WSM

WORKSHOP MANUAL

GASOLINE, LPG, NATURAL GAS ENGINE

WG1605-E3

Kubota

KiSC issued 03, 2022 A

TO THE READER

This Workshop Manual tells the servicing personnel about the mechanism, servicing and maintenance of the *WG1605-E3*. It contains 4 parts: Information, General, Mechanisms, and Servicing.

Information
This section contains information below.
- Safety first
- Specification
- Important items of exhaust emission regulation
- Performance curve
- Dimension
- Wiring diagram

General
This section contains information below.
- Engine identification
- General precautions
- Maintenance check list
- Check and maintenance
- Special tools

Mechanism
This section contains information on the structure and the function of the unit. Before you continue with the subsequent sections, make sure that you read this section.

Servicing
This section contains information below.
- Troubleshooting
- Servicing specifications
- Tightening torques
- Checking, disassembling and servicing

All illustrations, photographs and specifications contained in this manual are of the newest information available at the time of publication.
Kubota reserves the right to change all information at any time without notice.
Since this manual includes many models, information or illustrations and photographs can show more than one model.

January 2012

RECORD OF REVISIONS

Main revised contents and corrective measures are described in a table.
Find the main revised point and corrective measure through the reference page.

Last digit of the code No.	Month of revision	Main revised point and corrective measure [Search word]	Reference page
2	May 2014	Added these models. • WG1605-N-E3 • WG1605-LN-E3 • WG1605-GLN-E3	–
3	November 2016	Corrected the maintenance check list.	2-7
		Corrected the information about checking and adjusting these items. • Ignition coil • Throttle body • TMAP sensor	–
		Added the information about caution point of oxygen sensor when exchange it.	3-17
4	March 2017	Added the following maintenance item. • Lockoff valve filter	2-7 2-24
5	March 2021	Corrected these errors. • Changing the status from the allowable limit to the service limit • Changing the status from the factory specification to the service specification • Changing the status from ohmmeter to resistance range of circuit tester	–
6	March 2022	Added the information about adjusting a fan belt tension.	2-15 2-18 3-29
		Improved the procedure of measuring compression pressure.	3-36
		Corrected the word related to maintenance interval of the following item. • Cleaning of spark plug	2-7 2-15

CONTENTS

1. INFORMATION

2. GENERAL

1. INFORMATION

SAFETY FIRST

1. Safety first

⚠ SAFETY FIRST
- **This symbol, the industry's "Safety Alert Symbol", is used throughout this manual and on labels on the machine itself to warn of the possibility of personal injury. Read these instructions carefully.**
- **It is essential that you read the instructions and safety regulations before you attempt to repair or use this unit.**

⚠ DANGER
- **Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.**

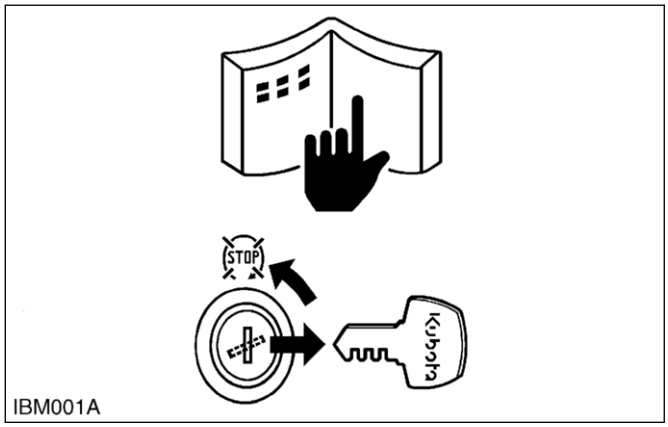
⚠ WARNING
- **Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.**

⚠ CAUTION
- **Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.**

■ IMPORTANT
- **Indicates that equipment or property damage could result if instructions are not followed.**

■ NOTE
- **Gives helpful information.**

2. Before you start service



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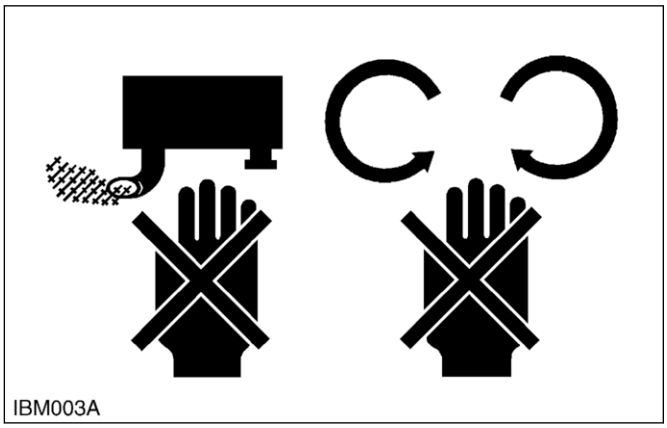
- Read all instructions and safety instructions in this manual and on your engine safety decals.
- Clean the work area and engine.
- Park the machine on a stable and level ground.
- Let the temperature of the engine decrease before you start a job.
- Stop the engine, then remove the key.
- Disconnect the battery negative cable.
- Hang a **[DO NOT OPERATE]** tag in the operator station.

3. Start safely


IBM011A

- Do not do the procedures below when you start the engine.
  - Short across starter terminals
  - Bypass the safety start switch
- Do not make unauthorized modifications to the engine. This can cause damage and decrease the engine life.

4. Operate safely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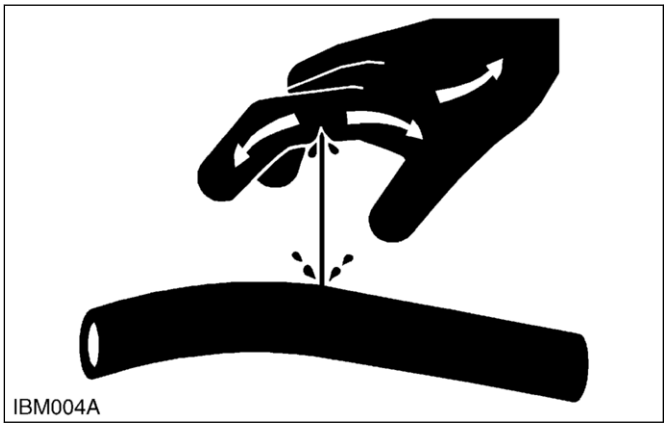
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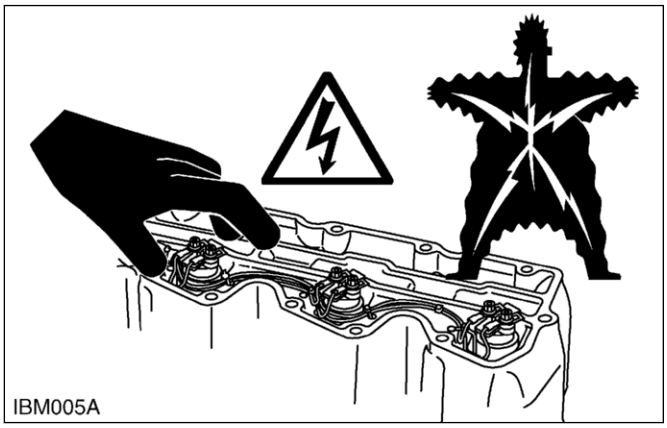
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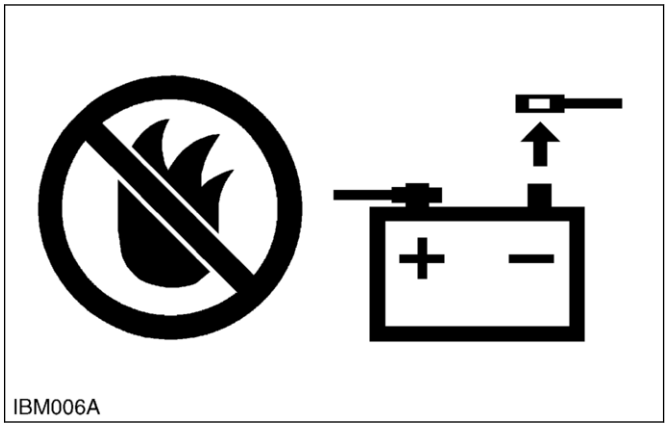
- Do not use the machine after you consume alcohol or medication or when you are tired.
- Put on applicable clothing and safety equipment.
- Use applicable tools only. Do not use alternative tools or parts.
- When 2 or more persons do servicing, make sure that you do it safely.
- Do not touch the hot parts or parts that turn when the engine operates.
- Do not remove the radiator cap when the engine operates, or immediately after it stops. If not, hot water can spout out from the radiator. Only remove the radiator cap when it is at a sufficiently low temperature to touch with bare hands. Slowly loosen the cap to release the pressure before you remove it fully.
- Released fluid (fuel or hydraulic oil) under pressure can cause damage to the skin and cause serious injury. Release the pressure before you disconnect hydraulic or fuel lines. Tighten all connections before you apply the pressure.
- Do not open a fuel system under high pressure. The fluid under high pressure that stays in fuel lines can cause serious injury. Do not disconnect or repair the fuel lines, sensors, or any other components between the fuel pump and injectors on engines with a common rail fuel system under high pressure.
- Put on an applicable ear protective device (earmuffs or earplugs) to prevent injury against loud noises.
- Be careful about electric shock. The engine generates a high voltage of more than DC100 V in the ECU and is applied to the injector.

5. Prevent a fire

- Fuel is very flammable and explosive under some conditions. Do not smoke or let flames or sparks in your work area.
- To prevent sparks from an accidental short circuit, always disconnect the battery negative cable first and connect it last.
- The battery gas can cause an explosion. Keep the sparks and open flame away from the top of battery, especially when you charge the battery.
- Make sure that you do not spill fuel on the engine.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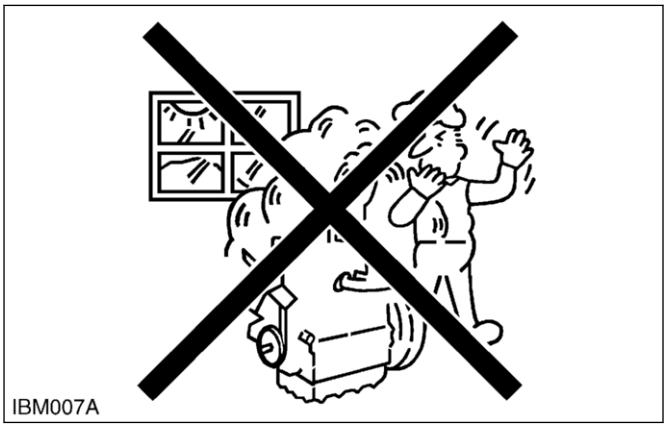
6. Keep a good airflow in the work area

- If the engine is in operation, make sure that the area has good airflow. Do not operate the engine in a closed area. The exhaust gas contains poisonous carbon monoxide.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7. Discard fluids correctly

- Do not discard fluids on the ground, down the drain, into a stream, pond, or lake. Obey related environmental protection regulations when you discard oil, fuel, coolant, electrolyte and other dangerous waste.


