crankshaft from turning while tightening the damper.

Step 1	**: 10 N·m (1.0 kg-m, 7 ft-lb)**
Step 2	**: 45 N·m (4.6 kg-m, 33 ft-lb)**
Step 3	**: 85 N·m (8.7 kg-m, 63 ft-lb)**
Step 4	**: 90 N·m (9.2 kg-m, 66 ft-lb) and turn the bolts 90 degrees clockwise.**

4. Remove the Tool (A).
CAUTION:
Failure to remove the timing alignment pin (A) before rotating the engine will result in damage to the vibration damper (1) and front cover.

Tool (A) : — (J-54404)



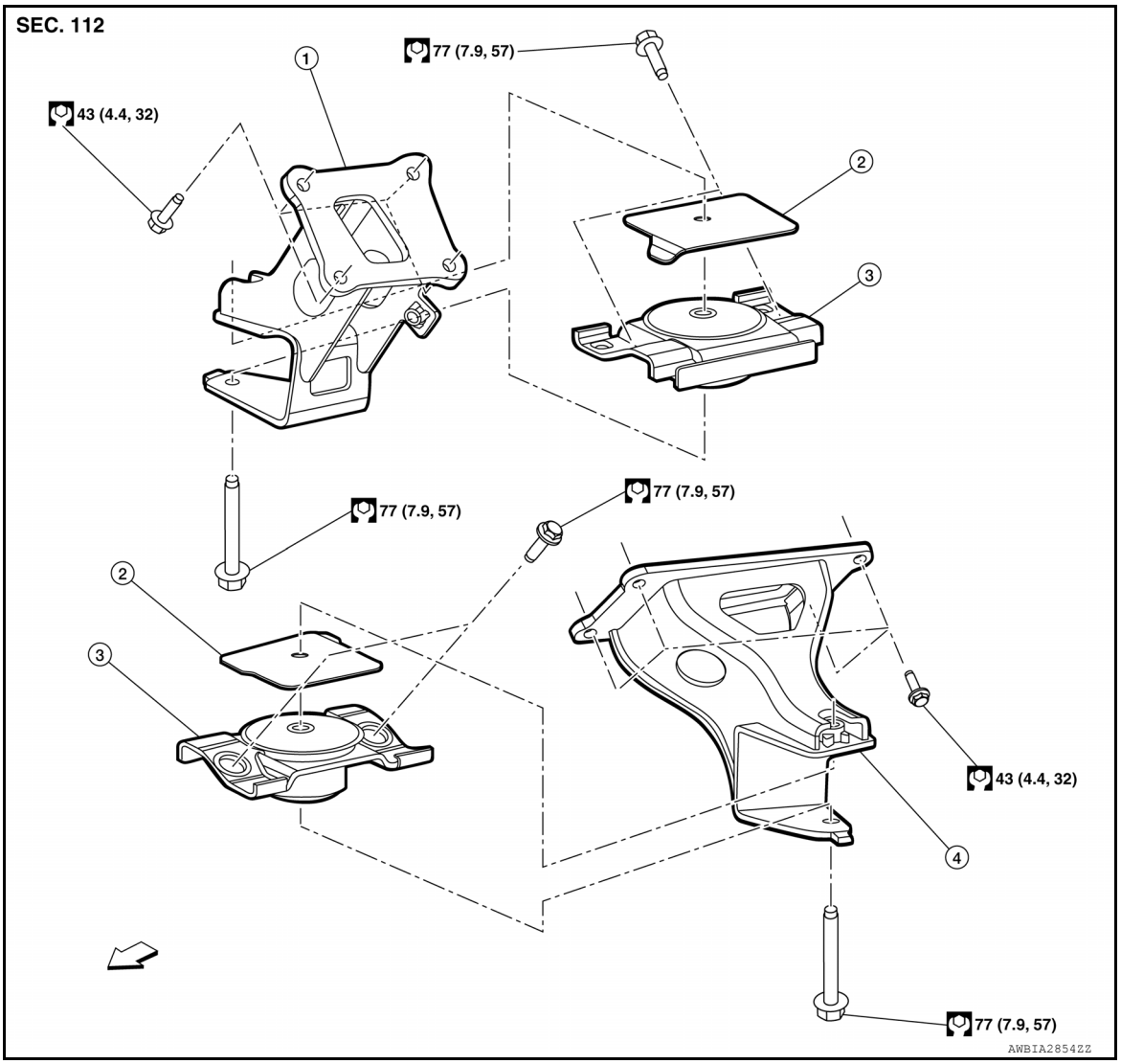
5. Installation of the remaining components is in the reverse order of removal.
NOTE:
If the vibration damper was replaced, in CONSULT click the Timing and Crank buttons in the Fuel or Timing System Table Reset in Work Support. Refer to EC-806, "CONSULT Function".

UNIT REMOVAL AND INSTALLATION

ENGINE ASSEMBLY

Exploded View

INFOID:0000000014418732



1. Engine mounting bracket (RH)
2. Engine mounting insulator
3. Heat shield plate
4. Engine mounting bracket (LH)
⇦ Front

Removal and Installation

INFOID:0000000014418733

WARNING:

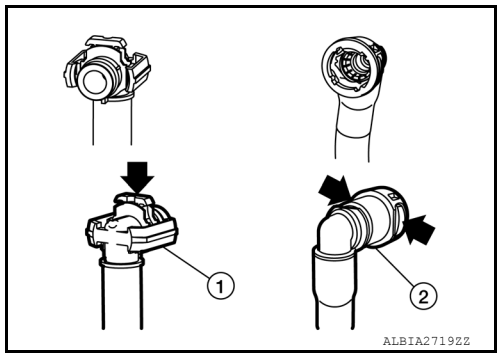
- **To avoid the risk of personal injury from a falling or shifting engine. Use only lifting equipment designed to lift the weight of the engine and transmission assemblies safely. To determine the weight of the engine and transmission assemblies refer to the Service Data Specification (SDS) section of the Engine Mechanical (EM) and Transmission (TM) sections of the service manual.**
- **To avoid the risk of personal injury by moving or shifting drive train components, always properly support the drive train components not being removed.**
- **Situate vehicle on a flat and solid surface.**
- **Place chocks at front and back of rear wheels.**
- **For engines not equipped with engine slingers, attach proper slingers and bolts described in PARTS CATALOG.**

CAUTION:
- **Always be careful to work safely, avoid forceful or uninstructed operations.**
- **Do not start working until exhaust system and engine coolant are cooled sufficiently.**
- **If items or work required are not covered by the engine section, follow the applicable procedures.**
- **Always use the support point specified for lifting.**
- **Use either 2-point lift type or separate type lift. If board-on type is used for unavoidable reasons, support at the rear axle jacking point with transmission jack or similar tool before starting work, in preparation for the backward shift of center of gravity.**
- **For supporting points for lifting and jacking point at rear axle, refer to GI-29, "XD MODELS : 2-Pole Lift".**

NOTE:
When removing components such as hoses, tubes/lines, etc., cap or plug openings to prevent fluid from spilling.

REMOVAL

1. Disconnect the battery or batteries. Refer to PG-185, "Battery Disconnect".
   CAUTION:
   Wait 10 minutes after disconnecting battery to service any fuel system components to allow time for system to release pressure.
2. Remove the front wheel and tires. Refer to WT-69, "Removal and Installation".
3. Remove fender protector. Refer to EXT-41, "Removal and Installation - Front Fender Protector".
4. Remove the front undercover. Refer to EXT-38, "REAR UNDER COVER : Removal and Installation".
5. Drain the engine coolant. Refer to CO-47, "Changing Engine Coolant".
6. Partially drain the A/T fluid. Refer to TM-218, "Changing the A/T Fluid (ATF)".
7. Remove the transmission assembly. Refer to TM-248, "2WD : Removal and Installation" (2WD models) or TM-252, "4WD : Removal and Installation" (4WD models).
8. Remove the hood. Refer to DLK-144, "HOOD ASSEMBLY : Removal and Installation".
9. Remove the cowl top extension. Refer to EXT-36, "Removal and Installation - Cowl Top Extension".
10. Remove the air cleaner and air duct assembly. Refer to EM-221, "Removal and Installation".
11. Disconnect the fuel supply and return lines from the fuel filter housing (Stage 2).
    CAUTION:
    Do not use any tools to disconnect the quick connector. This can result in damage to the quick disconnect fitting.

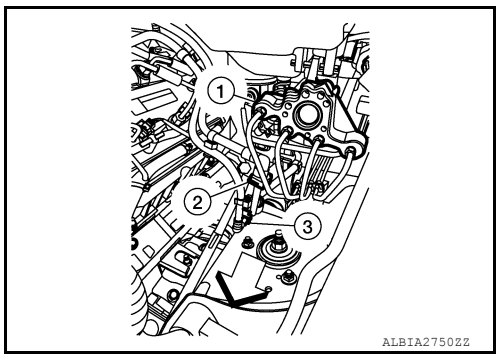
    

    Directions for service of a one-button quick-disconnect connector (1):
    - Disconnect the one-button quick-disconnect connector by pressing in the raised section of the clip on the connector.
    - With the clip fully depressed, the fuel line can be removed from the mating female port.
    - Connect the one-button quick-disconnect connector by pushing the connector into the female mating port until it clicks.

    Directions for service of a two-button quick-disconnect connector (2):
    - Disconnect the two-button quick-disconnect connector by pressing in the locking tangs on both sides of the connector.
    - After pressing the opposing locking tangs, the quick-disconnect connector can be removed from the male fuel fitting.
    - Connect the two-button quick-disconnect connector by pushing the quick-disconnect connector onto the male fuel fitting until it clicks.

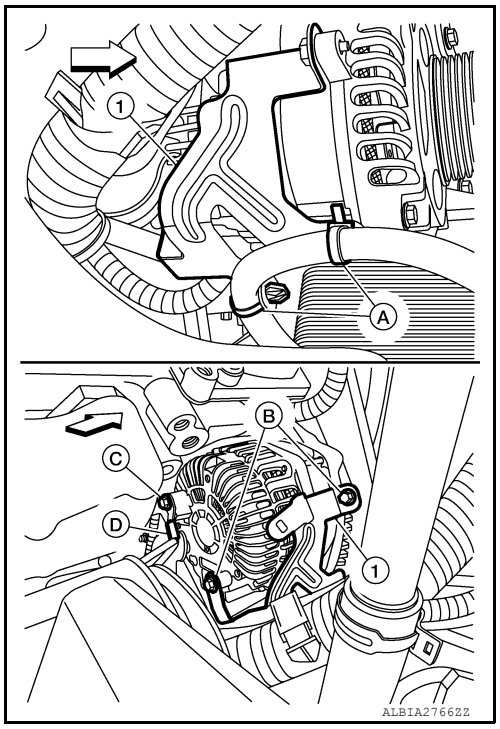
12. Disconnect the fuel supply line (2) and fuel return line (3) disconnects.
CAUTION:
Do not use any tools to disconnect the quick connector. This can result in damage to the quick disconnect fitting.

(1) : Master cylinder
⇦ : Front



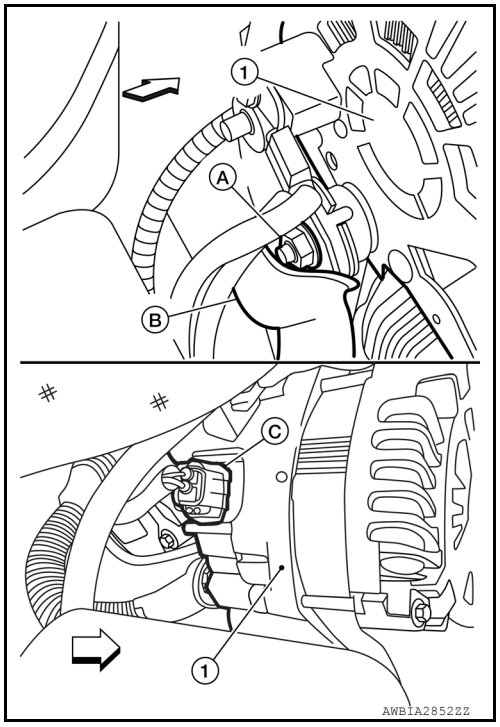
13. Remove the starter. Refer to STR-35, "Removal and Installation - For CUMMINS 5.0L".
14. Remove the harness clips (A) from the engine harness bracket (1).
15. Remove bolts (B) and remove the engine harness bracket (1).
16. Remove bolt (C) and remove the ground cable (D).

⇦ : Front

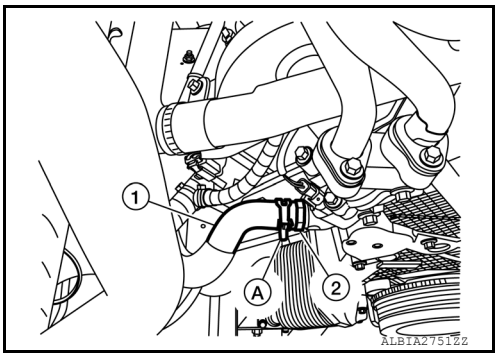


17. Remove the "B" terminal nut (A) and remove the harness (B).
18. Disconnect the harness connector (C).

(1) : Generator
⇦ : Front

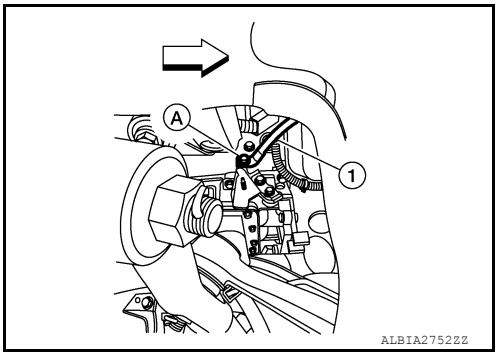


19. Recycle the refrigerant. Refer to HA-19, "Recycle Refrigerant".
20. Remove the high-pressure and low-pressure flexible hoses from the compressor. Refer to HA-40, "Exploded View".
21. Remove the low-pressure flexible hose. Refer to HA-42, "LOW-PRESSURE FLEXIBLE HOSE : Removal and Installation - CUMMINS 5.0L".
22. Drain the power steering fluid. Refer to ST-34, "Draining and Refilling".
23. Disconnect the power steering suction hose and power steering pressure hose from the power steering oil pump. Refer to ST-67, "Removal and Installation - Cummins 5.0".
24. Remove the reservoir tank. Refer to CO-52, "Removal and Installation".
25. Remove the radiator. Refer to CO-49, "Removal and Installation".
26. Release the clamp (A) and remove the heater core hose (1) from the front cover (2).



27. Disconnect the harness connectors from the glow control unit.Refer to EC-1996, "Exploded View".
28. Disconnect the harness connectors from the ECM. Refer to EC-1994, "Removal and Installation".
29. Remove the bolt (A) and remove the battery ground cable (1) from the engine block.

⇦ : Front



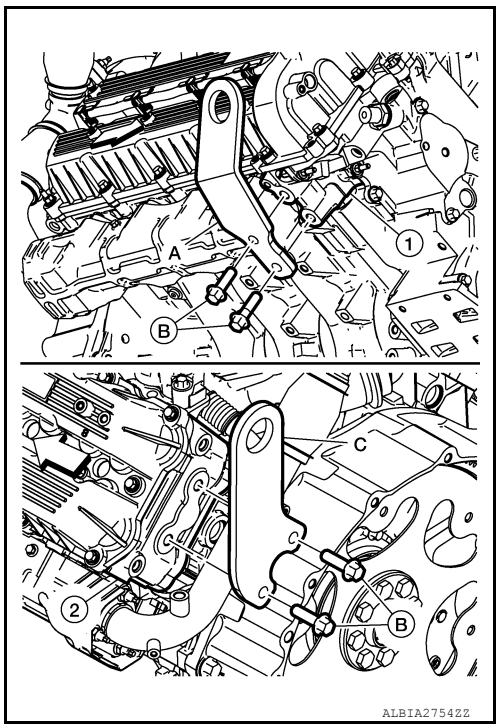
30. Remove the exhaust downpipe. Refer to EX-29, "Removal and Installation".

31. Install Tool (A) onto the bank 1 (1) and bank 2 cylinder heads (2) and tighten bolts (B) to the specified torque.

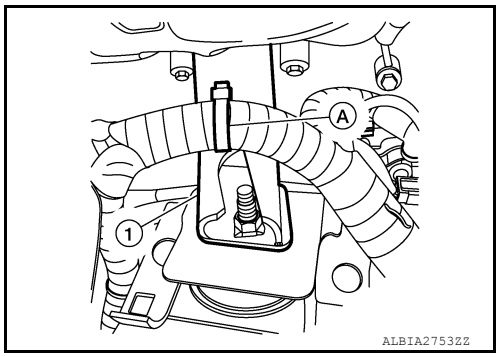
Tool number : — (J-54419)

Bolts (B) : 64 N·m (6.5 kg-m, 47 ft-lb)

⇦ : Front



32. Remove the engine mount bracket (RH) (1) bolts.
NOTE:
Remove the harness clip (A) from the engine mount bracket (RH)(1) before lifting engine.



33. Remove engine mount bracket (LH) bolt from the chassis.
34. Lift engine using a hoist and remove engine from the vehicle.
CAUTION:
Before and during lifting, always check to see if any harnesses are left connected.
NOTE:
The engine is very heavy and the engine hoist must be capable of safely lifting the engine. Refer to EM-529, "GENERAL SPECIFICATIONS".
35. Remove the following parts from the engine after removal (if necessary).
- Generator and generator bracket. Refer to CHG-48, "Removal and Installation: Cummins 5.0L".
- Compressor. Refer to HA-31, "Exploded View".
- Power steering oil pump. Refer to ST-66, "Exploded View".
- Engine mounts. Refer to EM-493, "Exploded View".
- Flexplate. Refer to EM-388, "Exploded View".
- Flywheel housing. Refer to EM-382, "Exploded View".

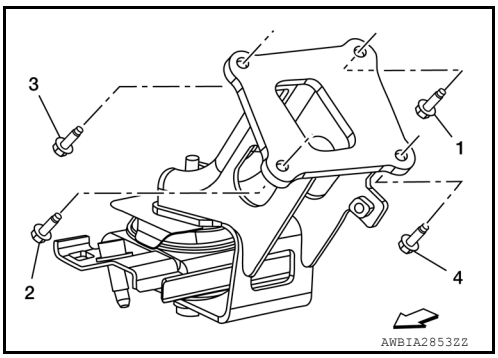
INSTALLATION

Installation is in the reverse order of removal.

- Tighten bank 1 engine mounting bracket (1) bolts in numerical order as shown to the specified torque.

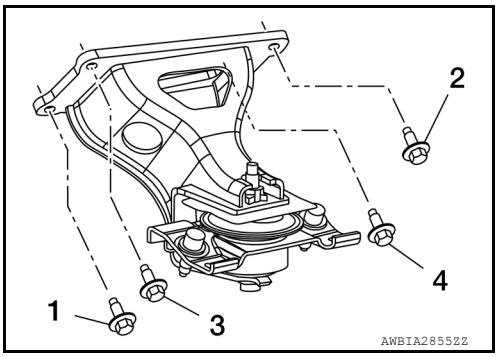
Engine mounting bracket bolts : 43 N·m (4.4 kg-m, 32 ft-lb)

⇦ : Front



- Tighten bank 2 engine mounting bracket (1) bolts in numerical order as shown to the specified torque.

Engine mounting bracket bolts : 43 N·m (4.4 kg-m, 32 ft-lb)



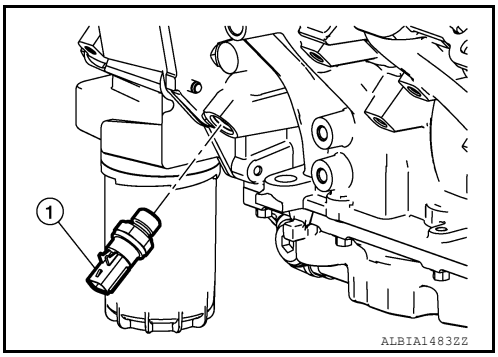
- Tighten battery ground cable to engine block.

Battery ground cable bolt : 18 N·m (1.8 kg-m, 13 ft-lb)

CAUTION:
- **When replacing an engine or transmission you must make sure the dowels are installed correctly during re-assembly.**
- **Improper alignment caused by missing dowels may cause vibration, oil leaks or breakage of drivetrain components.**

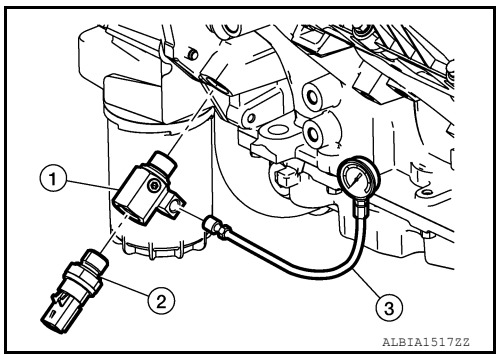
INSPECTION AFTER INSTALLATION

1. Check engine oil, engine coolant and other fluids levels, if less then the required quantity, fill to the specified level. Refer to MA-62, "Cummins 5.0L Engine : Fluids and Lubricants".
2. Disconnect the ECM to prevent engine from starting.
3. Remove the oil pressure sensor (1) from the cylinder block on the front left side of the engine. Refer to LU-59, "Removal and Installation".



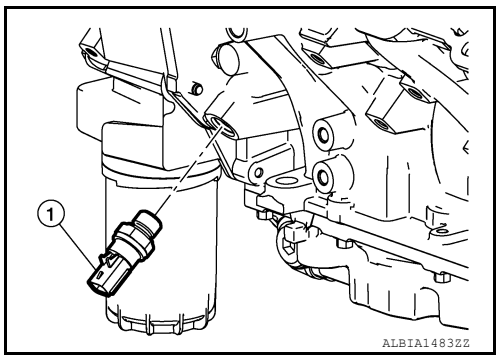
4. Install Tool (1) into the port and install the oil pressure sensor (2) into the other end of the Tool and thread Tool into Tool (1).

Tool number : — (J-54412)



5. Connect suitable tool (3) and crank the engine until the suitable tool indicates a positive oil pressure.
CAUTION:
If the lubricating oil pressure does not develop within 15 seconds, shut down the engine to reduce the possibility of internal damage.

6. After positive oil pressure is observed, connect the ECM.
7. Remove the Tool assembly from the port and install the oil pressure sensor (1). Refer to LU-59, "Removal and Installation".



8. Prime the fuel system. Refer to EM-219, "Priming".
NOTE:
During priming, check for fuel leaks at connection points.
9. Operate the engine at low idle for 2 to 3 minutes and shut the engine off.
NOTE:
Wait 5 to 7 minutes for engine oil to drain back to oil pan.
10. Check the engine oil level. Refer to LU-33, "Inspection".
11. Check the engine coolant level. Refer to CO-45, "System Inspection".
12. Operate the engine at 1000 to 1200 rpm for 8 to 10 minutes.
NOTE:
- Check for proper operation, unusual noises and coolant/fuel/exhaust/charge air/engine oil leaks.
- If hydraulic pressure inside timing chain tensioner drops after removal and installation, slack in the guide may generate a pounding noise during and just after engine start. However, this is normal. Noise will stop after hydraulic pressure rises.

13. Allow engine to cool and re-check engine oil and engine coolant.
14. Using CONSULT, read and clear any fault codes.
NOTE:
For any active fault codes. Refer to EC-838, "DTC Index".

- Summary of the inspection items:

Item		Before starting engine	Engine running	After engine stopped
Engine coolant		Level	Leakage	Level
Engine oil		Level	Leakage	Level
Transmission/ transaxle fluid	A/T and CVT Models	Leakage	Level/Leakage	Leakage
	M/T Models			
Other oils and fluids*		Level	Leakage	Level
Fuel		Leakage	Leakage	Leakage
Exhaust gas		—	Leakage	—

*Power steering fluid, brake fluid, etc.

UNIT DISASSEMBLY AND ASSEMBLY

ENGINE STAND SETTING

Setting

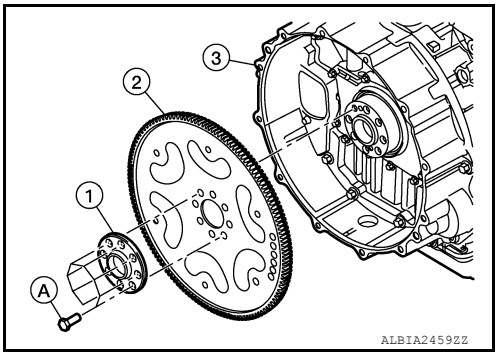
INFOID:0000000014418734

NOTE:
Explained here is how to disassemble with engine stand supporting flywheel housing surface. When using a different type of engine stand, note difference in steps, etc.

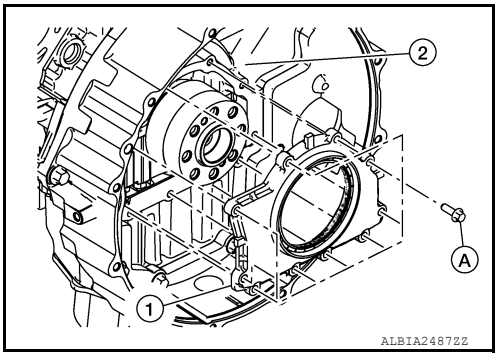
1. Remove engine assembly. Refer to EM-493, "Removal and Installation".
2. Install engine to engine stand with the following procedure:

a. Remove bolts (A) and remove the spacer (1) and flexplate (2).

(3) : Flywheel housing



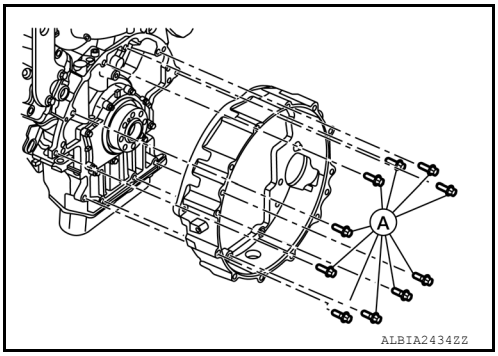
b. Remove bolts (A) and remove the rear seal carrier (1) from the cylinder block (2).



c. Loosen the flywheel housing bolts (A).

d. While supporting the flywheel housing, remove the bolts and the flywheel housing.

WARNING:
To avoid the risk of personal injury, use lifting equipment or acquire assistance when lifting components or assemblies that weight more than 23 kg (50 lbs).
NOTE:
Note the location of the flywheel housing bolts as removed. Some of the bolts are different length/size and **must** be installed in the same location as removed.



e. Lift the engine with a hoist to install it onto widely used engine stand.

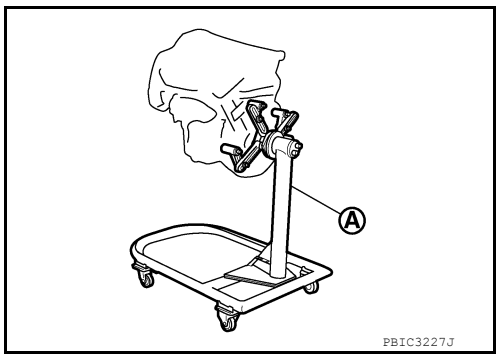
CAUTION:
- **Use the engine stand that has a load capacity [approximately 358 kg (790 lb) or more] large enough for supporting the engine weight.**
- If the load capacity of stand is not adequate, remove the following parts beforehand to reduce the potential risk of overturning stand.
- Intake manifold. Refer to EM-239, "Removal and Installation".
- Turbocharger. Refer to EM-399, "Removal and Installation".
- Exhaust manifold. Refer to EM-265, "Removal and Installation - Bank 1".
- Front cover. Refer to EM-338, "Removal and Installation".

NOTE:

The figure shows an example of widely used engine stand (A) that can support mating surface of flywheel housing.

CAUTION:

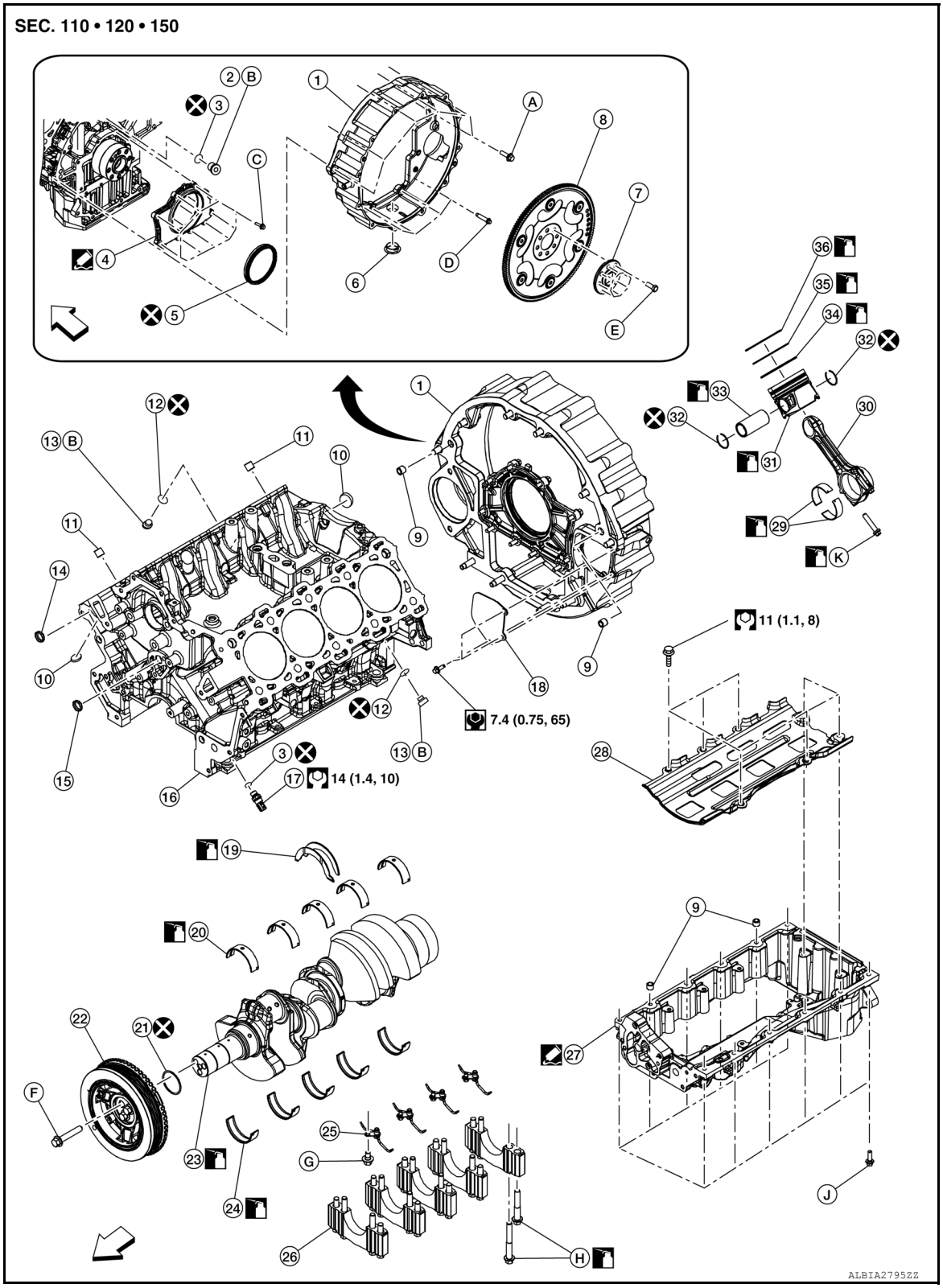
Before removing the hanging chains, check the engine stand is stable and there is no risk of overturning.