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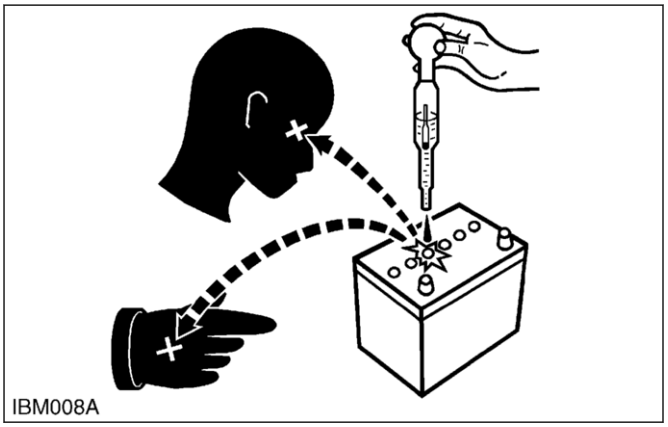
8. Prevent acid burns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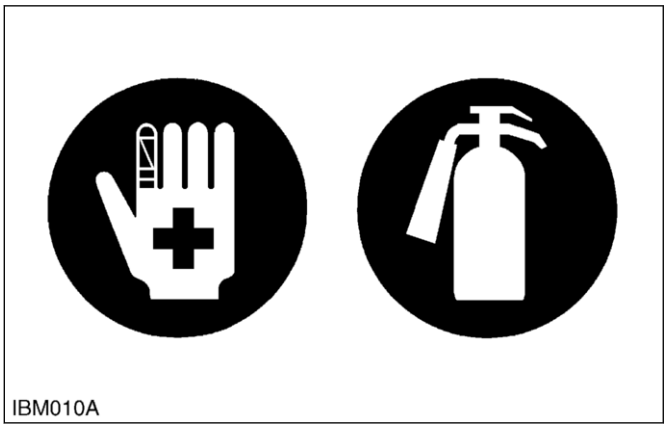
- Keep electrolyte away from your eyes, hands and clothing. Sulfuric acid in battery electrolyte is poisonous and it can burn your skin and clothing and cause blindness.
- If you spill electrolyte on yourself, clean yourself with water, and get medical aid immediately.

9. Prepare for emergencies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- Keep a first aid kit and fire extinguisher ready at all times.
- Keep the emergency contact telephone numbers near your telephone at all times.

SPECIFICATIONS

1. Specification for WG1605-G-E3, WG1605-L-E3

Model	WG1605-G-E3	WG1605-L-E3
	Gasoline fuel	**LPG fuel**
Number of cylinder	4	
Type	Vertical, water cooled, 4-cycle gasoline engine	Vertical, water cooled, 4-cycle LPG engine
Bore × stroke	79.0 × 78.4 mm (3.11 × 3.09 in.)	
Total displacement	1.537 L (93.79 cu.in.)	
SAE Gross Intermittent	42.5 kW (57.0 HP)/3600 min^{-1} (rpm) 37.0 kW (49.6 HP)/3000 min^{-1} (rpm)	41.0 kW (55.0 HP)/3600 min^{-1} (rpm) 36.0 kW (48.3 HP)/3000 min^{-1} (rpm)
ISO/SAE Net Intermittent	38.5 kW (51.6 HP)/3600 min^{-1} (rpm) 33.5 kW (44.9 HP)/3000 min^{-1} (rpm)	37.1 kW (49.8 HP)/3600 min^{-1} (rpm) 32.5 kW (43.6 HP)/3000 min^{-1} (rpm)
ISO Net Continuous	30.8 kW (41.3 HP)/3600 min^{-1} (rpm) 26.8 kW (35.9 HP)/3000 min^{-1} (rpm)	29.7 kW (39.8 HP)/3600 min^{-1} (rpm) 26.1 kW (35.0 HP)/3000 min^{-1} (rpm)
Maximum bare speed	3575 to 3625 min^{-1} (rpm) 2975 to 3025 min^{-1} (rpm)	
Minimum bare idling speed	725 to 775 min^{-1} (rpm)	
Cylinder head	Overhead-Valve	
Ignition system	Full transistor battery ignition type	
Governor	Electronic governor	
Direction of rotation	Counter-Clockwise (Viewed from flywheel side)	
Spark plug type/Spark plug gap	NGK IFR6F8DN 0.70 to 0.80 mm (0.028 to 0.031 in.)	
Ignition timing	0.45 rad (26°) before T.D.C./3000 min^{-1} (rpm), 3600 min^{-1} (rpm) 0.17 rad (10°) before T.D.C./750 min^{-1} (rpm), 800 min^{-1} (rpm)	0.35 rad (20°) before T.D.C./3000 min^{-1} (rpm), 3600 min^{-1} (rpm) 0.17 rad (10°) before T.D.C./750 min^{-1} (rpm), 800 min^{-1} (rpm)
Firing order	1-3-4-2	
Compression ratio	9.1: 1	
Lubricating system	Forced lubrication by trochoid pump	
Oil pressure indication	Electrical type switch	
Lubricating filter	Full flow paper filter (Cartridge type)	
Cooling system	Pressurized radiator, forced circulation with water pump	
Starting system	Electric starting with starter	
Starting motor	12 V, 1.0 kW	
Battery	12 V, 52 AH or equivalent	
Charging alternator	12 V, 480 W, 720 W	
Fuel	*Unleaded automobile gasoline	Commercial LPG
Lubricating oil	Better than SL Class (API) SAE 10W-30	
Lubricating oil capacity	6.0 L (1.6 U.S.gals)	
Catalytic muffler/Converter	Three way catalyst	

(Continued)

Model	WG1605-G-E3	WG1605-L-E3
	Gasoline fuel	LPG fuel
Weight (Dry)	119 kg (262 lbs)	120 kg (265 lbs)
Application	General power source	

NOTE
***The specification described above is of the standard engine of each model.**
***Conversion formula: HP = 0.746 kW, PS = 0.7355 kW**

*Kubota recommended LPG fuel specifications

- Commercial propane gas only.
- Equivalent to propanes H-D-5 of GPA* standards.

C_3H_8	C_3H_6	C_4H_{10}	Others
≥ 90 %	≤ 5 %	≤ 2.5 %	—

(vol %)

*GPA

- Gas processors association (U.S.A.)

2. Specification for WG1605-GL-E3

Model	WG1605-GL-E3	
	Gasoline fuel	**LPG fuel**
Number of cylinder	4	
Type	Vertical, water cooled, 4-cycle dual fuel (Gasoline/LPG) engine	
Bore × Stroke	79.0 × 78.4 mm (3.11 × 3.09 in.)	
Total displacement	1.537 L (93.79 cu.in.)	
SAE Gross Intermittent	42.5 kW (57.0 HP)/3600 min^{-1} (rpm) 37.0 kW (49.6 HP)/3000 min^{-1} (rpm)	41.0 kW (55.0 HP)/3600 min^{-1} (rpm) 36.0 kW (48.3 HP)/3000 min^{-1} (rpm)
ISO/SAE Net Intermittent	38.5 kW (51.6 HP)/3600 min^{-1} (rpm) 33.5 kW (44.9 HP)/3000 min^{-1} (rpm)	37.1 kW (49.8 HP)/3600 min^{-1} (rpm) 32.5 kW (43.6 HP)/3000 min^{-1} (rpm)
ISO Net Continuous	30.8 kW (41.3 HP)/3600 min^{-1} (rpm) 26.8 kW (35.9 HP)/3000 min^{-1} (rpm)	29.7 kW (39.8 HP)/3600 min^{-1} (rpm) 26.1 kW (35.0 HP)/3000 min^{-1} (rpm)
Maximum bare speed	3575 to 3625 min^{-1} (rpm) 2975 to 3025 min^{-1} (rpm)	
Minimum bare idling speed	725 to 775 min^{-1} (rpm)	
Cylinder head	Overhead-Valve	
Ignition system	Full transistor battery ignition type	
Governor	Electronic governor	
Direction of rotation	Counter-Clockwise (Viewed from flywheel side)	
Spark plug type/Spark plug gap	NGK IFR6F8DN 0.70 to 0.80 mm (0.028 to 0.031 in.)	
Ignition timing	0.45 rad (26°) before T.D.C./3000 min^{-1} (rpm), 3600 min^{-1} (rpm) 0.17 rad (10°) before T.D.C./750 min^{-1} (rpm), 800 min^{-1} (rpm)	0.35 rad (20°) before T.D.C./3000 min^{-1} (rpm), 3600 min^{-1} (rpm) 0.17 rad (10°) before T.D.C./750 min^{-1} (rpm), 800 min^{-1} (rpm)
Firing order	1-3-4-2	
Compression ratio	9.1: 1	
Lubricating system	Forced lubrication by trochoid pump	
Oil pressure indication	Electrical type switch	
Lubricating filter	Full flow paper filter (Cartridge type)	
Cooling system	Pressurized radiator, forced circulation with water pump	
Starting system	Electric starting with starter	
Starting motor	12 V, 1.0 kW	
Battery	12 V, 52 AH or Equivalent	
Charging Alternator	12 V, 480 W, 720 W	
Fuel	*Unleaded automobile gasoline	Commercial LPG
Lubricating oil	Better than SL Class (API) SAE 10W-30	
Lubricating oil capacity	6.0 L (1.6 U.S.gals)	
Catalytic muffler/Converter	Three way catalyst	
Weight (Dry)	121 kg (267 lbs)	
Application	General power source	

NOTE
***The specification described above is of the standard engine of each model.**
***Conversion formula: HP = 0.746 kW, PS = 0.7355 kW**

***Kubota recommended LPG fuel specifications**

- Commercial propane gas only.
- Equivalent to propanes H-D-5 of GPA* standards.

C_3H_8	C_3H_6	C_4H_{10}	Others
≥ 90 %	≤ 5 %	≤ 2.5 %	—

(vol %)

***GPA**

- Gas processors association (U.S.A.)