ENGINE UNIT

Exploded View

INFOID:0000000014418735



1. Flywheel housing
2. Drain plug
3. O-ring
4. Seal carrier
5. Rear oil seal
6. Plug
7. Spacer
8. Flexplate
9. Dowel

10.	Welch plug	11.	Dowel pin	12.	O-ring
13.	Drain plug	14.	Welch plug	15.	Welch plug
16.	Cylinder block	17.	Oil pressure sensor	18.	Access cover
19.	Thrust bearing	20.	Main bearing (upper)	21.	O-ring
22.	Vibration damper	23.	Crankshaft	24.	Main bearing (lower)
25.	Oil jet	26.	Main bearing cap	27.	Block stiffening plate
28.	Windage tray	29.	Connecting rod bearing	30.	Connecting rod
31.	Piston	32.	Snap ring	33.	Piston pin
34.	Oil ring	35.	Second ring	36.	Top ring
A.	Refer to EM-382, "Removal and Installation".	B.	Refer to ASSEMBLY	C.	Refer to EM-382, "Removal and Installation".
D.	Refer to EM-382, "Removal and Installation".	E.	Refer to EM-388, "Removal and Installation".	F.	Refer to EM-489, "Removal and Installation".
G.	Refer to ASSEMBLY	H.	Refer to ASSEMBLY	J.	Refer to EM-310, "Removal and Installation".
K.	Refer to ASSEMBLY	⇦	Front		

Disassembly and Assembly

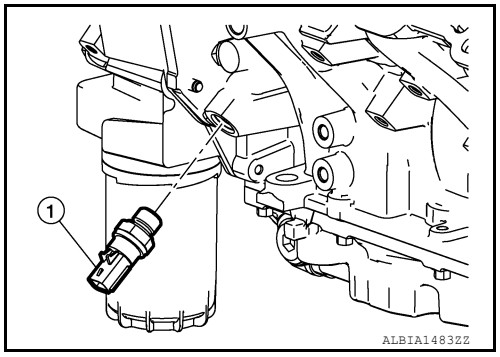
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DISASSEMBLY

NOTE:

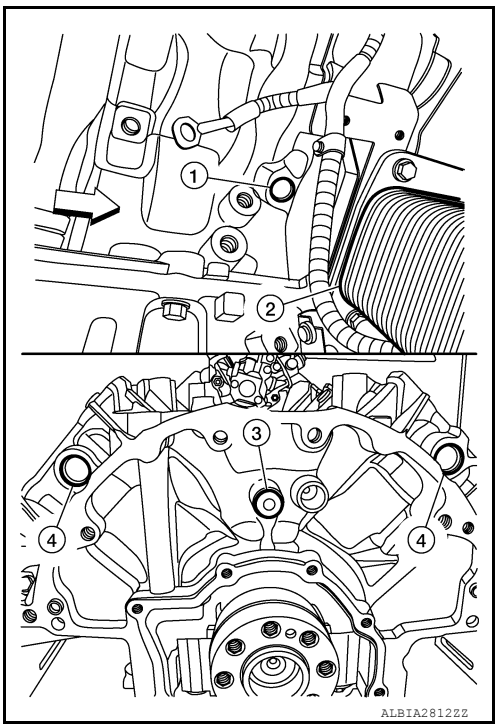
Explained here is how to disassemble with engine stand supporting flywheel housing surface. When using different type of engine stand, some steps may be different.

1. Attach engine on a suitable engine stand. Refer to EM-500, "Setting".
2. Drain engine oil. Refer to LU-35, "Changing Engine Oil".
3. Remove cylinder head. Refer to EM-358, "Removal and Installation".
4. Remove the fuel pump. Refer to EM-429, "Removal and Installation".
5. Remove the block stiffening plate. Refer to EM-310, "Removal and Installation".
6. Remove the oil pressure sensor (1).



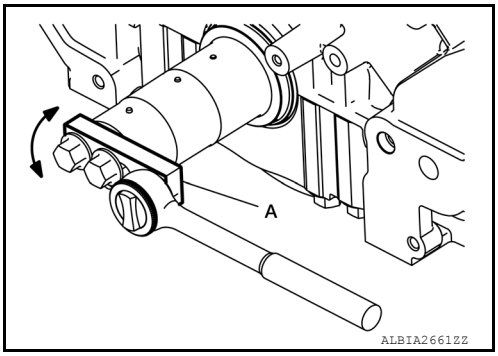
7. Remove the threaded plug (3) and welch plugs (1) and (4).
CAUTION:
Do not reuse the O-ring.

(2) : Oil cooler
⇦ : Front



8. Remove the piston and connecting rod assembly with the following procedure:
• Before removing piston and connecting rod assembly, check the connecting rod side clearance. Refer to EM-515, "Inspection After Disassembly".

a. Install Tool (A) onto the crankshaft. Using suitable tool, rotate the engine clockwise until the pistons are below the carbon deposits that are found above the piston ring travel area.
• Use a suitable tool to clean the built up carbon from the cylinder walls.

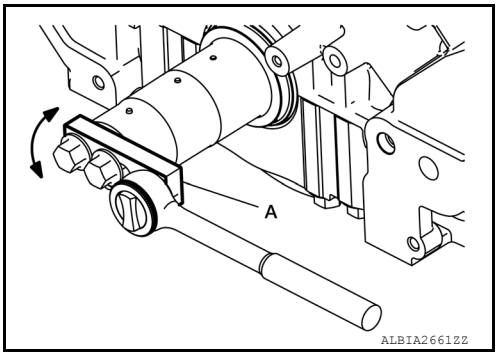


WARNING:
To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufacturers recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.

Tool : — (J-54401)

b. Place a mark on each piston according to the cylinder location so they can be installed in the same location.
NOTE:
Do **not** stamp on the aluminum piston crown above the piston pin axis.

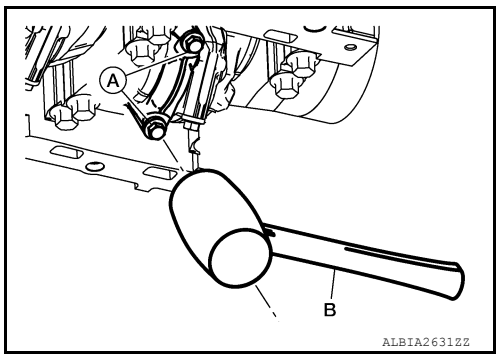
c. Use Tool (A) to rotate the engine clockwise until the connecting rod caps are at bottom dead center for removal and mark each connecting rod and connecting rod cap according to the cylinder number location.



Tool : — (J-54401)

d. Loosen the connecting rod bolts (A).
NOTE:
Do **not** remove the connecting rod bolts from the connecting rods at this time.

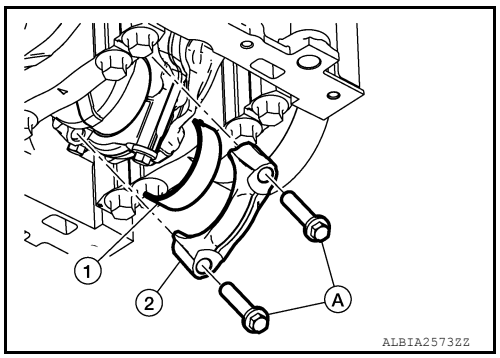
e. Using a suitable tool (B), hit the connecting rod bolts to loosen the connecting rod caps.
CAUTION:
Make sure to hit the connecting rod bolts square on the head of the bolt.



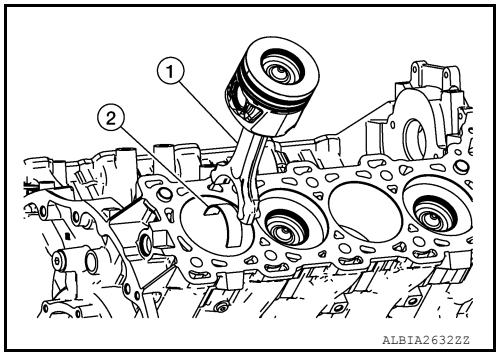
f. Remove the connecting rod bolts (A).

g. Remove the connecting rod cap (2) and connecting rod bearing [lower (1)].
CAUTION:
- **Do not damage the fracture-split surface on the connecting rod or connecting rod cap while the connecting rod cap is removed. If the fracture-split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage. Incorrect assembly can damage the rod.**
- **When setting the rod cap down, do not set the cap down on the fracture-split surface. Damage to the fracture-split surface can result.**

NOTE:
Mark the cylinder number and the letter L (lower) on the flat surface of the bearing stopper.



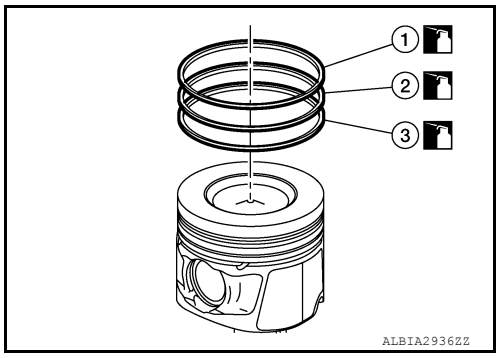
h. Push the piston and connecting rod assembly (1) out of the cylinder bore. Care **must** be taken **not** to damage the connecting rod, crankshaft journal, bearings or oil jets.
CAUTION:
- **Make sure the connecting rod does not scrape the cylinder wall while removing the piston and connecting rod assembly.**
- **If parts are reused, the piston and connecting rod assemblies must be installed in the same cylinder number from which they were removed to provide a proper fit of worn mating surfaces.**



i. Remove the connecting rod bearing [upper (2)].
NOTE:
- Mark the cylinder number and the letter U (upper) on the flat surface of the bearing stopper.
- Use a tag to mark the cylinder number from which each piston and connecting rod assembly was removed.
- Place the piston and connecting rod assemblies in a container or fixture to protect them from damage.

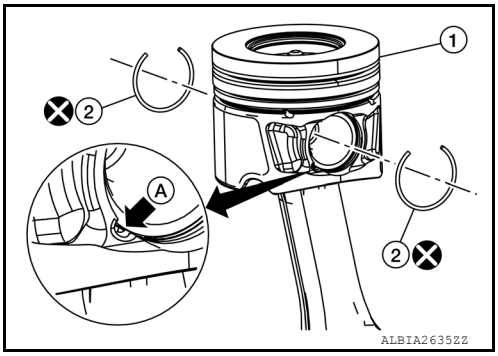
9. Use a suitable tool to remove the top ring (1), second ring (2) and oil ring (3).
- Before removing piston rings, check the piston ring side clearance. Refer to EM-515, "Inspection After Disassembly".

CAUTION:
- **When removing piston rings, be careful not to damage the piston.**
- **Do not damage piston rings by expanding them excessively.**

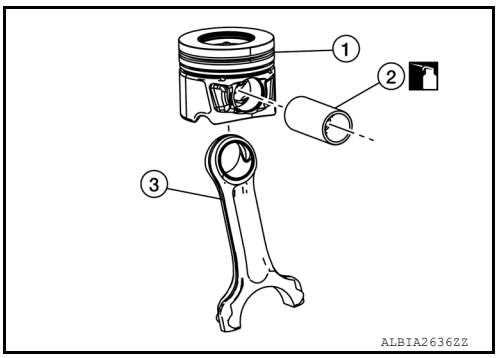


10. Remove the piston from the connecting rod using the following procedure:

a. Use a suitable tool to remove the snap rings (2) from both sides of the piston (1). There are notches (A) on the bottom of the piston skirt to access and use when removing the snap rings.
CAUTION:
Do not damage the piston while removing the snap rings. If the piston is damaged, it could also damage the piston pin upon removal.



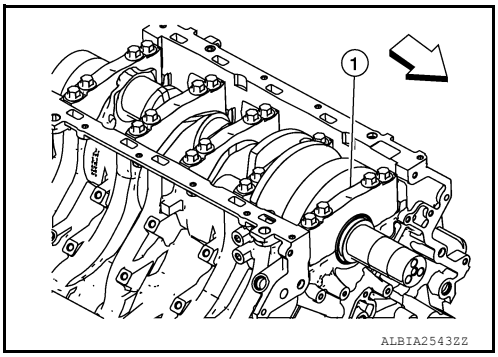
b. Remove the piston pin (2) and separate the piston (1) from the connecting rod (3).
NOTE:
Heating the piston is **not** required.



11. Remove the crankshaft using the following procedure:
- Measure crankshaft end play before loosening main cap bolts. Refer to EM-515, "Inspection After Disassembly".

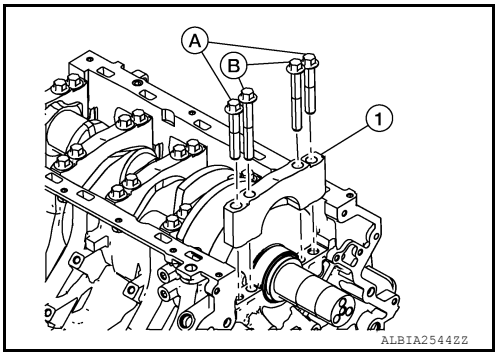
a. Before removing the main bearing caps, make certain the main bearing caps are clearly marked for their location.
NOTE:
The number 1 main bearing cap (1) is at the front of the engine and each main bearing cap should have an arrow indicating the direction of the main bearing cap, which is to the front of the engine.

⇦ : Front

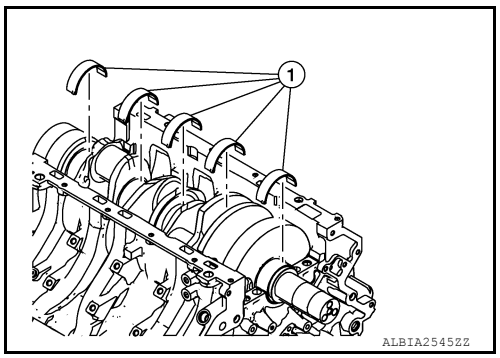


b. Loosen the main bearing cap bolts (A) first and then loosen main bearing cap bolts (B) completely and remove bolts (A).

c. Using main bearing cap bolts (B), rock the main bearing cap (1) forward and backward to remove.
CAUTION:
- **Do not pry on the main bearing caps to free them from the cylinder block. Damage to the main bearing caps and cylinder block can result.**
- **Be careful not to damage the main bearing cap bolts.**

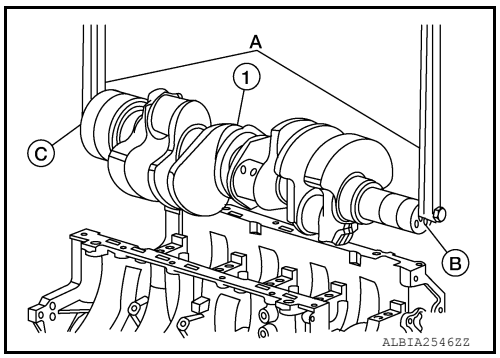


d. Remove the main bearings [lower (1)].
NOTE:
Mark the main bearings [lower (1)] for location as they are removed.

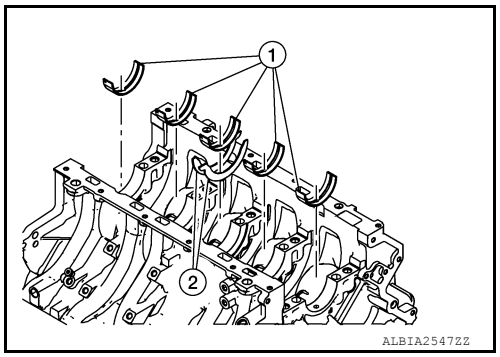


e. Install a suitable bolt or dowel into the vibration damper attachment holes (B) and flexplate attachment holes (C).

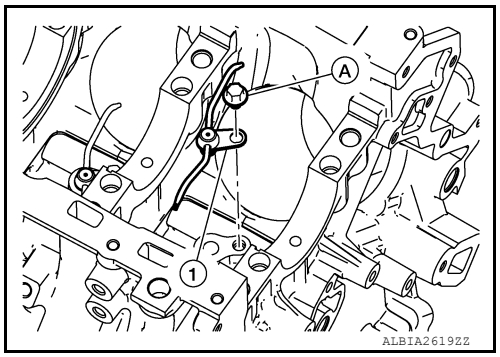
f. Install suitable tool (A) around the suitable bolt or dowel and remove the crankshaft (1).
WARNING:
To avoid the risk of personal injury, use lifting equipment or acquire assistance when lifting components or assemblies that weight more than 23 kg (50 lbs).
NOTE:
Lift the crankshaft straight up to avoid damage to the crankshaft and cylinder block.



g. Remove the main bearings [upper (1)] and thrust bearing (2).
NOTE:
Mark the main bearings [upper (1)] for location as they are removed.



12. Remove bolt (A) and remove the oil jets (1) from the cylinder block.

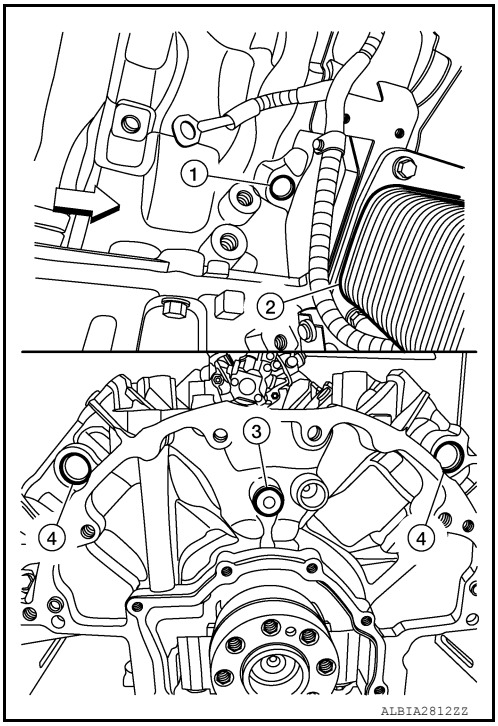


ASSEMBLY

1. Fully air-blow the coolant and oil passages in the cylinder block, cylinder bore, and crankcase to remove any foreign material.
WARNING:
Use goggles to protect your eyes.