3. Specification for WG1605-N-E3, WG1605-LN-E3

Model	WG1605-N-E3	WG1605-LN-E3	
	Natural gas fuel	Natural gas fuel	LPG fuel
Number of cylinder	4		
Type	Vertical, water cooled, 4-cycle natural gas engine		Vertical, water cooled, 4-cycle LPG engine
Bore × Stroke	79.0 × 78.4 mm (3.11 × 3.09 in.)		
Total displacement	1.537 L (93.79 cu.in.)		
SAE Gross Intermittent	38.4 kW (51.6 HP)/3600 min^{-1} (rpm) 33.9 kW (45.4 HP)/3000 min^{-1} (rpm)		41.0 kW (55.0 HP)/3600 min^{-1} (rpm) 36.0 kW (48.3 HP)/3000 min^{-1} (rpm)
ISO/SAE Net Intermittent	34.8 kW (46.7 HP)/3600 min^{-1} (rpm) 30.7 kW (41.1 HP)/3000 min^{-1} (rpm)		37.1 kW (49.8 HP)/3600 min^{-1} (rpm) 32.5 kW (43.6 HP)/3000 min^{-1} (rpm)
ISO Net Continuous	27.8 kW (37.3 HP)/3600 min^{-1} (rpm) 24.5 kW (32.9 HP)/3000 min^{-1} (rpm)		29.7 kW (39.8 HP)/3600 min^{-1} (rpm) 26.1 kW (35.0 HP)/3000 min^{-1} (rpm)
Maximum bare speed	3575 to 3625 min^{-1} (rpm) 2975 to 3025 min^{-1} (rpm)		
Minimum bare idling speed	725 to 775 min^{-1} (rpm)		
Cylinder head	Overhead-Valve		
Ignition system	Full transistor battery ignition type		
Governor	Electronic governor		
Direction of rotation	Counter-Clockwise (Viewed from flywheel side)		
Spark plug type/Spark plug gap	NGK IFR6F8DN 0.70 to 0.80 mm (0.028 to 0.031 in.)		
Ignition timing	0.40 rad (23°) before T.D.C./3000 min^{-1} (rpm) 0.35 rad (20°) before T.D.C./3000 min^{-1} (rpm) 0.26 rad (15°) before T.D.C./800 min^{-1} (rpm) 0.17 rad (10°) before T.D.C./800 min^{-1} (rpm)		0.35 rad (20°) before T.D.C./ 3000 min^{-1} (rpm), 3600 min^{-1} (rpm) 0.17 rad (10°) before T.D.C./ 750 min^{-1} (rpm), 800 min^{-1} (rpm)
Firing order	1-3-4-2		
Compression ratio	9.1: 1		
Lubricating system	Forced lubrication by trochoid pump		
Oil pressure indication	Electrical type switch		
Lubricating filter	Full flow paper filter (Cartridge type)		
Cooling system	Pressurized radiator, forced circulation with water pump		
Starting system	Electric starting with starter		
Starting motor	12 V, 1.0 kW		
Battery	12 V, 52 AH or equivalent		
Charging alternator	12 V, 480 W, 720 W		
Fuel	Natural gas		Commercial LPG
Lubricating oil	Better than SL class (API) SAE 10W-30		
Lubricating oil capacity	6.0 L (1.6 U.S.gals)		
Catalytic muffler/Converter	Three way catalyst		

(Continued)

Model	WG1605-N-E3	WG1605-LN-E3	
	Natural gas fuel	Natural gas fuel	LPG fuel
Weight (Dry)	120 kg (265 lbs)		

NOTE
***The specification described above is of the standard engine of each model.**
***Conversion formula: HP = 0.746 kW, PS = 0.7355 kW**

4. Specification for WG1605-GLN-E3

Model	WG1605-GLN-E3		
	Gasoline	**Natural gas fuel**	**LPG fuel**
Number of cylinder	4		
Type	Vertical, water cooled, 4-cycle gasoline engine	Vertical, water cooled, 4-cycle natural gas engine	Vertical, water cooled, 4-cycle LPG engine
Bore × Stroke	79.0 × 78.4 mm (3.11 × 3.09 in.)		
Total displacement	1.537 L (93.79 cu.in.)		
SAE Gross Intermittent	42.5 kW (57.0 HP) / 3600 min^{-1} (rpm) 37.0 kW (49.6 HP) / 3000 min^{-1} (rpm)	38.4 kW (51.6 HP) / 3600 min^{-1} (rpm) 33.9 kW (45.4 HP) / 3000 min^{-1} (rpm)	41.0 kW (55.0 HP) / 3600 min^{-1} (rpm) 36.0 kW (48.3 HP) / 3000 min^{-1} (rpm)
ISO / SAE Net Intermittent	38.5 kW (51.6 HP) / 3600 min^{-1} (rpm) 33.5 kW (44.9 HP) / 3000 min^{-1} (rpm)	34.8 kW (46.7 HP) / 3600 min^{-1} (rpm) 30.7 kW (41.1 HP) / 3000 min^{-1} (rpm)	37.1 kW (49.8 HP) / 3600 min^{-1} (rpm) 32.5 kW (43.6 HP) / 3000 min^{-1} (rpm)
ISO Net Continuous	30.8 kW (41.3 HP) / 3600 min^{-1} (rpm) 26.8 kW (35.9 HP) / 3000 min^{-1} (rpm)	27.8 kW (37.3 HP) / 3600 min^{-1} (rpm) 24.5 kW (32.9 HP) / 3000 min^{-1} (rpm)	29.7 kW (39.8 HP) / 3600 min^{-1} (rpm) 26.1 kW (35.0 HP) / 3000 min^{-1} (rpm)
Maximum bare speed	3575 to 3625 min^{-1} (rpm) 2975 to 3025 min^{-1} (rpm)		
Minimum bare idling speed	725 to 775 min^{-1} (rpm)		
Cylinder head	Overhead-Valve		
Ignition system	Full transistor battery ignition type		
Governor	Electronic governor		
Direction of rotation	Counter-Clockwise (Viewed from flywheel side)		
Spark plug type / Spark plug gap	NGK IFR6F8DN 0.70 to 0.80 mm (0.028 to 0.031 in.)		
Ignition timing	0.45 rad (26°) before T.D.C. / 3000 min^{-1} (rpm), 3600 min^{-1} (rpm) 0.17 rad (10°) before T.D.C. / 750 min^{-1} (rpm), 800 min^{-1} (rpm)	0.42 rad (24°) before T.D.C. / 3600 min^{-1} (rpm) 0.40 rad (23°) before T.D.C. / 3000 min^{-1} (rpm) 0.26 rad (15°) before T.D.C. / 750 min^{-1} (rpm), 800 min^{-1} (rpm)	0.35 rad (20°) before T.D.C. / 3000 min^{-1} (rpm), 3600 min^{-1} (rpm) 0.17 rad (10°) before T.D.C. / 750 min^{-1} (rpm), 800 min^{-1} (rpm)
Firing order	1-3-4-2		
Compression ratio	9.1: 1		
Lubricating system	Forced lubrication by trochoid pump		
Oil pressure indication	Electrical type switch		
Lubricating filter	Full flow paper filter (Cartridge type)		
Cooling system	Pressurized radiator, forced circulation with water pump		
Starting system	Electric starting with starter		
Starting motor	12 V, 1.0 kW		
Battery	12 V, 52 AH or equivalent		
Charging alternator	12 V, 480 W, 720 W		
Fuel	*Unleaded automobile gasoline	Natural gas	Commercial LPG
Lubricating oil	Better than SL class (API) SAE 10W-30		
Lubricating oil capacity	6.0 L (1.6 U.S.gals)		

(Continued)

Model	WG1605-GLN-E3		
	Gasoline	Natural gas fuel	LPG fuel
Catalytic muffler / Converter	Three way catalyst		
Weight (Dry)	120 kg (265 lbs)		
Application	General power source		

IMPORTANT ITEMS OF EXHAUST EMISSION REGULATION

WG1605 is available and unavailable in those countries.

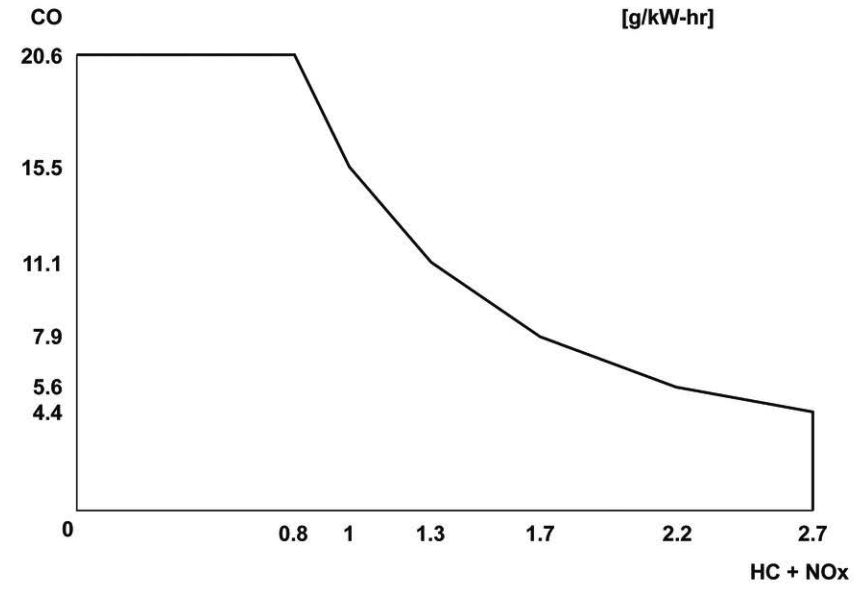
kW, Disp.	Model	Type	North America	Europe	Japan
19 < P, 1.0 < L	WG1605-G-E3, WG1605-L-E3, WG1605-N-E3, WG1605-GL-E3, WG1605-LN-E3, WG1605-GLN-E3	E3	Available	Available	Non-available

Current and future emission regulations.

Countries		kW, disp.	2009	2010	2011	2012	2013	2014	2015	2016
USA	CARB	19 < P < 560 1.0 < L	2.7 / 4.4***	0.8 / 20.6*						
	EPA	19 < P ≤ 560 1.0 < L	2.7 / 4.4***							
Canada		19 < P	None							
Japan		19 ≤ P < 560	HC / 0.6 g / kWh, NO_x/0.6 g / kWh, CO / 20 g / kWh							
EU		19 < P	None							

* with evaporative emission regulation

** See figure



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1. Three-way catalyst

A three-way catalyst is a catalyst that oxidizes HC to CO_2 and H_2O and also CO to CO_2 respectively and at the same time reduces NO_x to N_2 near the stoichiometric ratio.
The main basic component of an exhaust gas purification system that uses a three-way catalyst is feedback control of air-fuel ratio by means of an O_2 sensor for the purpose of maximizing the emission purification efficiency characteristic with reference to the intake air-fuel ratio of the three-way catalyst.
Kubota engines have two kinds of catalytic devices, catalytic muffler and catalytic converter.

2. Vaporizer and lock off valve (WG1605-L-E3, WG1605-N, WG1605-GL-E3, WG1605-LN-E3, WG1605-GLN-E3)

Vaporizer requires a normally-closed electrically controlled fuel lock off valve that is close coupled to the vaporizer and off when ignition switch is off or when the engine is not running normally (supplied from Kubota). In operation without a lock off upstream the vaporizer will flow fuel with the engine off. The vaporizer is not a fuel shut-off safety device.

3. Length of the vapor hose (WG1605-L-E3, WG1605-N, WG1605-GL-E3, WG1605-LN-E3, WG1605-GLN-E3)

Vapor hose length must not exceed 700 mm (27.6 in), shorter is generally considered better. Care should be taken with hose routing and length to minimize the affect on vaporizer vibration isolation. The metal reinforced hose should not be used.

4. Important notice

These instructions are provided to the final engine assemblers (FEA) who must ensure the engine, exhaust system (catalyst), fuel system etc, are installed correctly in the engine's certified configuration.
Please make sure whether emission-related items are certain on application review. (for EPA only)
Failing to follow these instructions when installing a certified engine in a piece of non-road equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the clean air act.
The contractual agreement contract is necessary before mass-production.

5. Emission-related installation instructions

5.1 Exhaust system

Kubota supplies a certified catalyst. FEA must use a Kubota certified catalyst and assemble the exhaust system parts according to the instructions.
No other catalyst is certified for use with WG1605 engine. No other catalyst can be used.
FEA may only install the exhaust system parts confirmed at application review.

5.2 Intake system

To prevent decreases of engine output performance, intake resistance must be kept below a certain point.

5.3 Crankcase ventilation connections

Crankcase emissions may not be discharged directly into the ambient atmosphere throughout its useful life. (40 CFR 1048.115 (a))

5.4 Gasoline fuel system

If your equipment uses a volatile liquid fuel (such as gasoline), they must meet the evaporative emission standards of 40 CFR 1048.

5.5 Gaseous fuel system

FEA must use only the vaporizer and the lock off valve Kubota offers and assemble the LPG fuel system parts according to the instructions.

5.6 Engine control unit (ECU)

Installation must use all 4 of the vibration mounts.
ECU header pins must be horizontal or point downward.

5.7 Vehicle interface connectors

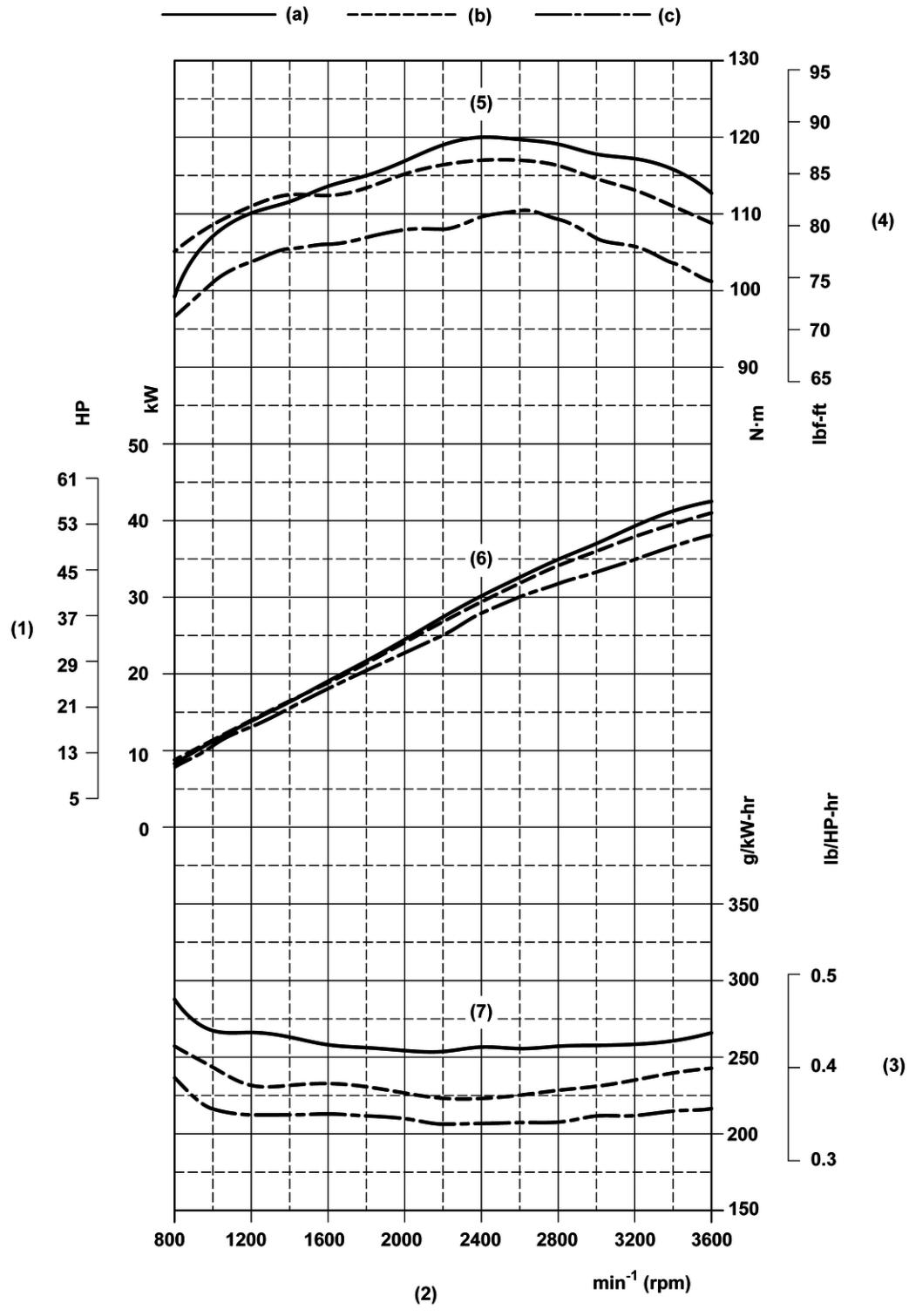
Vehicle interface connectors shall be connected with your wire harness.

5.8 Malfunction indicator light (MIL)

When the MIL goes on, it must display "Check engine", "Service engine soon", or a similar message that EPA approve. (40 CFR 1048.110 (b))