2. Install all drain plug (3) and welch plugs (1) and (4) into the cylinder block.
CAUTION:
Do not reuse the O-rings.

(2) : Oil cooler
⇦ : Front

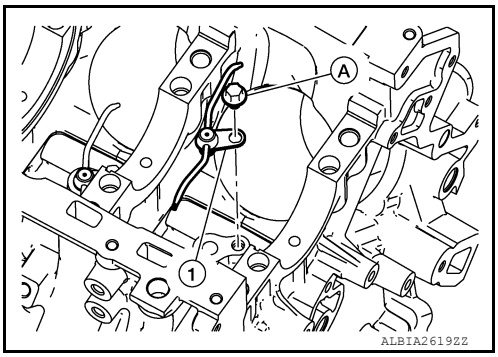


3. Install the oil jet (1) and tighten the bolt (A) to the specified torque.
CAUTION:
Slight bending of oil jets can cause severe engine damage. replace oil jet if it is bent or damaged during disassembly or assembly.
- When using a new oil jet and bolt:

Bolt (A) : 36 N·m (3.7 kg-m, 27 ft-lb)

- When using an existing oil jet and bolt:

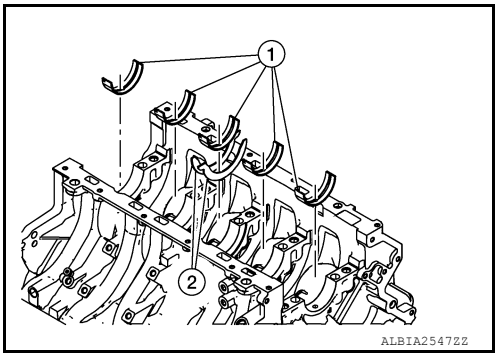
Bolt (A) : 24 N·m (2.4 kg-ms, 18 ft-lb)



4. Install the main bearings (upper), thrust bearing and crankshaft using the following procedure:

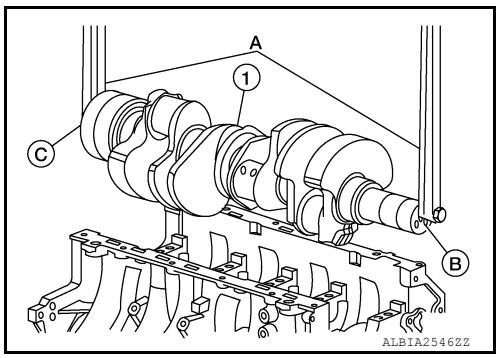
a. Remove dust, dirt and engine oil on the main bearing mating surfaces of the cylinder block.
CAUTION:
Do not lubricate the side that is against the cylinder block.
NOTE:
- Make sure the main bearing being installed is the same size as the main bearing removed, if the crankshaft has **not** been machined. The size is engraved on the back of the main bearing.
- The main bearings (upper) and main bearings (lower) are not interchangeable. The backs of the main bearings are marked with proper location.

b. Install the main bearings [upper (1)] and thrust bearing (2) into the cylinder block.
NOTE:
- Apply a coat of suitable assembly lube to the crankshaft-side of the main bearings [upper (1)] and main bearings (lower) and thrust bearing surfaces.
- This engine has a pair of 180 degree thrust bearings (2) which are installed in the number 3 main bearing (upper) position.



c. Install the crankshaft (1) with suitable tool (A).

WARNING:
To avoid the risk of personal injury, use lifting equipment or acquire assistance when lifting components or assemblies that weight more than 23 kg (50 lbs).
NOTE:
Lower the crankshaft straight down to avoid damage to the crankshaft and cylinder block.



d. Remove suitable bolts or dowels from the crankshaft.

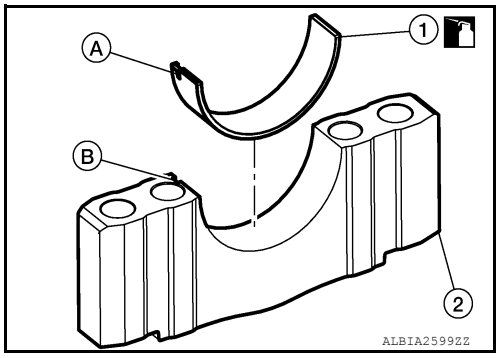
(B) : Vibration damper attachment holes
(C) : Flexplate attachment holes

5. Install the main bearings [lower (1)] using the following procedure:

a. Remove dust, dirt and engine oil on the main bearing mating surfaces of the main bearing cap.

b. Install the main bearing [lower (1)] into the main bearing cap (2).

CAUTION:
Do not lubricate the back side of the main bearing (lower) that contacts the main bearing cap.



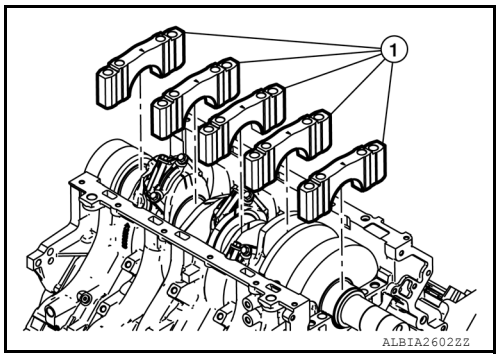
c. Align the bearing stopper (A) on the main bearing (lower) (1) with the notch (B) in the main bearing cap (2).
NOTE:
Apply a coat of suitable assembly lube to the crankshaft-side of the main bearings (upper) and main bearing (lower) and thrust bearing surfaces.

6. Install the main bearing caps using the following steps:

CAUTION:
Make sure the caps are correctly installed in the same position as removed, with the arrow towards the front of the engine.

a. Make sure the main bearing cap surfaces between the main bearing cap and block are clean and free of debris.

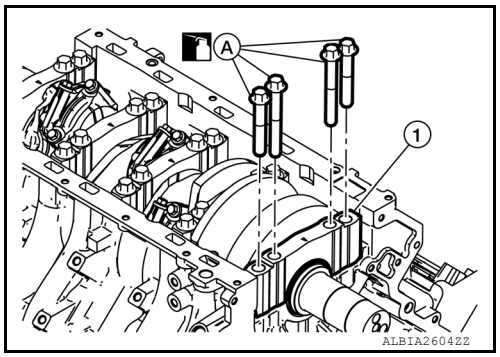
b. Install the main bearing cap (1) aligning the main bearing cap bolt hole with the cylinder block threaded hole.
NOTE:
- It may be necessary to gently tap the main bearing caps into location with a suitable tool.
- Main bearing cap number 1 starts with the front of the cylinder block and each main bearing cap has an arrow which points to the front of the engine.
- The bearing stopper in the main bearing saddle and main bearing cap **must** be on the same side.



c. Install the main bearing caps.

d. Lubricate the main bearing bolt threads and the underside of the bolt head with clean engine oil.

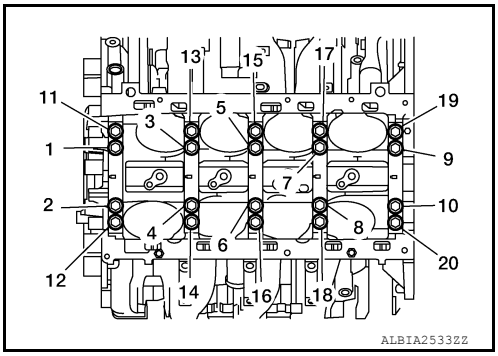
e. Install the main bearing bolts (A) into the main bearing caps (1) and tighten to the specified torque.
NOTE:
Do **not** tighten bolts (A) to the final torque until **all** main bearing caps are installed and bolts have been tightened to the specified torque.



Main bearing cap bolts : 50 N·m (5.1 kg-m, 37 ft-lb)

f. Check that the crankshaft rotates freely after installing main bearing caps.

g. Tighten the main bearing cap bolts in the order shown to the specified torque.



- When using existing main bearing cap inner bolts:

Step 1 : Tighten inner bolts to 50 N·m (5.1 kg-m, 37 ft-lb)
Step 2 : Loosen inner bolts 90°
Step 3 : Tighten inner bolts to 95 N·m (9.7 kg-m, 70 ft-lb)
Step 4 : Tighten inner bolts 120°
Step 5 : Tighten outer bolts to 85 N·m (8.7 kg-m, 63 ft-lb)
Step 6 : Tighten outer bolts 90°

- When using new main bearing cap inner bolts:

Step 1 : Tighten inner bolts to 50 N·m (5.1 kg-m, 37 ft-lb)
Step 2 : Loosen inner bolts 90°
Step 3 : Tighten inner bolts to 50 N·m (5.1 kg-m, 37 ft-lb)
Step 4 : Tighten inner bolts to 95 N·m (9.7 kg-m, 70 ft-lb)
Step 5 : Tighten inner bolts 120°
Step 6 : Tighten outer bolts to 85 N·m (8.7 kg-m, 63 ft-lb)
Step 7 : Tighten outer bolts 90°

NOTE:
New outer bolts do not have to go through a new main bearing bolt break-in procedure.

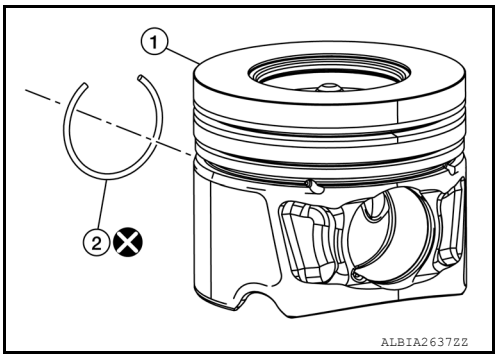
h. Make sure that the crankshaft rotates freely after installing main bearing caps. If crankshaft does not rotate freely, check the following:
- Confirm the correct main bearing caps were installed correctly.
- Confirm the main bearing cap ring dowels or mounting surfaces were **not** damaged during installation.
- Confirm the correct main bearings were installed.

i. Check crankshaft end play. Refer to EM-515, "Inspection After Disassembly".

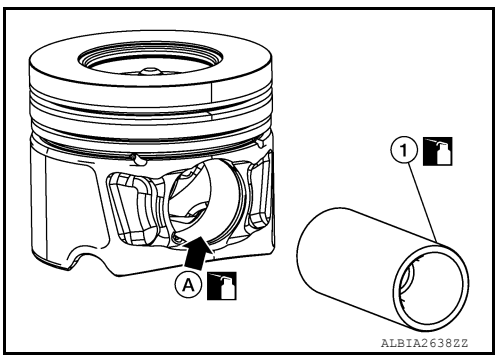
7. Assemble the piston and connecting rod assembly using the following procedure:

a. Use a suitable tool to install the snap ring (2) in the snap ring groove on one side of the piston (1).

CAUTION:
Do not reuse the snap ring.



b. Lubricate the piston pin (1) and piston pin bore (A) with clean engine oil.



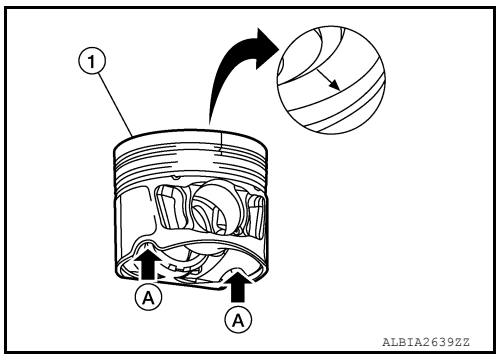
c. Make note of the orientation of the piston (1) before assembly with the connecting rod.

CAUTION:

To prevent engine damage, the piston and connecting rod must be assembled with the proper orientation.

NOTE:

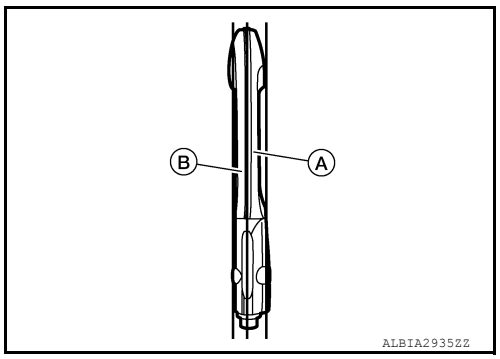
- The pistons have an arrow on the crown to indicate the installed direction. The arrow always points to the front of the engine.
- The two notches (A) on the bottom of the piston on the piston skirt are for oil jet clearance. They provide clearance regardless of the bank on which a piston is installed.



d. The crankshaft end of the connecting rod has one side (A) that is wider than the other side (B).

NOTE:

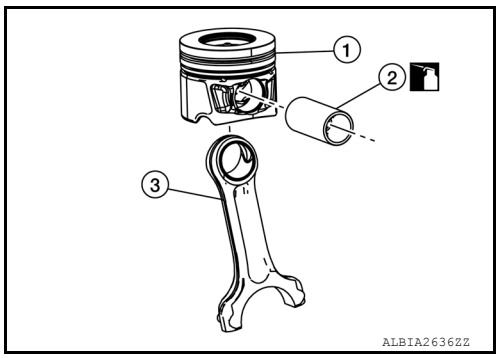
- The wide side of the connecting rods for cylinders 1, 3, 5, and 7 point toward the **front** of the engine.
- The wide side of the connecting rods for cylinders 2, 4, 6, and 8 point toward the **rear** of the engine.



e. Install the piston (1) onto the connecting rod (3) and insert the piston pin (2).

NOTE:

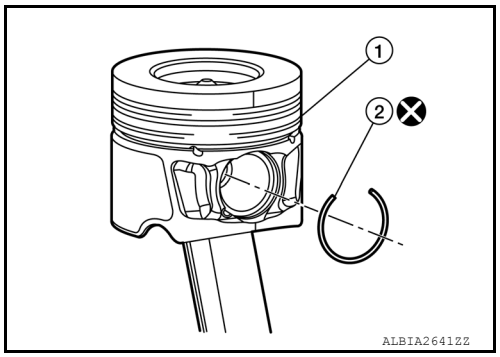
Pistons do **not** require heating to install the pin, however, the pistons do need to be at room temperature or above.



f. Install the second snap ring (2) into the piston (1).

CAUTION:

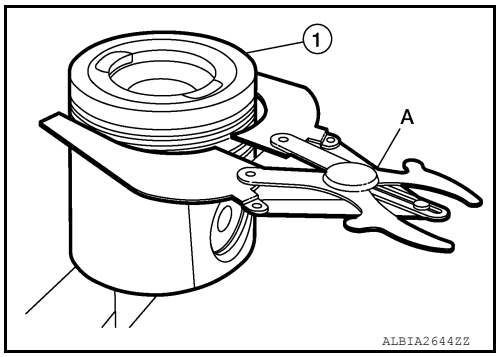
Do not reuse the snap ring.



g. Install the piston rings on the piston (1) using a suitable tool (A).

CAUTION:

Do not damage piston rings by expanding them excessively.



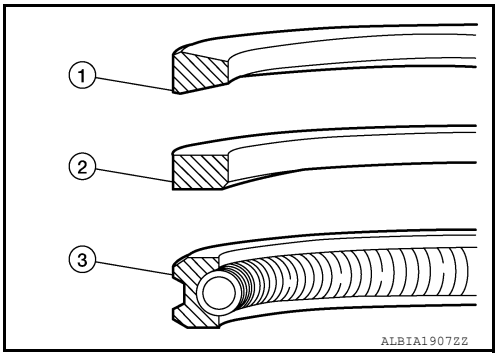
i. Make sure the piston rings are installed in the correct location.

CAUTION:

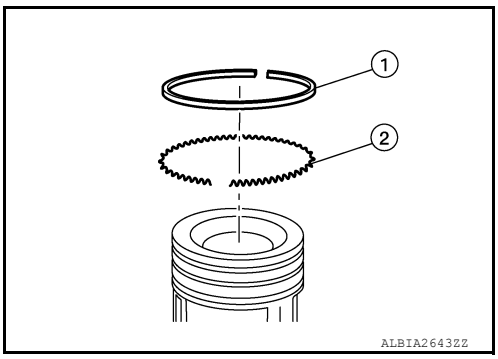
Most piston rings look similar but have significant differences. Make sure the correct part number is being used for the engine.

NOTE:

- The top surfaces of the top ring (1) and second ring (2) are identified either with the word TOP or a supplier identification mark, such as a stamped dot. Assemble with the word TOP or the supplier mark facing upward.
- The bottom, or oil ring (3), can be installed with either side facing upward.

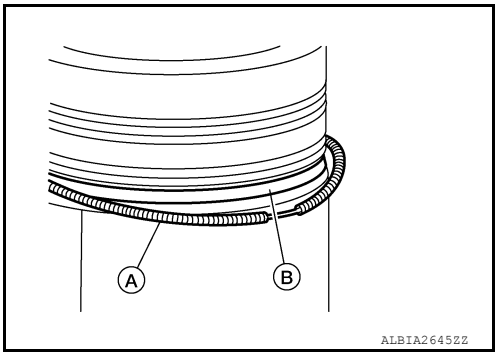


ii. The two-piece oil ring **must** be installed with the expander ring (2) gap 180-degrees from the gap of the oil ring (1).



iii. Position the oil ring expander (A) in the oil ring groove (B).

iv. Install the oil ring, then the second ring and then the top ring.



8. Install the piston and connecting rod assembly using the following procedure:

a. Make sure the connecting rod and connecting rod cap surfaces are clean and free of debris.

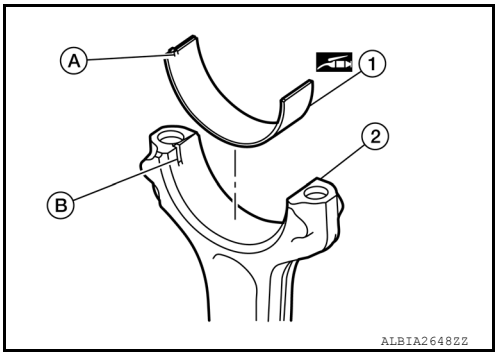
b. Install the connecting rod bearing [upper (1)] into the connecting rod (2).

CAUTION:

Do not lubricate the back side of the connecting rod bearings (upper) and connecting rod bearings (lower) that contacts the connecting rod cap.

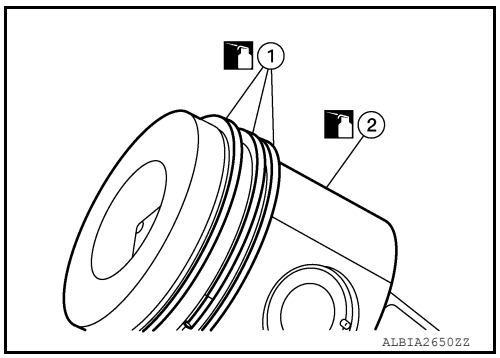
NOTE:

- The bearing stopper (A) **must** be in the notch (B) of the rod. The end of the connecting rod bearing **must** be even with the connecting rod cap mounting surface.
- The connecting rod bearings (upper) and connecting rod bearings (lower) are **not** interchangeable on fracture-split connecting rods.
- If new connecting rod bearings are **not** used, the used connecting rod bearings **must** be installed on the same connecting rod and location from where they were removed.

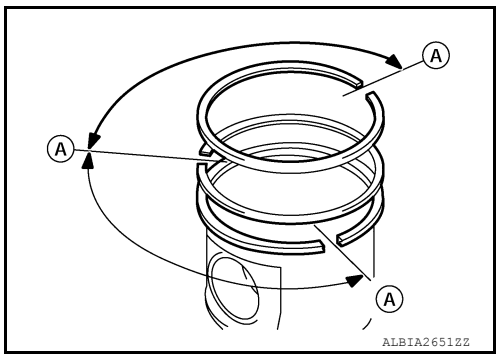


c. Lubricate the connecting rod bearing (upper) and connecting rod bearings (lower) inside surface with a suitable assembly lubricant.

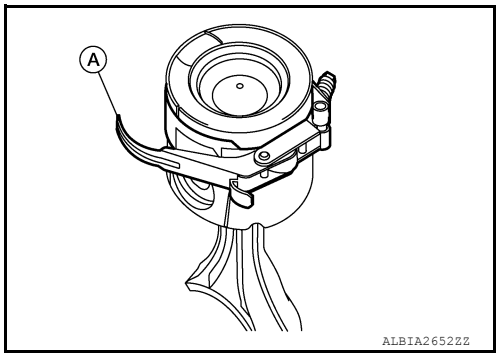
d. Lubricate the piston skirt (A), piston rings (1) and the cylinder block walls of the piston and connecting rod assembly being installed with clean engine oil.



e. Position the ring gaps (A) equally around the piston circumference as shown.
NOTE:
The ring gap of each piston ring **must not** be aligned with the piston pin or with any other ring. If the ring gaps are **not** aligned correctly, the rings will **not** seal properly.

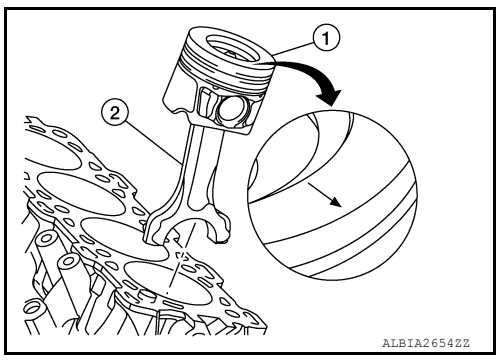


f. Compress the piston rings using a suitable tool (A).



g. Rotate the crankshaft so the connecting rod journal for the piston and connecting rod assembly being installed is at bottom dead center.

h. The orientation of the connecting rod (2) relative to the piston (1) is critical (shown in the illustration). Connecting rod (crank end) is wider on one side, the four right bank connecting rods will have the wider side facing the front face of block. The left bank connecting rods will have the wider sides facing the rear face of block.
CAUTION:
Failure to follow this step will result in extensive engine damage.
NOTE:
The piston and connecting rod assembly **must** be installed with the correct orientation.

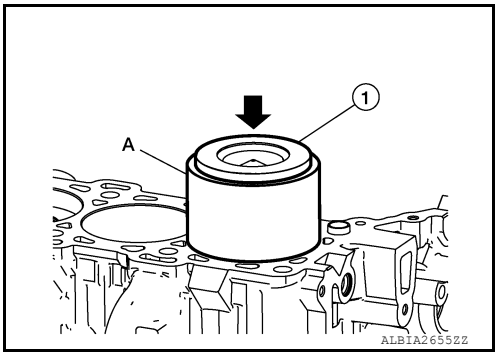


i. To reduce the possibility of engine damage, the piston and connecting rod **must** be assembled with the proper orientation.
- The piston has an arrow pointing toward the front of the engine.
- The large end of the connecting rod has one side that is wider than the other.
- The wide side of the connecting rods for cylinders 1, 3, 5, and 7 point toward the front of the engine.
- The wide side of the connecting rods for cylinders 2, 4, 6, and 8 point toward the rear of the engine.
- Align the front marking and/or arrow on the top of the piston so that it points towards the front of the engine. Insert the connecting rod through the cylinder bore until the ring compressor contacts the top of the cylinder block.

i. Hold the suitable tool (A) against the cylinder block and push the piston (1) through the suitable tool and into the cylinder block bore.

NOTE:

- Push the piston until the top ring is completely in the cylinder block bore.
- If the piston does **not** move freely, remove the piston and inspect for broken or damaged rings.



j. Carefully push the piston into the cylinder block bore while guiding the connecting rod to the crankshaft journal.

CAUTION:

Do not damage the oil jets when installing piston and connecting rod assembly. Misalignment of the oil stream can cause severe engine damage.

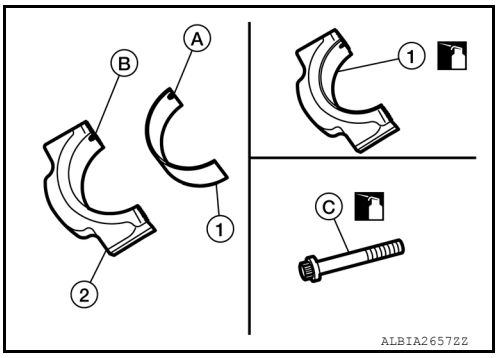
k. Install the connecting rod bearing [lower (1)] in the connecting rod cap (2).

CAUTION:

Do not lubricate the back side of the connecting rod bearings (upper) and connecting rod bearings (lower) that contacts the connecting rod cap.

NOTE:

- The bearing stopper (A) **must** be in the notch (B) of the connecting rod cap.
- If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod cap from which they were removed.



- Apply a coat of suitable assembly lube to the crankshaft-side of the connecting rod bearings (upper) and connecting rod bearings (lower).
- Use clean engine oil to lubricate the connecting rod bolt threads and the underside of the connecting rod bolt head.

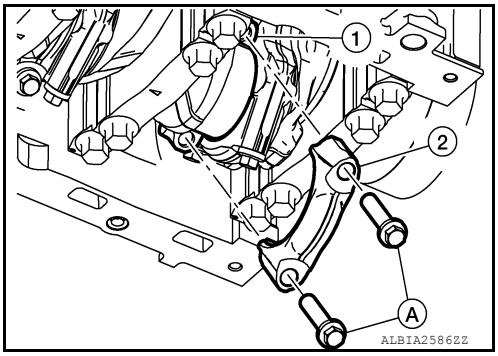
l. Install the connecting rod cap (2) and hand-tighten the bolts (A).

CAUTION:

Do not damage the fracture-split surface on the connecting rod or connecting rod cap while the connecting rod cap is removed. If the fracture-split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage.

NOTE:

- The connecting rod (1) and connecting rod cap (2) **must** have the same number and **must** be installed in the proper cylinder.
- The connecting rod cap number and rod number **must** be on the same side of the connecting rod to prevent engine damage during engine operation.



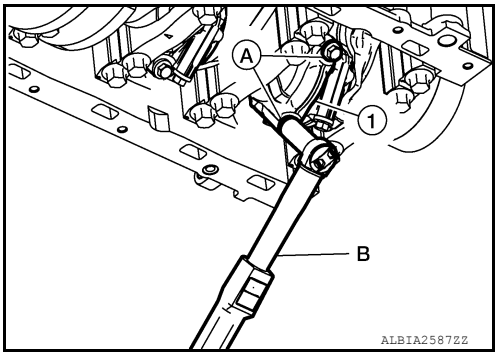
m. Tighten the bolts (A) to the specified torque in the order shown using suitable tool (B).

NOTE:

If new bolts are used, the bolt threads should be burnished. To burnish the bolts, follow the torque sequence below, then loosen the bolts completely.

Step 1 : 40 N·m (4.1 kg-m, 30 ft-lb)

Step 2 : 40 N·m (4.1 kg-m, 30 ft-lb)
+ Tighten 60 Degrees



(1) : Connecting rod cap

n. After tightening connecting rod bolts, check that crankshaft rotates smoothly.

o. Check the connecting rod side clearance and piston protrusion. Refer to EM-515, "Inspection After Disassembly".

9. Installation of the remaining components is in the reverse order of removal.
   - If the crankshaft was removed and reinstalled, in CONSULT click the timing button in the Fuel or Timing System Table Reset in Work Support. Refer to EC-806, "CONSULT Function".
   - If the crankshaft was replaced, in CONSULT click the crank and timing button in the Fuel or Timing System Table Reset in Work Support. Refer to EC-806, "CONSULT Function".

Inspection After Disassembly

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INSPECTION AFTER DISASSEMBLY

Connecting Rod Bearings

WARNING:

- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
- **Wear appropriate eye protection and protective clothing including gloves and a face shield.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- Wash the bearing and connecting rod caps.
- Dry with compressed air.
- Inspect the connecting rod caps, connecting rod bearing saddles and bolts for nicks, cracks, burrs, scratches, or fretting.
- Inspect the connecting rod bearings for damage.
- Replace any connecting rod bearings with the following damage:
- Pitting
- Flaking
- Corrosion
- Bearing stopper damage
- Scratches.
- Inspect the connecting rod bearing shell seating surface for nicks or burrs.

  NOTE:
  - If nicks or burrs can **not** be removed with a suitable abrasive pad the bearings **must** be replaced.
  - If bearings are damaged they **must** be replaced as a set.
- Check the rod bearing journals for damage or excessive wear. Minor scratches are acceptable.

Main Bearings

WARNING:

- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
- **Wear appropriate eye protection and protective clothing including gloves and a face shield.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- Steam clean or use hot, soapy water to clean the main bearing caps.
- Dry with compressed air.
- Inspect all main bearing caps, bolts and thrust bearings for deep scoring, overheating, etc.
- Replace any damaged components. If the main bearing cap is damaged, the block **must** be replaced.
- Check the crankshaft main bearing journals for damage or excessive wear. Minor scratches are acceptable.
- If the crankshaft end clearance measured during the initial check was found to be out of specification, make sure to check the crankshaft thrust surface at the number 3 main cap for excessive wear or damage. Minor scratches are acceptable.
- If damage is found, the crankshaft will need to be removed.
- Also check the thrust bearing surfaces for excessive wear. Replace the thrust bearing(s), if excessive wear is found.
- Inspect the bearings for damage.
- Replace any bearings with the following damage:
- Pitting
- Flaking
- Corrosion

- Bearing stopper damage
- Scratches.

• Inspect the main bearing shell seating surfaces for debris, nicks, or burrs. If debris, nicks, or burrs can **not** be removed with isopropyl alcohol and a lint-free cloth, the main bearings **must** be replaced.

NOTE:
If bearings are damaged, they **must** be replaced as a set.

Connecting Rod

• This engine uses fracture-split connecting rods. The contact surface between the connecting rod and connecting rod cap is **not** a machined surface. These surfaces can **not** be re-machined or resized. Extreme care **must** be given to **not** damage the rod cap/rod mating surfaces. Care **must** be exercised so these parts are **not** damaged during handling. Surfaces **must** be very clean and free of any debris when being assembled. Failure to do so will result in engine damage.

WARNING:
• When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:
- Wear appropriate eye protection and protective clothing including gloves and a face shield.
• When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:
- Do not exceed 30 psi (207 kPa).
- Wear appropriate eye protection and protective clothing including gloves.
CAUTION:
The contact surface between the connecting rod and connecting rod cap is not a machined surface. Care must be exercised so these parts are not damaged during handling.

• Use solvent to clean the connecting rods.

NOTE:
Unless cleaning the contact surface between the connecting rod and connecting rod cap, the rod and cap **must** be assembled together with the bolts tightened hand-tight to prevent damage to the mating surfaces.

• Use solvent and a suitable tool to clean the contact surface between the connecting rod and connecting rod cap. Dry the contact surface with compressed air.
• Dry the connecting rods with compressed air.
• Inspect the connecting rod caps, connecting rod bearing saddles and bolts for nicks, cracks, burrs, scratches, and fretting.

CAUTION:
The connecting rod and rod cap must be replaced as an assembly if any fretting damage is visible on either piece.

• Inspect the contact surface between the connecting rod and the connecting rod cap.

NOTE:
The contact surface between the connecting rod and the connecting rod cap is **not** a machined surface. This surface **must not** be considered damaged unless there are deep nicks or cracks across the surface.

• Inspect the connecting rod piston pin bore for damage.
• The connecting rod bushing is not serviceable. If the bushing is damaged, the connecting rod must be replaced.

Crankshaft

• Check the threads at both ends of the crankshaft for damage.

CAUTION:
Do not chase threads on the crankshaft. Sever engine damage can occur.

• If damage is found, replace the crankshaft.
• Use fine crocus cloth to polish the machined surfaces.
• Use a suitable tool to clean the oil passages.

WARNING:
• When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:
- Wear appropriate eye protection and protective clothing including gloves and a face shield.
• When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:
- Do not exceed 30 psi (207 kPa).
- Wear appropriate eye protection and protective clothing including gloves.

• Steam clean the crankshaft and dry with compressed air.
• Make sure to blow out the threaded holes on each end of the crankshaft and the oil passages.
• Inspect the sprocket dowel pin and timing pin hole for damage. If either is damaged, replace the crankshaft.

- Inspect the threaded bolt holes for damage. If there are any threaded holes which have damaged threads, the crankshaft **must** be replaced.
- Inspect the connecting rod.
- Inspect the cylinder block and main bearings.
- Inspect the main bearing journals for damage or excessive wear. Minor scratches are acceptable.
- Inspect the connecting rod bearing journals for damage, deep scoring, overheating, etc. Minor scratches are acceptable.
- **NOTE:**
  If the crankshaft is not going to be used immediately use a suitable preservative oil to lubricate the crankshaft to prevent rust. Protect the part with a plastic cover to prevent dirt from sticking to the oil.

Cylinder Block

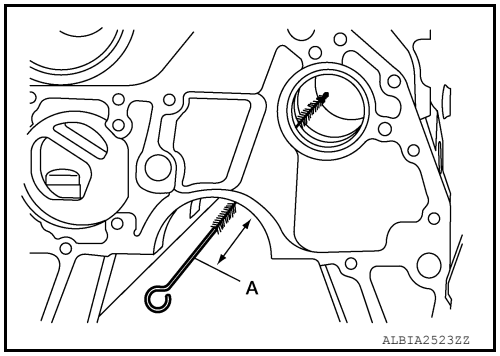
WARNING:

To avoid the risk of injury to eyes and skin, when using caustic solutions, solvents, acids, or alkaline materials follow the manufactures recommendations for use and wear appropriate eye protection and protective clothing. Some of these materials are also flammable. To avoid risk of fire or burns, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area. Avoid spilling onto a hot exhaust manifold which can cause a fire.