PERFORMANCE CURVES

1. Performance curve for WG1605-G-E3, WG1605-L-E3, WG1605-GL-E3, WG1605-N-E3

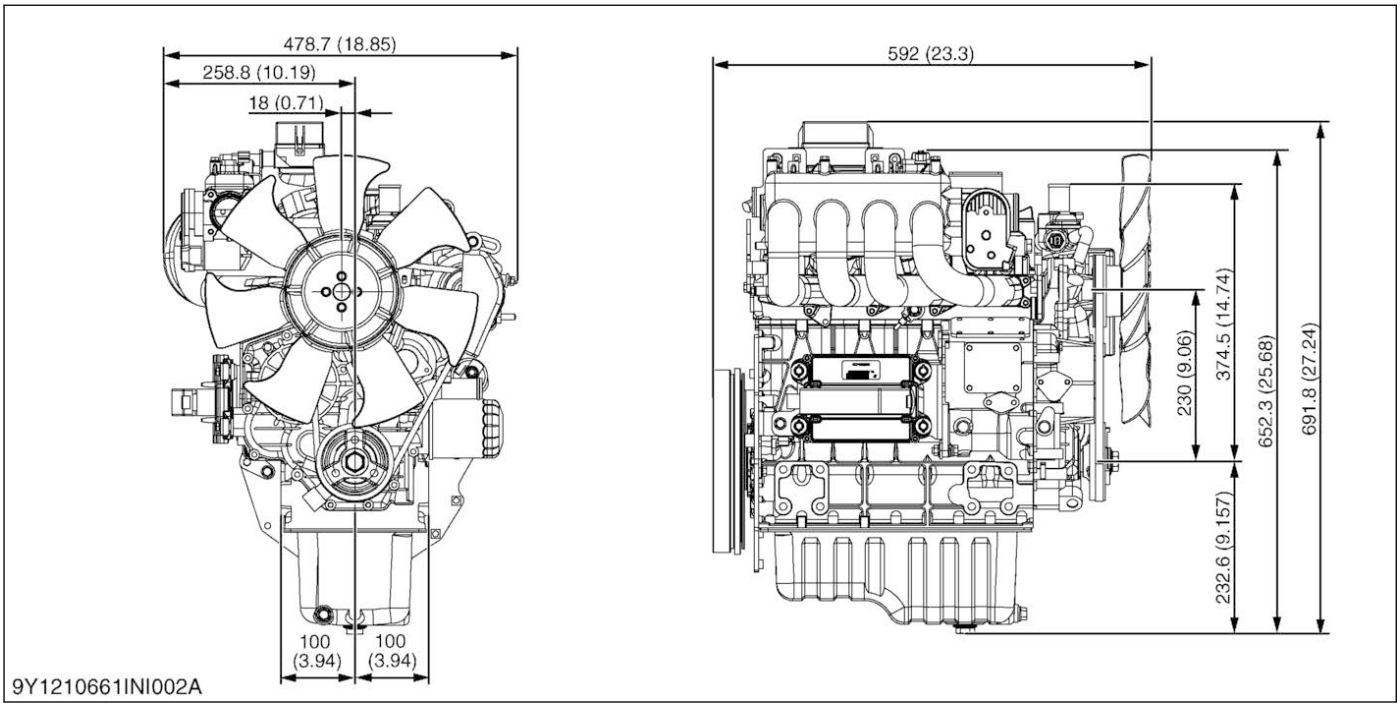


9Y1210661IEI002enUS

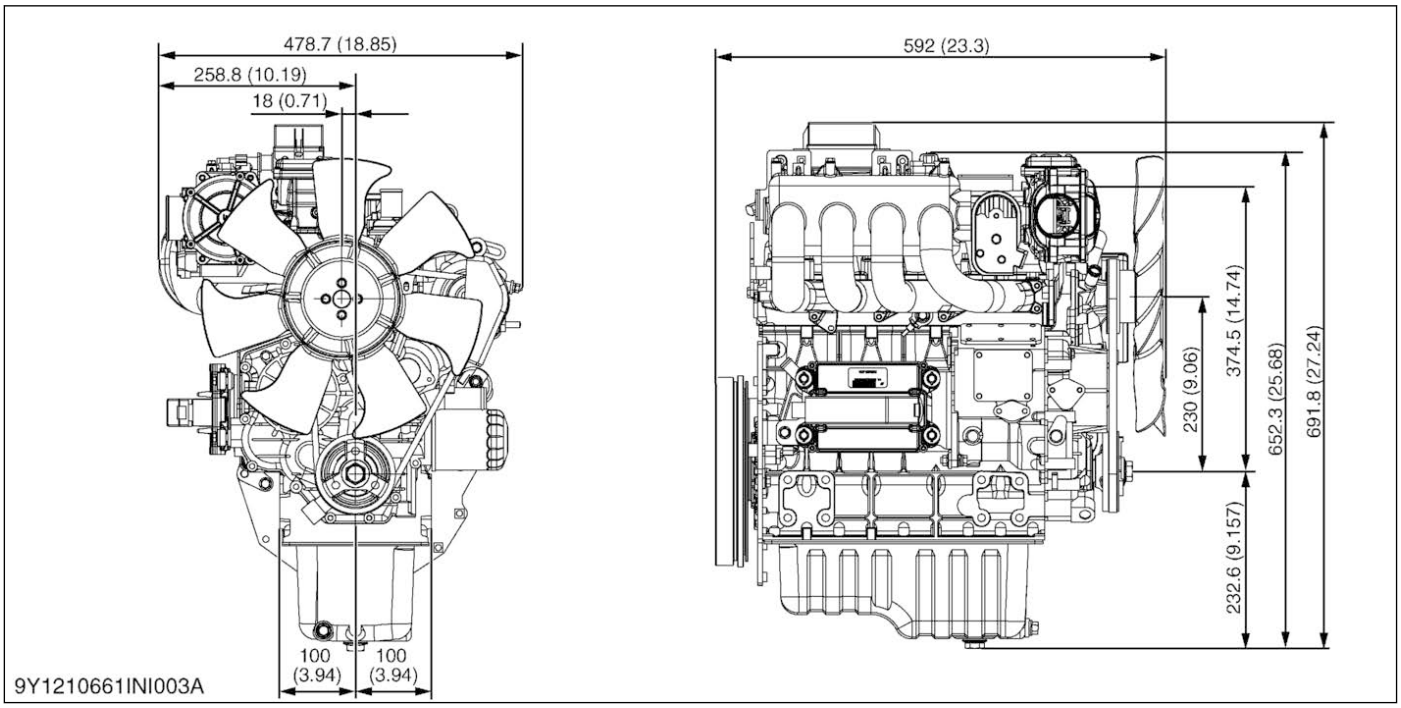
(1) Brake horsepower
(2) Engine speed
(3) Specific fuel consumption
(4) Torque
(5) Gross intermittent torque
(6) Gross intermittent brake horsepower
(7) Gross intermittent specific fuel consumption
(a) Gasoline use
(b) LP gas use
(c) Natural gas use

DIMENSIONS

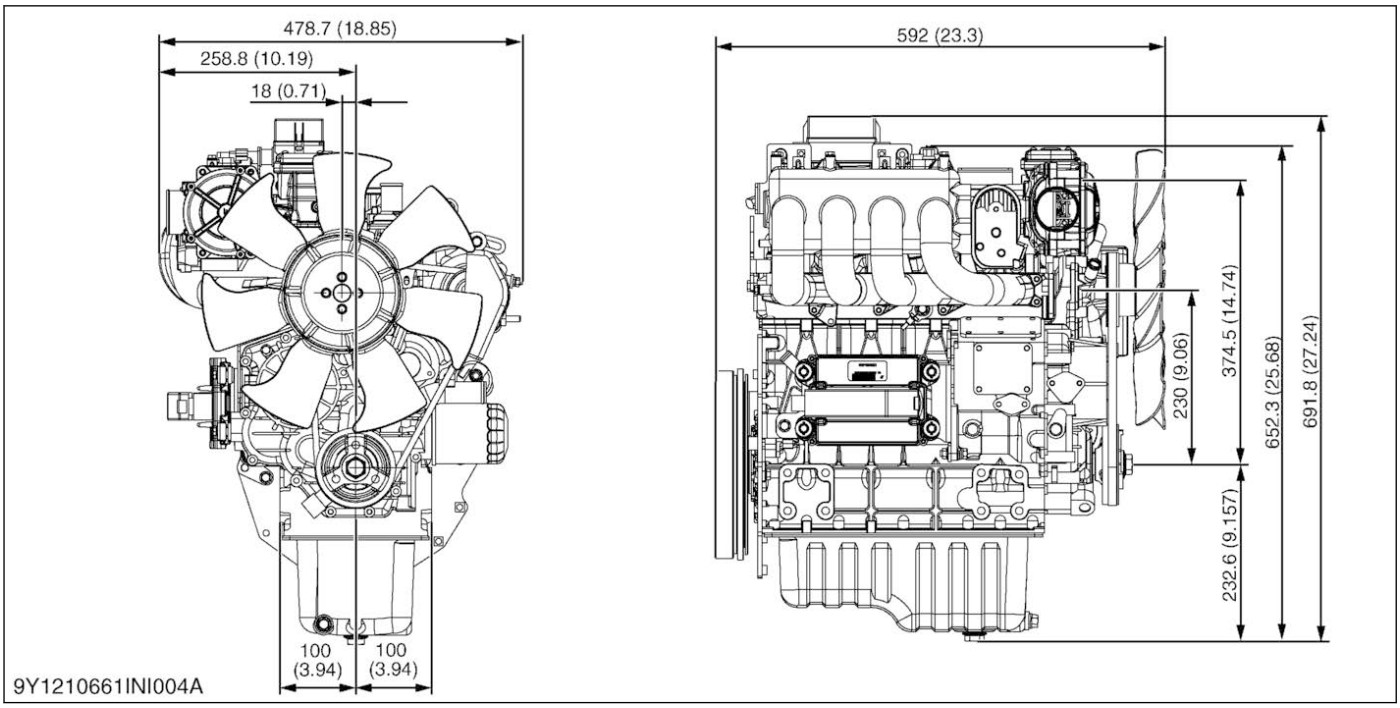
1. Dimension for WG1605-G-E3



2. Dimension for WG1605-L-E3, WG1605-N-E3, WG1605-LN-E3

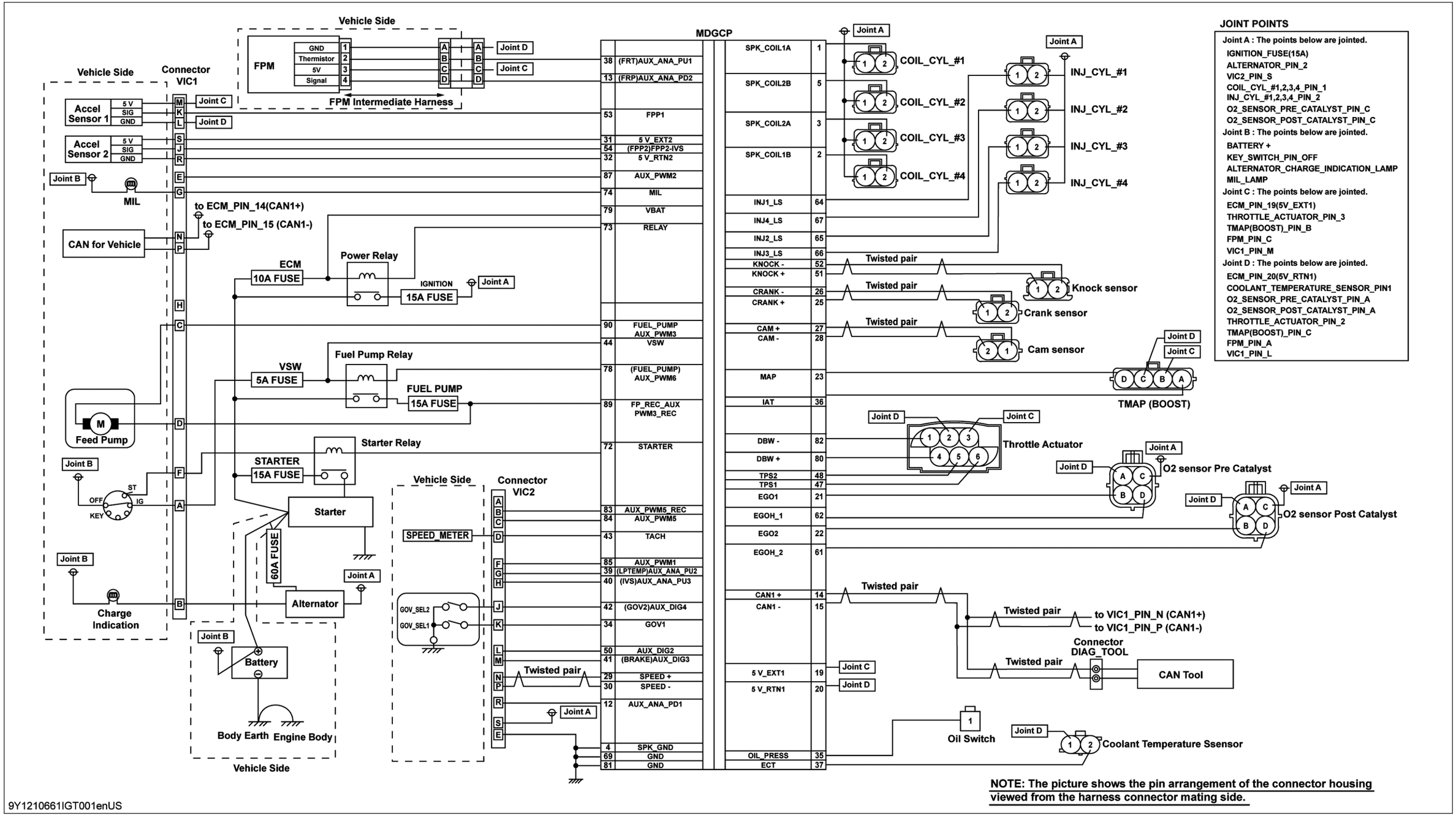


3. Dimension for WG1605-GL-E3, WG1605-GLN-E3

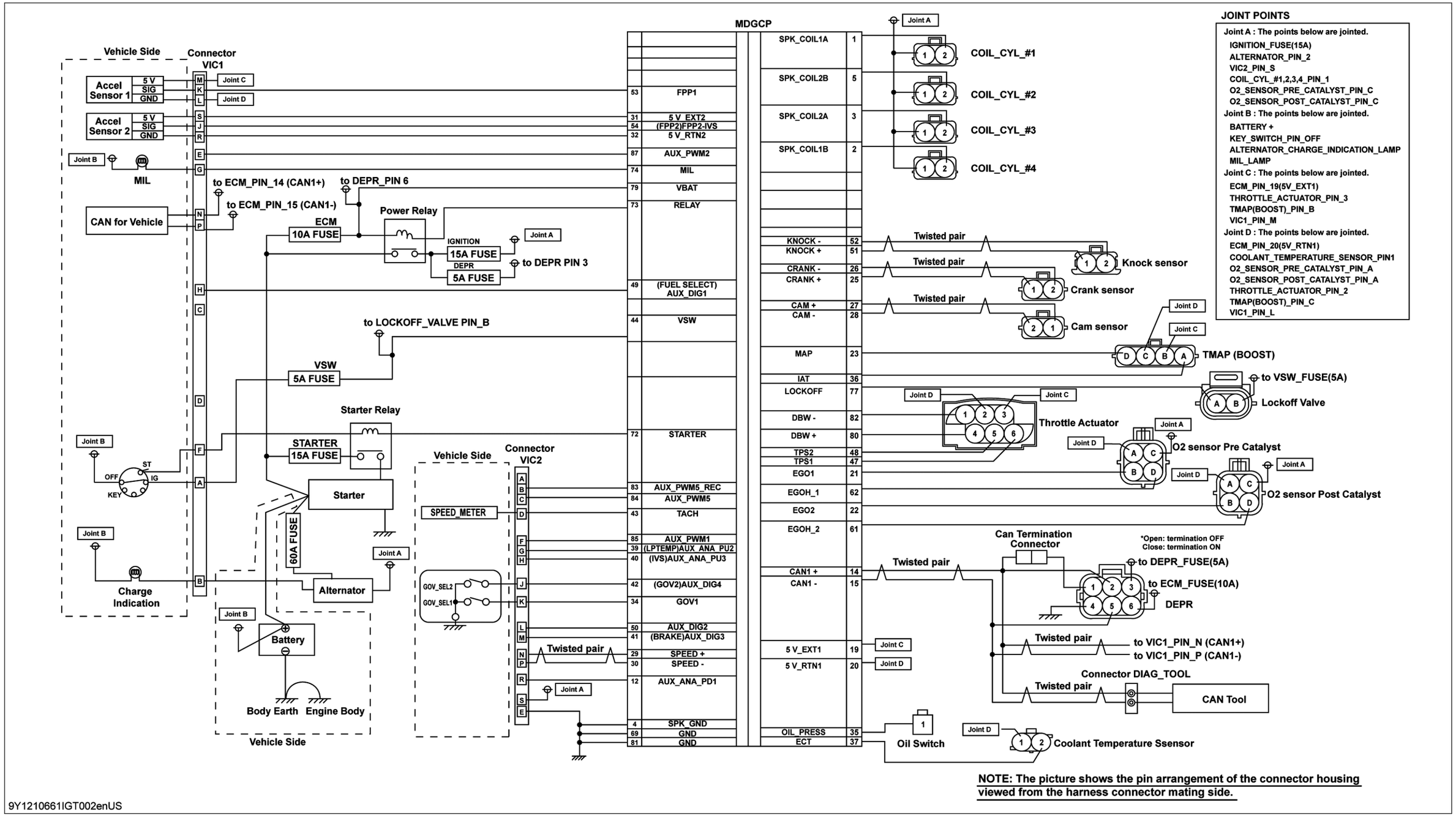


WIRING DIAGRAM

1. Wiring diagram for WG1605-G-E3



2. Wiring diagram for WG1605-L-E3, WG1605-N-E3, WG1605-LN-E3



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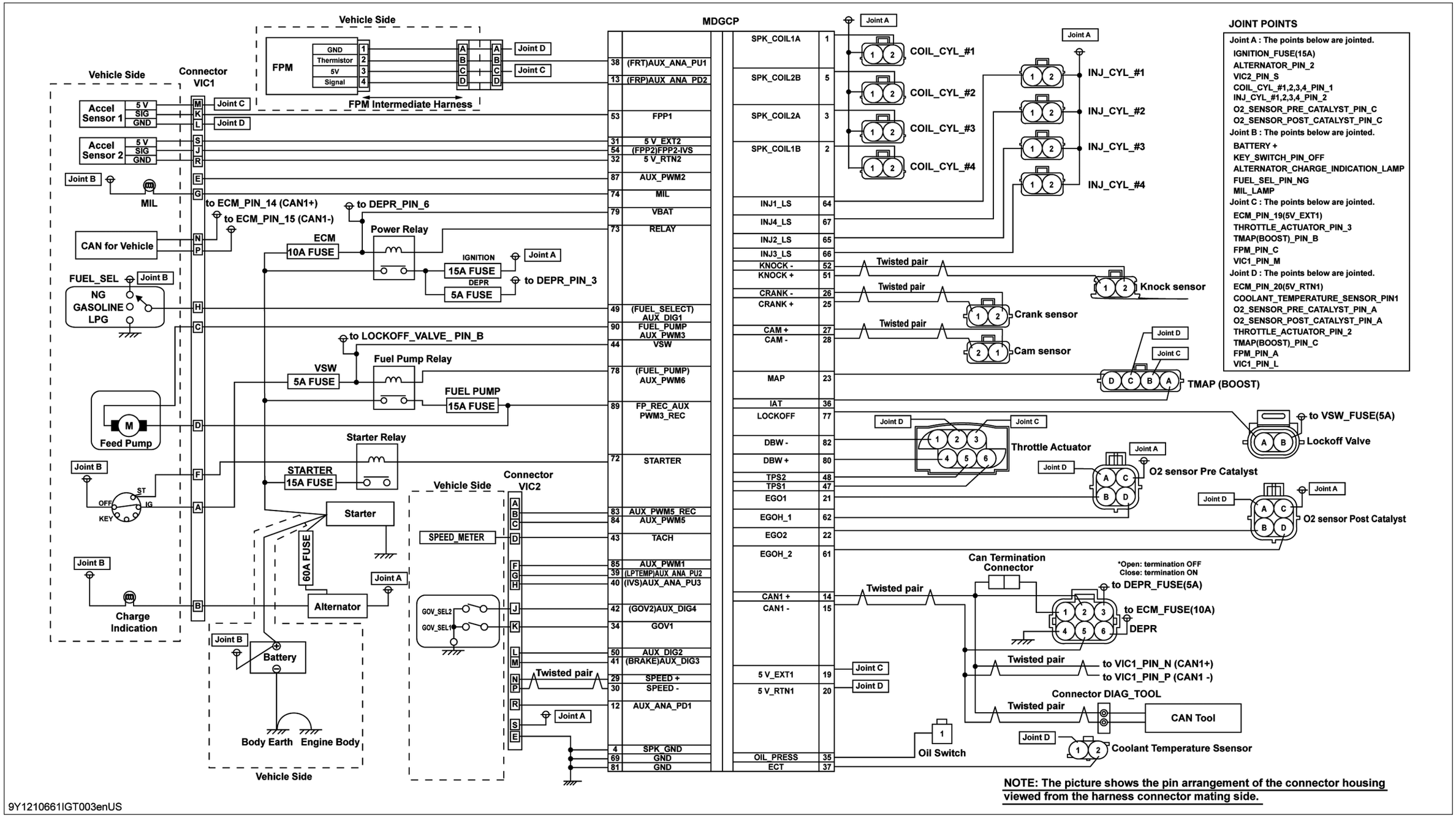
3. Wiring diagram for WG1605-GL-E3, WG1605-GLN-E3



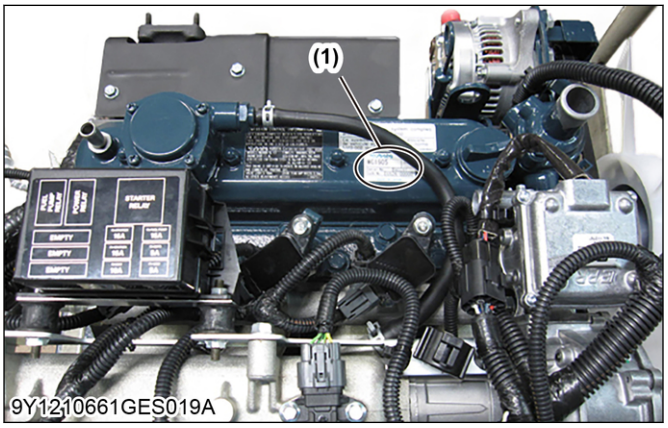
2. GENERAL

ENGINE IDENTIFICATION

1. Engine model name, code number and engine serial number

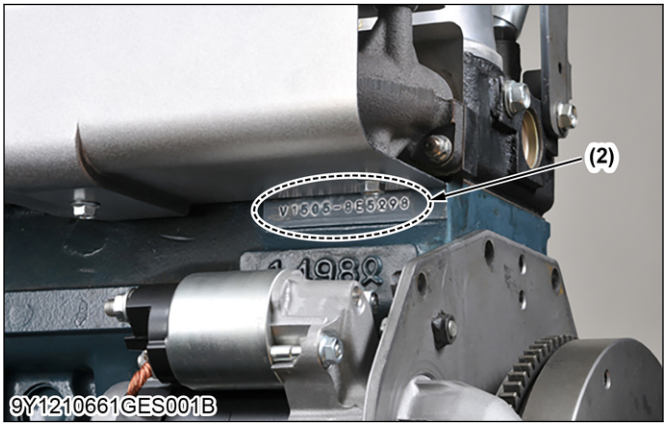
When contacting the manufacture, always specify your engine model name, code number and serial number.
The engine model, code number and its serial number need to be identified before the engine can be serviced or parts replaced.

Engine Model Name and Number Label
The engine model name, the engine serial number and engine code number are written in this label.



(1) Engine model name and number label

Engine Serial Number
The engine serial number is an identification number for the engine.
It is marked after the engine model name.



(2) Engine serial number

It indicates the engine series, the production year and month, and the lot number.