CAUTION:

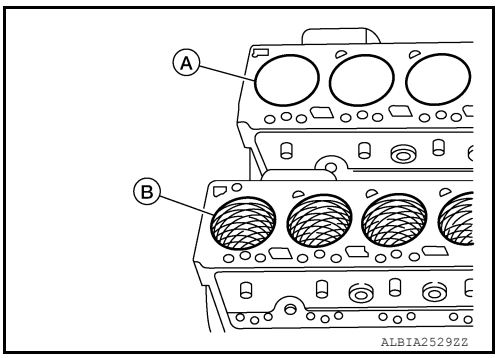
Do not use abrasive pads to clean the block. Only use pads that do not contain abrasive materials. Thoroughly remove all debris afterward.

- The block uses bored cylinders as opposed to liners. If the cylinder bores are damaged or worn beyond specification, the block **must** be replaced.
- Inspect the block for cracks, fretting, scratches, and other damage.
- Thoroughly clean all gasket sealing surfaces of any remaining gasket residue with isopropyl alcohol and a lint-free cloth.
- Makes sure all oil and coolant passages are cleaned out. Use a suitable solvent and a suitable tool (A) to clean the oil passages as shown.



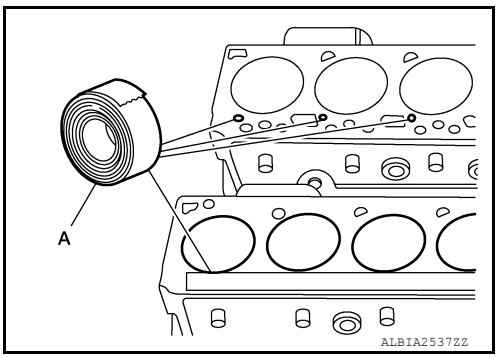
- Inspect all welch plugs and drain plugs for signs of damage or leaks. Replace damaged plugs if necessary.
- Use isopropyl alcohol and a lint-free cloth to clean the cylinder block.
  NOTE:
  If the cylinder block is not going to be used immediately, apply a coating of a suitable preservative oil to prevent rust. Cover the cylinder block to prevent dirt from sticking to the oil.
- Inspect the main bearing caps and main bearing saddle areas for cracks, fretting, and signs of discoloration.
  NOTE:
  If any cracks are found, the cylinder block and main bearing caps **must** be replaced.
- Inspect all threaded bolt holes for damaged threads. If thread damage is found, repair threads or replace component as required.
  NOTE:
  Coiled thread inserts **must not** be used to repair main bearing saddle bolt holes or cylinder head bolt holes. If these holes are damaged, the cylinder block **must** be replaced.

- Inspect the cylinder bores for glazing (A).
- A surface without glaze (B) will have a crosshatched appearance with the lines at 20 to 25 degree angles with top of the cylinder bore.

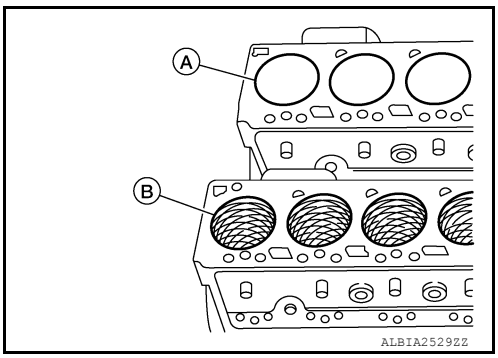


Deglazing Cylinder Block

1. Prior to any reconditioning of the cylinder bores, make sure to cover the lubricating oil holes and coolant holes in the top of the cylinder block with suitable tool (A).



2. A deglazed cylinder bore (B) gives the correct surface finish required to seat the piston rings. Honing **must only** be performed if the cylinder bores are still within specification. Refer to EM-531, "CYLINDER BLOCK".
   NOTE:
   New piston rings will **not** seat in glazed (A) cylinder bores.



3. Use a ball-type hone sized appropriately for a 94 mm bore and a rotational speed of 300 to 400 rpm with a stroke frequency of one stroke up and down per second. Make sure to use a good grade of honing oil or a mixture of equal parts 30W engine oil and diesel fuel for a honing lubricant.
   NOTE:
   - Vertical strokes **must** be smooth, continuous passes along the full length of the cylinder bore.
   - The crosshatch angle is a function of drill speed and how fast the hone is moved vertically. Moving too fast or too slow will give an incorrect crosshatch angle.

a. Inspect the cylinder bore after 10 strokes.

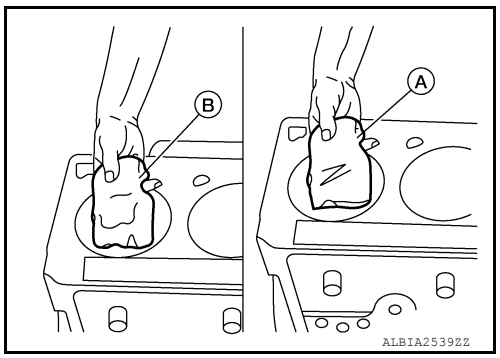
b. A correctly deglazed surface will have a crosshatched appearance with the lines at 20 to 25 degree angles with the top of the cylinder block.

4. After honing, use a strong solution of hot water and a suitable detergent to clean the cylinder bores.

5. Rinse the cylinder bores until the detergent is removed.
   WARNING:
   When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:
   - **Do not exceed 30 psi (207 kPa).**
   - **Wear appropriate eye protection and protective clothing including gloves.**

   NOTE:
   Dry the cylinder block with compressed air.

6. Check the cylinder bore cleanliness by wiping with a white, lint-free, lightly oiled cloth. If gritty residue is still present (A), repeat the cleaning process until all residue is removed (B).
Clean the cylinder bores with solvent. Dry the cylinder block with compressed air.



7. If the cylinder block is not going to be used immediately, coat all machined surfaces with a suitable rust preventative solvent.
NOTE:
Make sure to cover the cylinder block to prevent dust and debris from collecting on and in the cylinder block.

Piston

WARNING:
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
- **Wear appropriate eye protection and protective clothing including gloves and a face shield.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**

CAUTION:
- **Do not use the bead-blast method to clean the pistons. The pistons will be damaged by blast material embedded in the aluminum.**
- **Do not clean the pistons in an acid tank. Damage to the piston can occur.**
- **Do not use a metal brush. A metal brush will damage the piston ring grooves.**
- Soak the pistons in cold parts cleaner. Soaking the pistons overnight will usually loosen the carbon deposits.
- After soaking, wash the pistons in a strong solution of a suitable detergent and hot water.
- Clean the remaining deposits from the ring grooves with the square end of a broken ring.

CAUTION:
Do not use a ring groove cleaner and make sure not to scratch the ring sealing surface in the piston groove.
- Wash the pistons again in a suitable detergent solution or solvent.

CAUTION:
Do not clean the pistons and connecting rods in an acid tank. Damage to the pistons and connecting rods can occur.
- Rinse the pistons in clean, hot water.
- Dry the pistons with compressed air.
- Inspect the piston for damage and wear to the skirt, pin bore, top, and ring lands.
- Inspect the piston pin for damage and wear.

NOTE:
It is important to note that the illustrations relate to early detection of a piston malfunction. Progressive damage will make it difficult to categorize the root cause of the malfunction. The degree of progressive damage can make a difference as to the extent of the damage, and therefore, the illustrations **only** provide a guideline for identification.

- Abrasive and/or Debris Wear
Scratching on the piston skirt with material embedded into the piston can be caused by:
- Ingested abrasive material.
- Inadequate cleaning during a previous repair.
- Particles embedded in the cylinder bore.
- Improper maintenance of the lubrication system.
- Debris in the lubrication oil system from another malfunction.
- Scuffing and scoring.

• Scuffing and scoring can be caused by:
- Engine overheating.
- Oil dilution.
- Improper maintenance of the lubrication system.
- Piston cooling nozzle malfunction.
- Injector overfueling/engine running on an alternative fuel source, for example, oil in the intake air system.

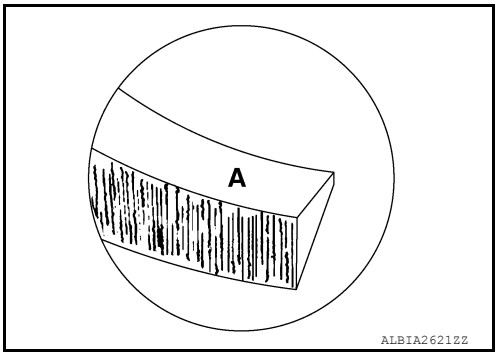
• **NOTE:**
Scuffing and scoring on the piston rings indicates a breakdown of the oil film on the cylinder bore wall, causing transfer of material from the piston ring face to the cylinder bore wall.

• Other Types of Piston Damage:
- Hydraulic Lock - Hydraulic locks (oil, fuel, or water) can cause the piston to split in half, or the lands can break and the connecting rods can be bent.
- Dustouts - Particular attention to the wear pattern of the intermediate (second) ring is required for diagnosis of a dustout piston scuff. The ring will have a polished appearance on the full-face ear of the intermediate ring. The polished area starts at the bottom of the ring and continues upward on the tapered ring. Occasionally, the edges of the rings are razor-sharp, and the block cylinder bore has indications of ridges approximately 38.1 mm (1.50 in) below the top deck.
- Top of Piston Meltdown - The top of the piston appears to be melted down and the malfunction resembles an overfueling situation, such as a stuck injector. A plugged oil jet can also resemble this malfunction.

Piston Ring

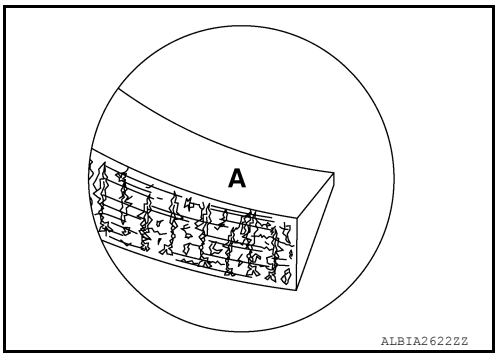
• Inspect the piston rings for the following:
- Abrasive wear.

NOTE:
Abrasive wear of the second ring can be indicated by a rapid reduction of the finish coating on the front face of the piston ring (A). This is commonly referred to as full face ring wear. This rapid reduction will typically leave a sharp edge on the bottom of the second ring. Abrasive wear can also be indicated by concentrated vertical scratches on the top ring.



- Abrasive wear can be caused by:
• Ingested abrasive material.
• Inadequate cleaning during a previous repair.
• Particles embedded in the bore.
• High soot content in the lubricating oil from extended oil drain intervals.
• Scuffing and scoring.

• Scuffing and scoring can be caused by:
- Engine overheating.
- Oil dilution (coolant or fuel in the oil).
- Improper maintenance of the lubrication system.
- Piston cooling nozzle malfunction.
- Oil ring plugged by deposits.
- **NOTE:**
  • Scuffing and scoring is indicated by heavy scratches, metal discoloration, and voids.
  • Scuffing and scoring on the piston rings (A) indicates a breakdown of the oil film on the cylinder bore wall, causing transfer of material from the piston ring face to the cylinder bore.



• Oil ring plugging can be caused by:
- Low engine operating temperatures - long periods of idling or a cooling system malfunction.
- Extended oil change intervals.

- Use of wrong grade of engine oil.
- Use of a poor quality engine oil.
- **NOTE:**
  - Oil ring plugging is indicated by deposits in the oil ring grooves.
  - Plugging of the oil ring groove drains restricts oil drainback, which floods the piston ring belt area, resulting in a loss of oil control.

Oil Jets

WARNING:

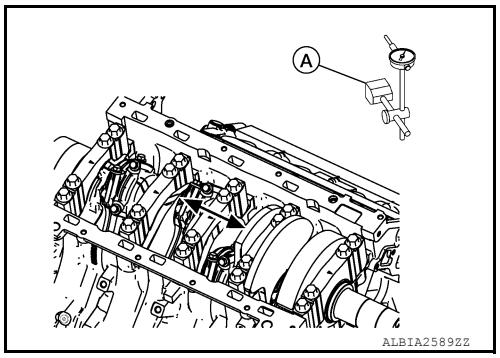
- **When using high-pressure water or steam cleaning equipment, to avoid the risk of personal injury from flying debris and hot steam:**
- **Wear appropriate eye protection and protective clothing including gloves and a face shield.**
- **When using compressed air for cleaning, to avoid the risk of personal injury from flying debris and dirt:**
- **Do not exceed 30 psi (207 kPa).**
- **Wear appropriate eye protection and protective clothing including gloves.**
- Clean the oil jets and oil passages using a suitable solvent.
- Dry oil jets with compressed air.
- Inspect the oil jets and bolts for damage. Replace components as necessary.

CRANKSHAFT END PLAY

- Measure the crankshaft end clearance using suitable tool (A).

NOTE:

- Measurements can be taken from either the front or rear face of the crankshaft.
- The dimensions of the thrust bearing and crankshaft journal determine end clearance.
- If the crankshaft end clearance is **not** within specification, make sure to inspect the crankshaft and thrust bearing surfaces for damage.
- If measured value exceeds the specification, replace the thrust bearings and measure again. If it still exceeds the specification, replace crankshaft also.

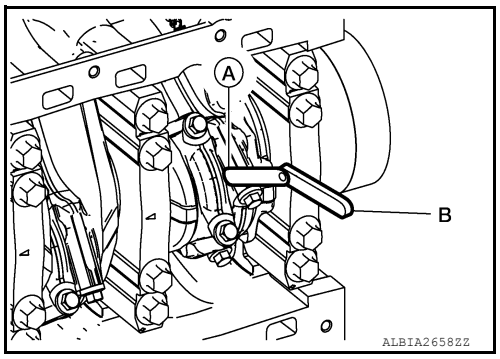


Standard : Refer to EM-533, "CRANKSHAFT".

CONNECTING ROD SIDE CLEARANCE

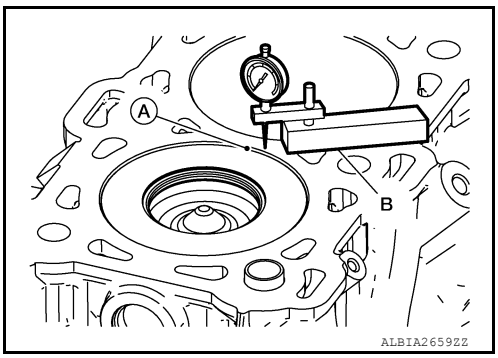
- Measure the side clearance (A) between the connecting rods with a suitable tool (B).

Standard : Refer to EM-532, "CONNECTING ROD".



PISTON PROTRUSION

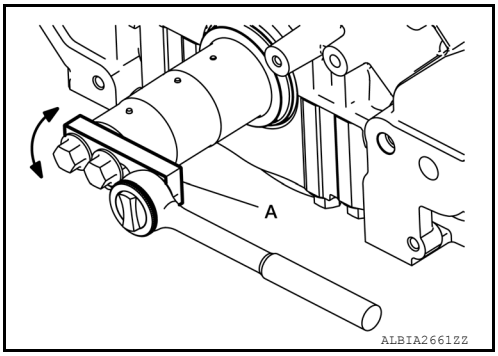
- Install suitable tool (B) on the cylinder block surface to measure the piston protrusion (A).



- Install Tool (A) on the front nose of the crankshaft and rotate the crankshaft clockwise and counterclockwise to find the highest measurement.

Standard : Refer to EM-532, "PISTON, PISTON RING AND PISTON PIN".

Tool : — (J-54401)



NOTE:
- Piston protrusion can be a positive or negative value.
- If the piston protrusion is **not** within specification, verify the correct parts are installed and the cylinder block combustion deck has been machined properly.

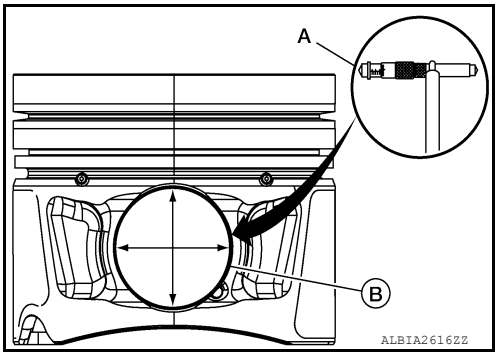
PISTON AND PISTON PIN CLEARANCE

Piston Pin Hole Diameter

- Measure the inner diameter of the piston pin hole (B) using suitable tool (A).

NOTE:
The piston pin hole **must** be measured within the first 5.0 mm (0.197 in) from the snap ring/piston pin keeper groove. This is due to the piston pin profile.

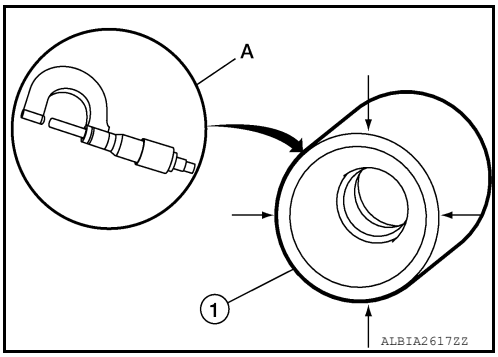
Standard : Refer to EM-532, "PISTON, PISTON RING AND PISTON PIN".



Piston Pin Outer Diameter

- Measure the piston pin diameter as shown in the illustration in three equally-spaced locations along the piston pin (1) axis, using a suitable tool (A)

Standard : Refer to EM-532, "PISTON, PISTON RING AND PISTON PIN".



Piston and Piston Pin Clearance

(Piston pin clearance) = (Piston pin hole diameter) – (Piston pin diameter)

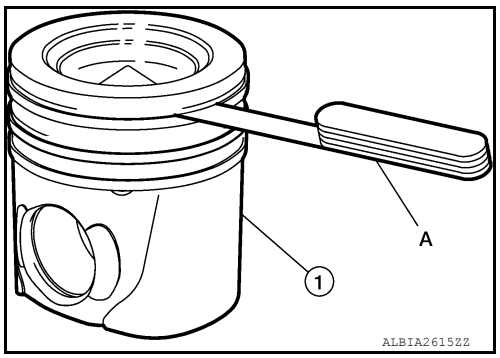
Standard : Refer to EM-532, "PISTON, PISTON RING AND PISTON PIN".

PISTON RING SIDE CLEARANCE

- Measure the piston ring clearance. Use a new piston ring to measure the clearance in the ring groove.
  NOTE:
  The top piston ring clearance is **not** measured due to the type of piston ring used. The clearance can **not** be measured accurately with a suitable tool (A).

Standard : Refer to EM-532, "PISTON, PISTON RING AND PISTON PIN".

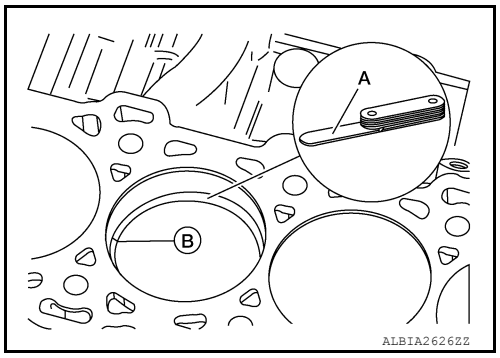
(1) : Piston



PISTON RING END GAP

- Use suitable tool (A) to measure the gap (B).
  NOTE:
  The piston ring gap must be measured 30 mm (1.181 in) from the cylinder block surface.

Standard : Refer to EM-532, "PISTON, PISTON RING AND PISTON PIN".



If the piston ring gap is not within specification:
- Verify the correct type and part number piston ring is being used
- Verify the cylinder bore is within specification. Refer to EM-531, "CYLINDER BLOCK".
- Verify the piston ring gap measurement is being taken 30 mm (1.181 in) below the cylinder block deck
- Try another set of piston rings.

- After each ring gap is checked and verified, identify the ring sets for installation in the cylinder bore where the end gap was measured.

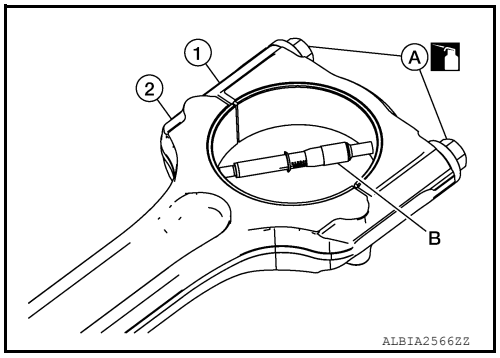
CONNECTING ROD BEARING (BIG END)

Connecting Rod Big End Diameter (Bearing Installed)

- Assemble the connecting rod (2), rod cap (1) and bolts (A) and tighten bolts to the specified torque. (Make sure the bearings are clean and **no** lubrication is applied.)
- Lubricate the bolts (A) with clean engine oil.
- Use a suitable tool (B) to measure the inside diameter within a 20-degree arc from each side of the parting line.
- Measure the inside diameter at 90 degrees from the parting line.

Standard : Refer to EM-532, "CONNECTING ROD".

Step 1 : 40 N·m (4.1 kg-m, 30 ft-lb)
Step 2 : 40 N·m (4.1 kg-m, 30 ft-lb)
Step 3 : Tighten 60°



CAUTION:
- **Use a vise with brass jaws to hold the connecting rod. Notches, scratches, or dents in the I-beam area can cause engine damage.**
- **The number on the connecting rod must be the same as the number on the rod cap. Connecting rods and caps are manufactured as an assembly and cannot be interchanged. Engine damage can result.**

NOTE:
If the measurements are out of specification, try a new set of connecting rod bearings and measure again.

Connecting Rod Big End Diameter (Bearing Removed)

- Repeat the above inspection with the connecting rod bearings removed.

Standard : Refer to EM-532, "CONNECTING ROD".

NOTE:
If the connecting rod crankshaft bore measurements are **not** within specifications, the connecting rod **must** be replaced.

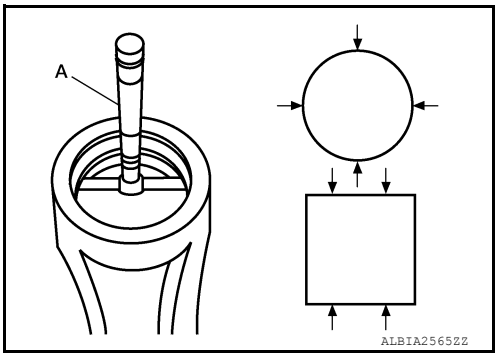
CONNECTING ROD BUSHING OIL CLEARANCE (SMALL END)

Connecting Rod Bushing Inner Diameter (Bushing Installed)

- Measure the connecting rod piston pin bushing inside diameter using suitable tool (A).

Standard : Refer to EM-532, "CONNECTING ROD".

NOTE:
If the bushing is found to be damaged or out of specification, replace the connecting rod assembly.



Connecting Rod Bushing Oil Clearance (Small End)
(Connecting rod small end oil clearance) = (Inside diameter of connecting rod small end) – (Piston pin diameter)

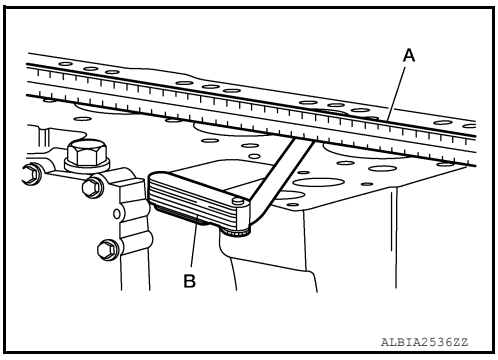
Standard : Refer to EM-532, "CONNECTING ROD".

CYLINDER BLOCK DISTORTION

- Remove any oil, scale, gasket, sealant and carbon deposits from the cylinder block surface.
  CAUTION:
  Do not allow any debris to enter the oil or coolant passages.
- Use suitable tools (A) and (B) to inspect the block head decks for flatness.

Limit : Refer to EM-531, "CYLINDER BLOCK".

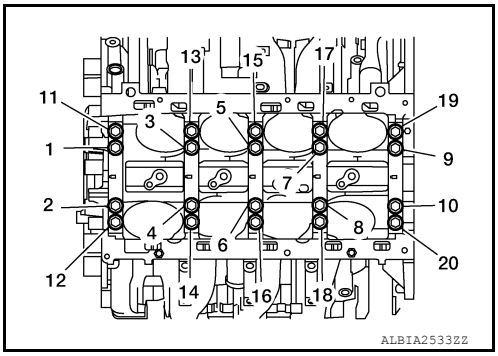
- If flatness is out of specification, the block **must** be replaced.



MAIN BEARING HOUSING INSIDE DIAMETER

- Install the main bearings into the cylinder block and main bearing caps.
- Lubricate the main bearing bolt threads and the underside of the bolt head with clean engine oil.
- Gently tap the main bearing cap into position with suitable tool. When the cap is seated, install the main bearing bolts and tighten to the specified torque in the sequence shown.
- When using existing main bearing cap inner bolts:

Step 1 : Tighten inner bolts to 50 N·m (5.1 kg-m, 37 ft-lb)
Step 2 : Loosen inner bolts 90°
Step 3 : Tighten inner bolts to 95 N·m (9.7 kg-m, 70 ft-lb)
Step 4 : Tighten inner bolts 120°



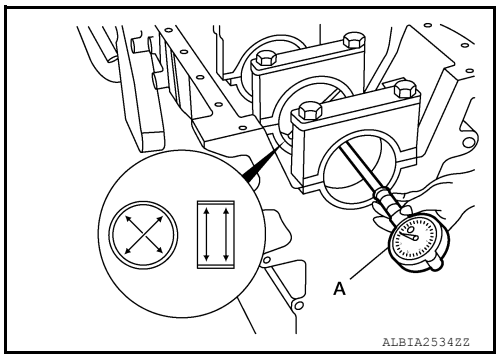
Step 5 : Tighten outer bolts to 85 N·m (8.7 kg-m, 63 ft-lb)
Step 6 : Tighten outer bolts 90°

- When using new main bearing cap inner bolts:

Step 1 : Tighten inner bolts to 50 N·5.1 kg-m, 37 ft-lb)
Step 2 : Loosen inner bolts 90°
Step 3 : Tighten inner bolts to 50 N·m (5.1 kg-m, 37 ft-lb)
Step 4 : Tighten outer bolts to 95 N·m (9.7 kg-m, 70 ft-lb)
Step 5 : Tighten inner bolts 120°
Step 6 : Tighten outer bolts to 85 N·
Step 7 : Tighten outer bolts 90°

- Measure the main bearing bore using suitable tool (A) with the bearings removed. Measure the bore in four locations, 90 degrees apart, at the front and back of the bore.
NOTE:
If the main bearing bore diameters are out of specification, the cylinder block **must** be replaced. Oversize bearings are **not** available.

Standard : Refer to EM-534, "MAIN BEARING".



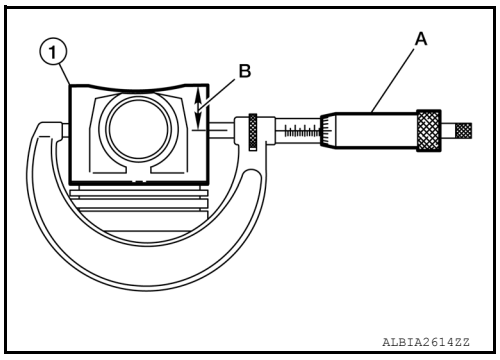
PISTON TO CYLINDER BORE CLEARANCE

Piston Skirt Diameter

- Measure the piston skirt diameter.
NOTE:
To be sure of accuracy, the following measurements **must** be completed with the components at room temperature [20°C (68°F)].

Standard : Refer to EM-531, "CYLINDER BLOCK".

(1) : Piston
(A) : Suitable tool
(B) : 16 mm (0.630 in)

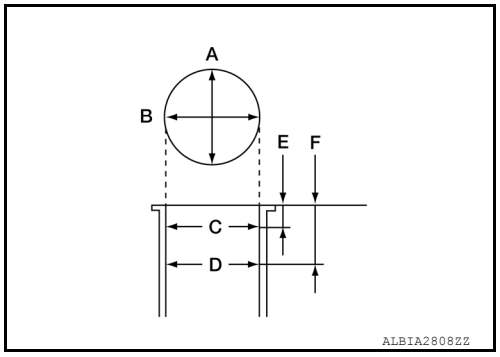


Cylinder Bore Diameter

- Use a suitable tool to measure the cylinder bore for wear, out-of-round and taper at six different points on each cylinder. [(A) and (B) directions at (C) and (D)] [(A) is in longitudinal direction of engine]
CAUTION:
If the cylinder bores are out of specification, the cylinder block must be replaced.

Standard and Limit : Refer to EM-531, "CYLINDER BLOCK".

(E) : Piston TDC
(F) : Piston BDC



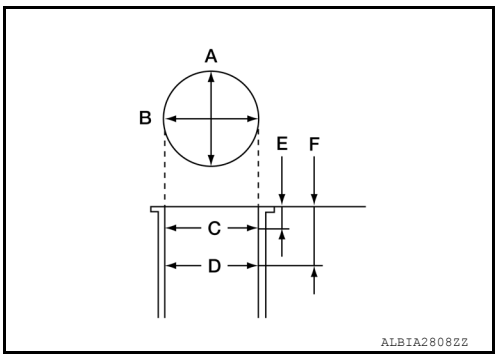
- Inspect the cylinder bores for damage or excessive wear, such as scuffing.

Piston to Cylinder Bore Clearance

- Calculate by using diameter of the piston skirt and the cylinder bore diameter (direction B, position D).
  (Clearance) = (Cylinder bore diameter) – (piston skirt diameter)

Standard : Refer to EM-531, "CYLINDER BLOCK".

(A) : Bore dimension (longitudinal direction if engine)
(C) : Bore dimension
(E) :Piston TDC
(F) : Piston BDC

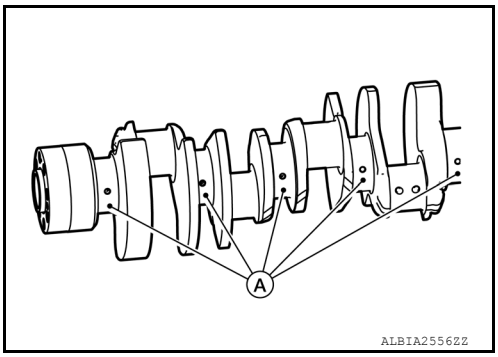


CRANKSHAFT JOURNAL DIAMETER

- Measure diameter of crankshaft journals (A).

Standard : Refer to EM-533, "CRANKSHAFT".

- If measurement is out of standard, measure the main bearing oil clearance. Then use the undersize bearing.



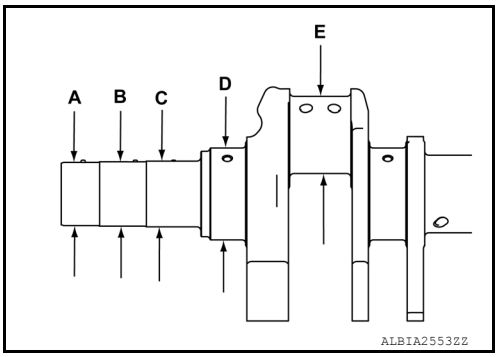
- Use a suitable tool to measure all crankshaft journals.

Standard : Refer to EM-533, "CRANKSHAFT".

NOTE:
If the crankshaft connecting rod journals are **not** within the given specifications, the crankshaft **must** be replaced. Oversize connecting rod or main bearings are **not** available.

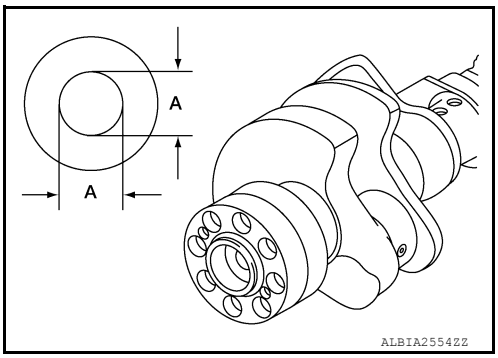
- Check the bearing clearance of the connecting rod to the crankshaft.

(A) : Crankshaft vibration damper journal
(B) : Crankshaft sprocket (oil/fuel pump) journal
(C) : Crankshaft sprocket (camshaft) journal
(D) : Main bearing journal
(E) : Connecting rod journal



- Measure the rear oil seal flange outside diameter (A).
  NOTE:
  If the rear seal flange area is **not** within specifications, replace the crankshaft.

Standard : Refer to EM-533, "CRANKSHAFT".

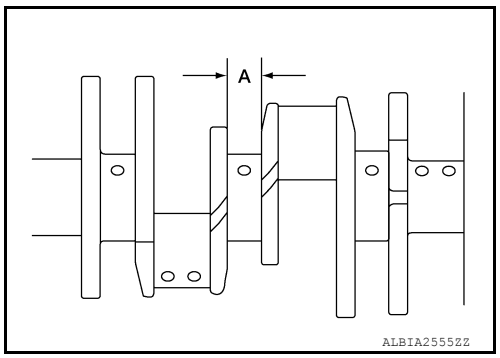


THRUST DISTANCE

- Measure the thrust distance.

NOTE:
- If the thrust distance (A) is **not** within specifications, the crankshaft **must** be replaced.
- Oversize thrust bearings are **not** available. If the thrust distance is **not** within specifications, replace the crankshaft.
- The thrust bearing surfaces are located at the number 3 crankshaft main bearing journal.