Engine Series

Number or Alphabet	Series
1	05 (include: WG)
2	V3
3	08
4	SM (include: WG)
5	Air Cooled Gasoline
6	GZ, OC, AC, EA, E
7	03 (include: WG)
8	07
A	EA, RK
B	03 (KET Production)

Production Year

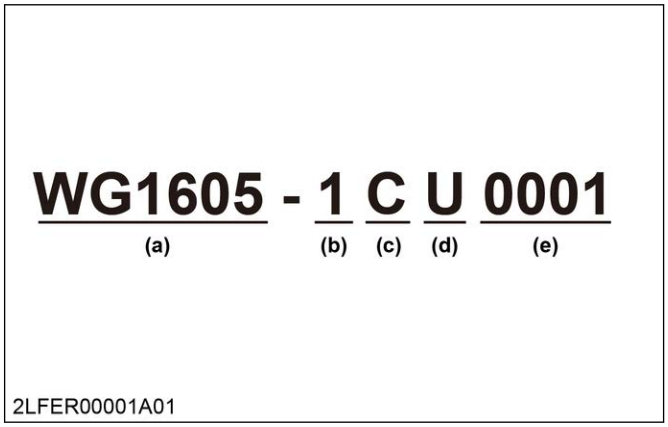
Alphabet or Number	Year
1	2001
2	2002
3	2003
4	2004
5	2005
6	2006
7	2007
8	2008
9	2009
A	2010
B	2011
C	2012
D	2013
E	2014
F	2015
G	2016
H	2017
J	2018
K	2019
L	2020
M	2021
N	2022
P	2023
R	2024
S	2025
T	2026
V	2027

Production Month and Lot Number

Month	Engine Lot Number	
January	A0001～A9999	B0001～
February	C0001～C9999	D0001～
March	E0001～E9999	F0001～
April	G0001～G9999	H0001～
May	J0001～J9999	K0001～
June	L0001～L9999	M0001～
July	N0001～N9999	P0001～
August	Q0001～Q9999	R0001～
September	S0001～S9999	T0001～
October	U0001～U9999	V0001～
November	W0001～W9999	X0001～
December	Y0001～Y9999	Z0001～

NOTE
- **Alphabetical letters "I" and "O" are not used.**

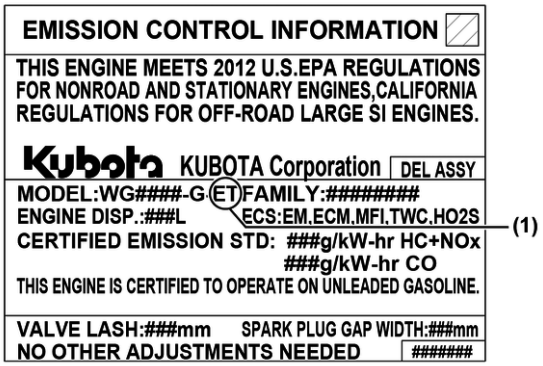
Example of model name and engine serial number



(a) WG1605: Engine model name
(b) 1: Engine series (WG1605 series)
(c) C: Production year (2012)
(d) U: Production month (October)
(e) 0001: Lot number (0001～9999 or A001～Z999)

2. E3 engine

[A]



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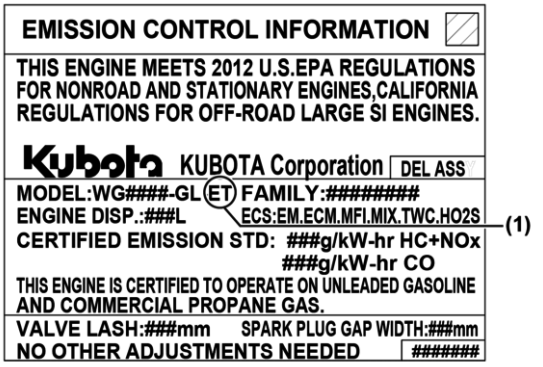
[B]

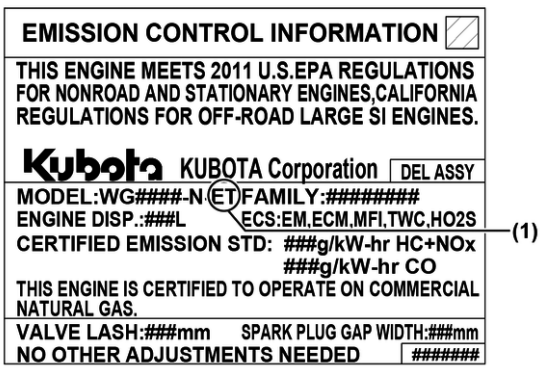
9Y1210661GES013B

[C]



9Y1210661GES014B

[D]



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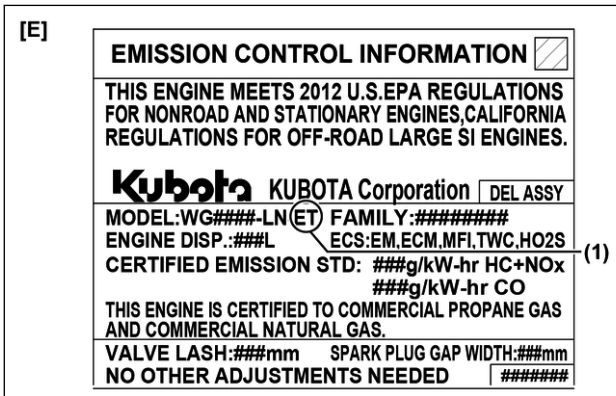
[E]



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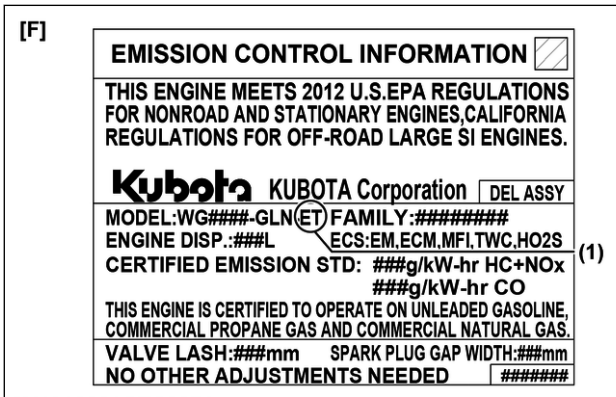
[F]



9Y1210661GES025A

(1) *"E3"* engines are identified with **[ET]** at the end of the model designation, on the US EPA label. *"E3"* designates phase 3 / tier 3 models, depending on engine displacement and output classification.

[A] WG1605-G-E3
[B] WG1605-L-E3
[C] WG1605-GL-E3
[D] WG1605-N-E3
[E] WG1605-LN-E3
[F] WG1605-GLN-E3

The emission controls previously implemented in various countries to prevent air pollution will be stepped up as non-road emission standards continue to change. The timing or applicable date of the specific non-road emission regulations depends on the engine displacement and output classification.

Over the past several years, Kubota has been supplying SI engines that comply with regulations in the respective countries affected by non-road emission regulations. For Kubota engines, E3 will be the designation that identifies engine models affected by the next emission phase (See the table).

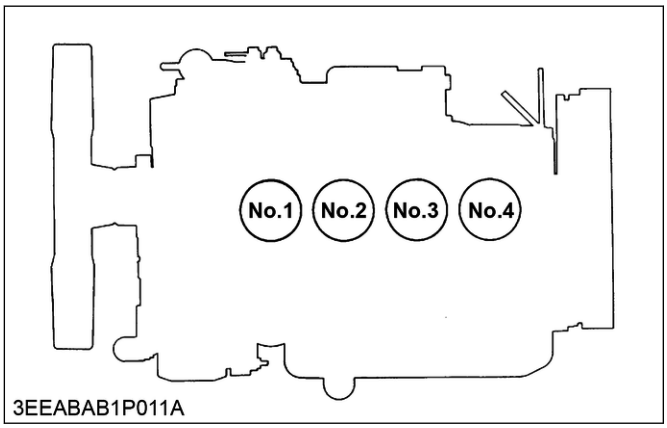
Category (1)	Displacement and Output classification	EPA regulation
ET	Label / Family name: #KBXB#######	Phase 3

When servicing or repairing ###-E3 series engines, use only replacement parts for that specific E3 engine, designated by the appropriate E3 Kubota parts list and perform all maintenance services listed in the appropriate Kubota operator's manual or in the appropriate E3 Kubota workshop manual. Use of

incorrect replacement parts or replacement parts from other emission level engines (for example: E2 engines), may result in emission levels out of compliance with the original E3 design and EPA or other applicable regulations. Please refer to the emission label located on the engine head cover to identify Engine Displacement and Output classification and Emission Control Information. E3 engines are identified with **[ET]** at the end of the Model designation, on the US EPA label. Please note : E3 is not marked on the engine.

[Example: Engine model name WG1605-G/L/N/GL/LN/GLN-E3-XXXX]

3. Cylinder number



The cylinder numbers of KUBOTA gasoline, gasoline / LPG and natural gas engine are designated as shown in the figure.
The sequence of cylinder numbers is given as No.1, No.2, No.3 and No.4 starting the gear case side.

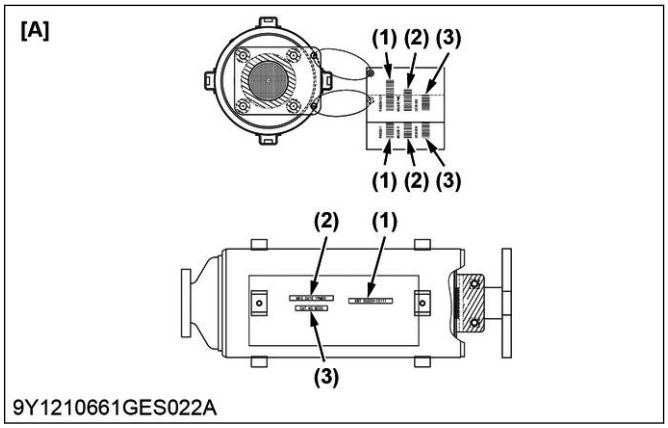
4. Catalytic muffler / converter

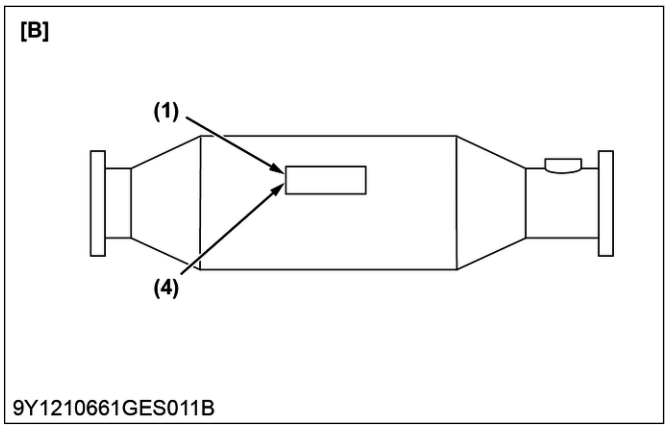
IMPORTANT

- **To trace of the catalytic muffler/converter, put down the catalyst identification and engine identification when new service catalytic muffler/converter is installed.**

NOTE

- **New service catalytic muffler/converter has the bar code tag of the catalyst identification as the figure.**
- **Catalyst identification are catalyst lot number, parts number and manufacturing date.**
- **Engine identification are engine model name, code number and serial number.**



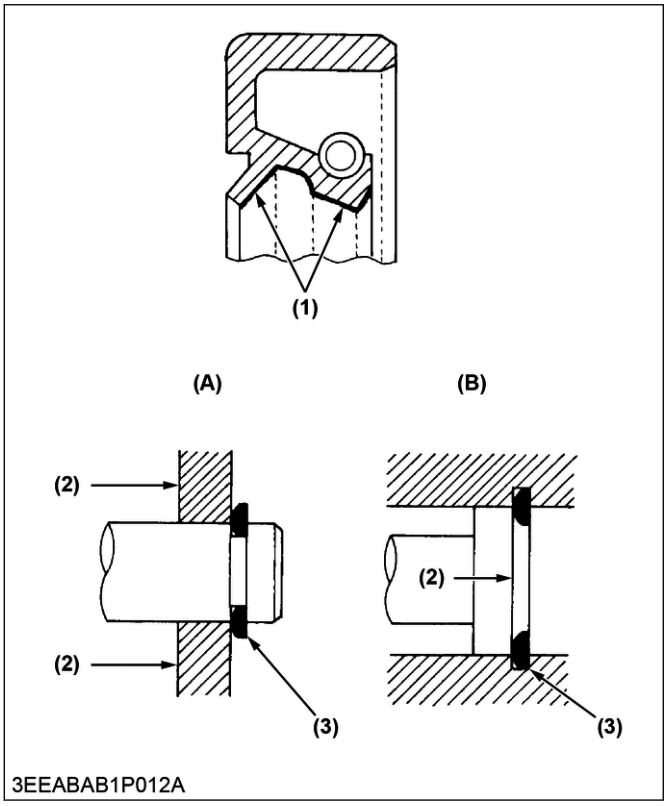


(1) Part number
(2) Manufacturing date 5 digits
(3) Catalyst lot number 4 digits
(4) Date / Serial number
[A] Catalytic muffler
[B] Catalytic converter

Kubota provides the catalytic muffler and converter as the catalyst parts.
The parts number, the manufacturing date and the catalyst lot number are marked on surfaces of the catalyst parts as the catalyst identification.