Standard : Refer to EM-533, "CRANKSHAFT".



CONNECTING ROD BEARING OIL CLEARANCE

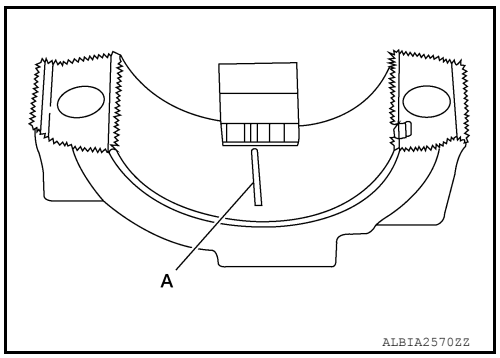
Method of Measurement
- Install connecting rod bearings to the connecting rod and cap. Tighten connecting rod bolts to the specified torque. Refer to EM-503, "Disassembly and Assembly".
- (Oil clearance) = (Inside diameter of connecting rod bearing) – (Crankshaft pin diameter)

Standard : Refer to EM-534, "MAIN BEARING".

Method of Using Plastigage
- Remove oil and dust on the crankshaft pin and surfaces of each bearing completely.
- Cut a plastigage (A) slightly shorter than the bearing width, and place it in the crankshaft axial direction, avoiding oil holes.
- Lubricate the connecting rod bolts with clean engine oil.
- Install the connecting rod bearings to the connecting rod and connecting rod bearing cap, and tighten the connecting rod bolts to the specified torque.

CAUTION:
Do not rotate crankshaft with plastigage installed.

Step 1 : 40 N·m (4.1 kg-m, 30 ft-lb)
Step 2 : 40 N·m (4.1 kg-m, 30 ft-lb) + Tighten 60°



- Remove the connecting rod bearing cap and bearings. Measure the plastigage width using the scale on the plastigage bag.

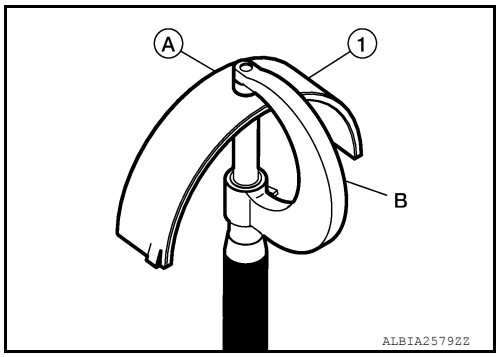
NOTE:
- The procedure when the measured value exceeds the repair limit is the same as that described in “Method of Measurement”.
- If the clearance is found to be out of specification, try another set of connecting rod bearings.

MAIN BEARING

- Measure the main bearing thickness with a suitable tool (B) that has a ball tip. Main bearing (1) thickness is to be measured in the center (A) and halfway between the bearing ends.

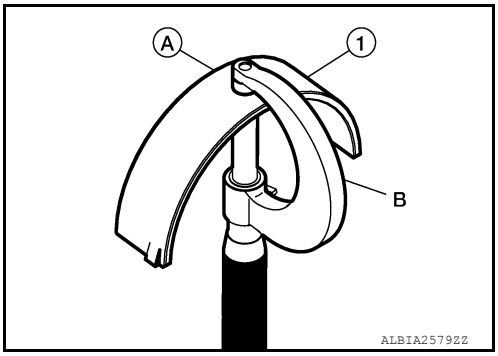
Standard : Refer to EM-534, "MAIN BEARING".

- Do not reuse a main bearing if its thickness is below the minimum specifications.



CONNECTING ROD BEARINGS

- Measure the connecting rod bearing (1) thickness in the center (A) and halfway between the bearing ends with a suitable tool (B) that has a ball tip.
  NOTE:
  The upper and lower connecting rod bearings have different part numbers.



Standard : Refer to EM-534, "MAIN BEARING".

- Do not reuse the connecting rod bearing if its thickness is below the minimum specification.
- If any connecting rod bearing is replaced, they **must** be replaced as a pair.

SERVICE DATA AND SPECIFICATIONS (SDS)

SERVICE DATA AND SPECIFICATIONS (SDS)

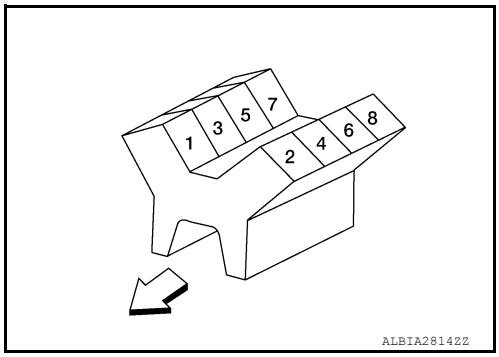
GENERAL SPECIFICATIONS

INFOID:0000000014418738

GENERAL SPECIFICATIONS

Cylinder arrangement		V-8
Displacement cm^3(in^3)		5,000 (305.12)
Bore and stroke mm (in)		94 x 90 (3.70 x 3.54)
Valve arrangement		DOHC
Firing order		1-2-7-8-4-5-6-3
Compression ratio		16.3:1
Engine weight kg (lbs.)		358.34 (790)
Crankshaft rotation	Viewed from engine front	Clockwise
Number of piston rings	Compression	2
	Oil	1
Number of main bearings		5
Fuel rail pressure operating range kPa (kg/cm^2, psi)		25,000 - 200,000 (255 - 2,040, 3626 - 29,000)
Engine idle speed (RPM)		600 - 1000
Engine cranking speed (RPM)		100
Recommended ambient air temperature to use block heater (if equipped) °F (°C)		0 (-18) or less

Cylinder number



DRIVE BELT

INFOID:0000000014418739

DRIVE BELT

Tension of drive belt	Auto adjustment by auto-tensioner

EXHAUST MANIFOLD

INFOID:0000000014418740

EXHAUST MANIFOLD

Unit: mm (in)

Items		Limit
Surface distortion	Exhaust manifold	0.13 (0.005)

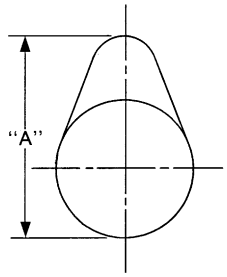
CAMSHAFT

INFOID:0000000014418741

CAMSHAFT

Unit: mm (in)

Items	Standard



SEM671

Camshaft cam height "A"	Intake	38.232 - 38.592 (1.505 - 1.519)
	Exhaust	38.886 - 39.246 (1.531 - 1.545)
Outside diameter of camshaft bearing journal		24.938 - 24.958 (0.982 - 0.938)
Camshaft cap inside diameter		24.987 - 25.013 (0.9837 - 0.9847)
Camshaft journal clearance		0.029 - 0.075 (0.001 - 0.003)
Camshaft end play		0.061 - 0.254 (0.002 - 0.010)
Camshaft backlash	Dial indicator	0.083 - 0.175 (0.003 - 0.007)
	Feeler gauge	0.088 - 0.186 (0.003 - 0.007)

CYLINDER HEAD

INFOID:0000000014418742

CYLINDER HEAD

Unit: mm (in)

Items		Limit
Surface flatness	Total	0.1 (0.0039)
	Within 25 mm^2 (0.98 in^2) area	0.025 (0.0009)
	Within 150 mm^2 (5.91 in^2) area	0.050 (0.0019)

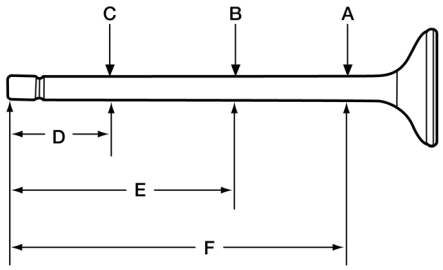
Valve Depth

Unit: mm (in)

Item	Standard
Exhaust valve	0.757 - 1.701 (0.030 - 0.067)
Intake valve	0.775 - 1.734 (0.031 - 0.068)

Valve Dimensions

Unit: mm (in)



ALBIA2320ZZ

Items		Standard
Valve stem diameter at (C)	: 22 mm (0.87 in) (D)	5.99 - 6.01 (0.236 - 0.237)

Valve stem diameter at (B)	: 47 mm (1.85 in) (E)	5.99 - 6.01 (0.236 - 0.237)
Valve stem diameter at (A)	: 72 mm (2.83 in) (F)	5.99 - 6.01 (0.236 - 0.237)
Valve tip to retainer height		5.410 - 6.524 (0.2129 - 0.2568)
Valve runout (measured at valve head outer diameter)	Maximum	0.254 (0.010)

Valve Guide

Unit: mm (in)

Items	Standard
Valve guide inside diameter	6.035 - 6.065 (0.2376 - 0.2388)

Valve Spring

Free height mm (in)	48.5 mm (1.91 in)
Valve spring pressure load	275 - 305 N (28.1 - 31.1 kg, 61.8 - 68.6 lb) at 31.56 mm (1.243 in)
Out-of-square mm (in)	Less than 1.49 mm (0.059 in)

Injector

Unit: mm (in)

Item	Standard
Injector protrusion	2.180 - 2.680 (0.0858 - 0.1055)

Glow Plug

Unit: mm (in)

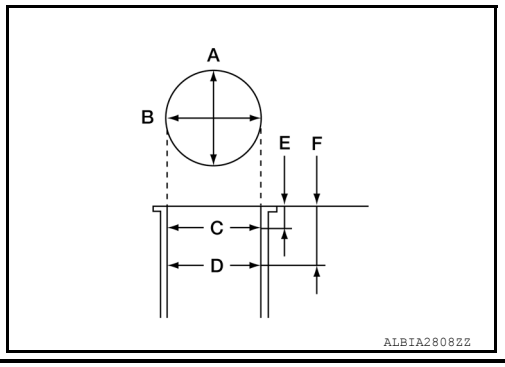
Item	Standard
Glow plug protrusion	1.620 - 2.306 (0.0638 - 0.0908)

CYLINDER BLOCK

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CYLINDER BLOCK

Unit: mm (in)



Surface flatness	Total	Limit	0.1 (0.004)
	Within 25 mm^2 (1 in^2) area		0.025 (0.001)
	Within 150 mm^2 (6 in^2) area		0.05 (0.002)
Main bearing housing inside diameter (bearings removed)		Standard	75.10 - 75.12 (2.957 - 2.957)
Cylinder bore diameter [(A) and (B) at (C) and (D)]		Standard	93.99 - 94.01 (3.700 - 3.701)
Out-of-round [Difference between (A) and (B)]		Limit	0.05 (0.002)
Taper [Difference between (C) and (D) at (E*) and (F*)]			0.015 (0.0006)

*(E) is 11.5 mm (0.453 in) and (F) is 117.825 mm (4.639).

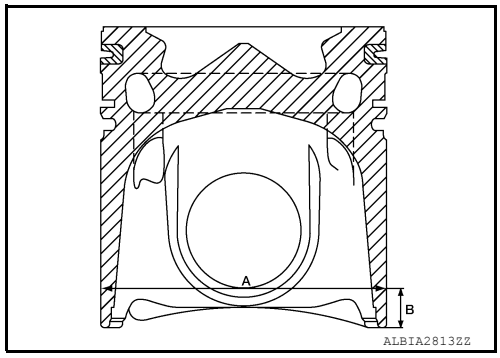
PISTON, PISTON RING AND PISTON PIN

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PISTON, PISTON RING AND PISTON PIN

Piston

Unit: mm (in)



Items	Standard
Piston skirt diameter (A) at (B)	93.901 - 93.919 (3.6969 - 3.6976)
Height (B)	16 (0.630)
Piston pin hole diameter	34.510 - 34.515 (1.3587 - 1.3589)
Piston to cylinder bore clearance	0.089 - 0.091 (0.0035 - 0.0036)

To be sure of accuracy, the measurements must be completed with components at room temperature of 20°C (68°F).

Piston Ring

Unit: mm (in)

Items		Standard	Limit
Side clearance	Intermediate	0.055 - 0.100 (0.0022 - 0.0039)	—
	Oil ring	0.040 - 0.090 (0.0016 - 0.0035)	—
End gap	Top ring	0.23 - 0.39 (0.009 - 0.015)	—
	Second ring	0.47 - 0.78 (0.019 - 0.031)	—
	Oil ring	0.22 - 0.53 (0.009 - 0.021)	—

Piston Pin

Unit: mm (in)

Items	Standard
Piston pin diameter	34.494 - 34.500 (1.3580 - 1.3583)
Piston to piston pin clearance	0.010 - 0.021 (0.0004 - 0.0008)

CONNECTING ROD

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CONNECTING ROD

Unit: mm (in)

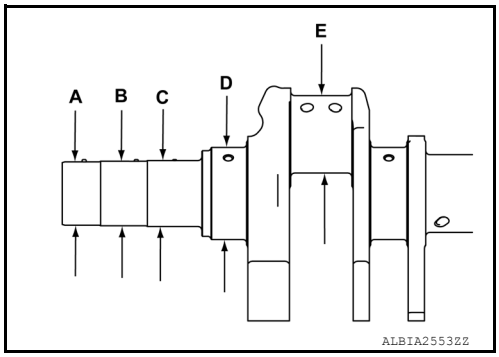
Items	Standard	Limit
Connecting rod bushing inside diameter (small end)	34.523 - 34.543 (1.359 - 1.360)	—
Connecting rod big end inside diameter (without bearing)	62.997 - 63.023 (2.480 - 2.481)	—
Connecting rod big end inside diameter (with bearing)	59.029 - 59.075 (2.324 - 2.326)	—
Side clearance	0.150 - 0.450 (0.006 - 0.018)	—
Connecting rod bushing oil clearance	0.023 - 0.049 (0.0009 - 0.0019)	—
Connecting rod bearing (thickness)	1.9740 - 1.9840 (0.0777 - 0.0781)	—

CRANKSHAFT

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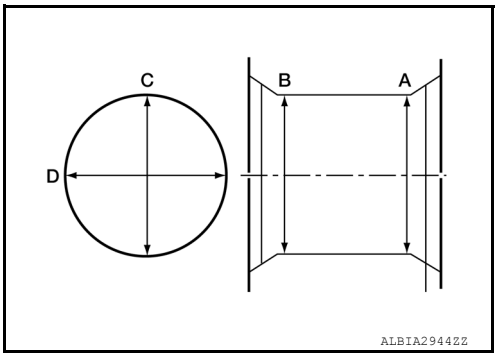
CRANKSHAFT

Unit: mm (in)



Main bearing journal (D)		69.987 - 70.013 (2.755 - 2.756)
Connecting rod journal (E)		58.987 - 59.013 (2.322 - 2.323)
Crankshaft vibration damper mounting journal (A)		47.98 - 48.02 (1.889 - 1.891)
Crankshaft sprocket (oil/fuel pump) journal (B)		48.98 - 49.02 (1.928 - 1.930)
Crankshaft sprocket (camshaft) journal (C)		49.98 - 50.02 (1.968 - 1.969)
Rear oil seal flange outside diameter		109.975 - 110.025 (4.3297 - 4.3317)
Crankshaft end play	Standard	0.150 - 0.450 (0.006 - 0.018)
	Limit	—

Unit: mm (in)



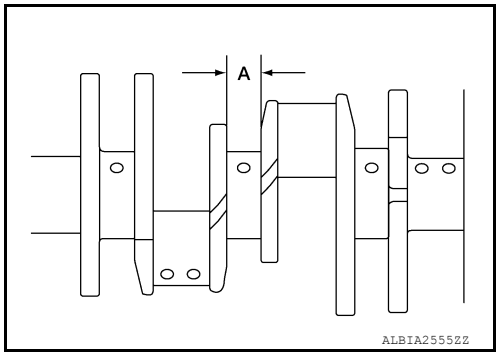
Main bearing journal	Out-of-round**	0.006 (0.0002)
	Taper*	0.006 (0.0002)
Connecting rod journal	Out-of-round**	0.006 (0.0002)
	Taper*	0.006 (0.0002)

*: Difference between (A) and (B).

**: Difference between (C) and (D).

Thrust Distance

Unit: mm (in)



Item	Standard
Thrust distance (A)	27.875 - 27.976 (1.097 - 1.101)

MAIN BEARING

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MAIN BEARING

Unit: mm (in)

Item	Standard
Main bearing (thickness)	2.513 - 2.525 (0.0989 - 0.0994)

Main Bearing Oil Clearance

Unit: mm (in)

Items	Standard	Nominal
Main bearing oil clearance	0.037 - 0.107 (0.001 - 0.004)	0.072 (0.003)

Connecting Rod Bearing Oil Clearance

Unit: mm (in)

Items	Standard	Nominal
Connecting rod bearing oil clearance	0.016 - 0.088 (0.0006 - 0.0035)	0.052 (0.002)