GENERAL PRECAUTIONS

- During disassembly, carefully arrange removed parts in a clean area to prevent confusion later. Screws, bolts and nuts should be replaced in their original position to prevent reassembly errors.
- When special tools are required, use Kubota genuine special tools. Special tools which are not frequently used should be made according to the drawings provided.
- Before disassembling or servicing live wires, make sure to always disconnect the grounding cable from the battery first.
- Remove oil and dirt from parts before measuring.
- Use only Kubota genuine parts for parts replacement to keep engine performance and to ensure safety.
- You must replace the gaskets and O-rings when you assemble again. Apply grease (1) to new O-rings or oil seals before you assemble.
- When reassembling external or internal circlips, position them so that sharp edge faces against the direction from which a force is applied.
- Be sure to perform run-in the serviced or reassemble engine. Do not try to give heavy load at once, or serious damage may result to the engine.



(1) Grease
(2) Force
(3) Place the sharp edge the direction of force
(A) External circlip
(B) Internal circlip

MAINTENANCE CHECK LIST

To keep long-lasting and safe engine performance, make it a rule to do regular inspections by following the table below. (The schedule applies to an engine in use under normal conditions.)

CAUTION

- **When changing or inspecting, be sure to level and stop the engine.**

[WG1605-E3]

	Item	Service interval								
		Every 8 hrs (Daily)	Every 50 hrs (Weekly)	Every 100 hrs	Every 200 hrs	Every 500 hrs	Every 1000 hrs	Every 2000 hrs	Every 1 year	Every 2 years
	Checking engine oil level	☆								
	Checking and fill coolant	☆								
	Checking air cleaner element	if necessary								
	Cleaning air cleaner element	if necessary		☆						
	Checking LPG / natural gas tank setting condition	if necessary								
	Checking LPG / natural gas fuel connector	☆								
	Changing engine oil		★		☆					
	Replacing oil filter cartridge		★		☆					
	Checking gasoline fuel hose and clamp bands		☆							
	Checking LPG / natural gas fuel hose and clamp bands		☆							
	Cleaning spark plug			☆						
	Checking fuel filter			☆						
	Check fan belt tension and damage			☆						
	Replacing fuel filter			if necessary					☆	
	Checking LPG / natural gas tank setting condition				☆				Natural gas only	
	Replacing fan belt					☆				
	Checking radiator hoses and clamp bands				☆					
	Checking PCV valve						☆			
	Checking coolant hose of LPG / natural gas vaporizer						☆			
	Checking LPG / natural gas lock off valve						☆			
	Checking valve clearance						☆			
	Replacing spark plug							if necessary		
*	Replacing air cleaner element								☆	
	Replacing gasoline fuel hose, clamp bands and fuel filter								☆	
	Cleaning fuel tank inside (for gasoline fuel)								☆	
	Cleaning water jacket and radiator interior								☆	

(Continued)

Item		Service interval								
		Every 8 hrs (Daily)	Every 50 hrs (Weekly)	Every 100 hrs	Every 200 hrs	Every 500 hrs	Every 1000 hrs	Every 2000 hrs	Every 1 year	Every 2 years
	Replacing intake air line									☆
	Replacing breather hose									☆
	Replacing LPG / natural gas fuel hose and clamp bands									☆
	Replacing coolant hose of LPG / natural gas vaporizer									☆
**	Checking LPG / natural gas vaporizer									☆
	Replacing radiator hoses and clamp bands									☆
	Replacing lock-off valve filter									☆
	Changing radiator coolant									☆

★ Change engine oil and replace oil filter cartridge after the first 50 hours of operation.

* Change more often when operating under dusty conditions.

** If you do not have the proper tools and / or are not mechanically proficient, contact your local KUBOTA dealer.

CHECK AND MAINTENANCE

1. Daily check points

1.1 Checking engine oil level

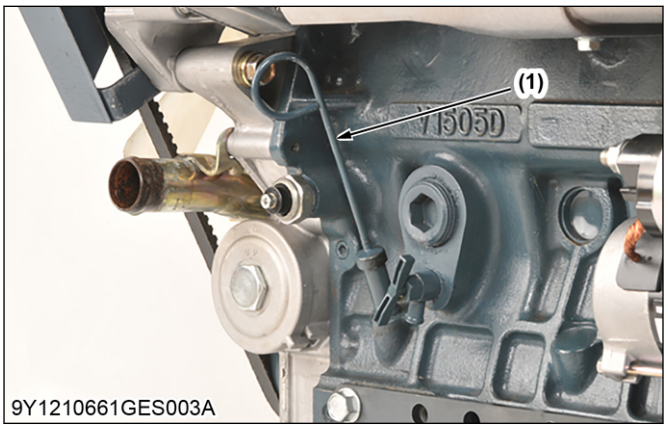
■ IMPORTANT

- **When using an oil of different maker or viscosity from the previous, drain old oil. Never mix two different types of oil.**
- **Use the proper SAE Engine oil according to ambient temperatures.**

■ NOTE

- **Be sure to inspect the engine, locating it on a horizontal place. If placed on gradients, accurately, oil quantity may not be measured.**
- **Be sure to keep the oil level between upper and lower limits of the dipstick. Too much oil may cause a drop in output or excessive blow-by gas. On the closed breather type engine in which mist is sucked through port, too much oil may caused oil hammer. While too little oil, may seize the engine's rotating and sliding parts.**

1. Level the engine.
2. To check the oil level, draw out the dipstick (1), wipe it clean, reinsert it, and draw it out again.



(1) Dipstick

3. Check to see that the oil level lies between the two notches.
4. If the level is too low, add new oil to the specified level.

1.2 Checking and fill coolant

⚠ CAUTION

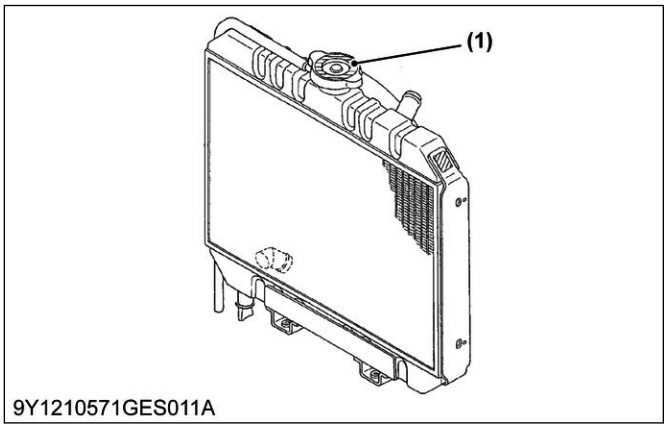
- **Do not remove the radiator cap until coolant temperature is below its boiling point. Then loosen the cap slightly to relieve any excess pressure before removing the cap completely.**

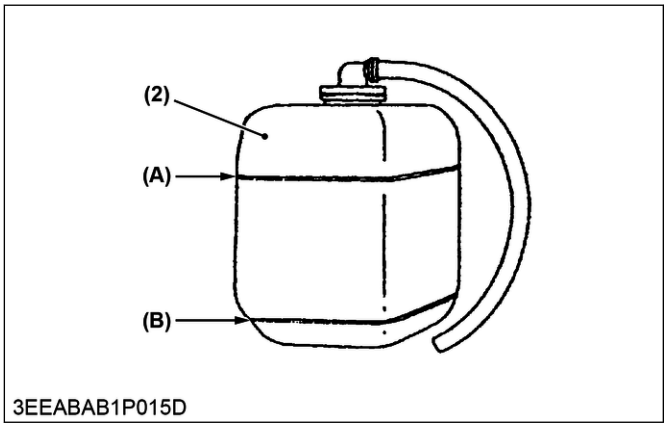
■ IMPORTANT

- **During filling the coolant, air must be vented from the engine coolant passages. The air vents by jiggling the radiator upper and lower hoses.**
- **Be sure to close the radiator cap securely. If the cap is loose or improperly closed, coolant may leak out and the engine could overheat.**
- **Do not use an antifreeze and scale inhibitor at the same time.**
- **Never mix the different type or brand of L.L.C..**

1. Without recovery tank (2), Remove the radiator cap (1) and check to see that the coolant level is just below the port.

2. With recovery tank (2), Check to see that the coolant level lies between FULL (A) and LOW (B).



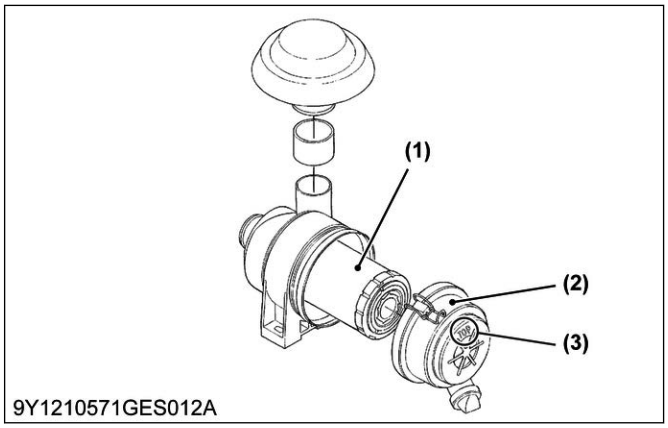


(1) Radiator cap
(2) Recovery tank
(A) FULL
(B) LOW

3. If coolant level is too low, check the reason for decreasing coolant.
   a. If coolant is decreasing by evaporation, fill only fresh, soft water.
   b. If coolant is decreasing by leak, fill coolant of the same manufacture and type in the specified mixture ratio (fresh, soft water and L.L.C.). If the coolant brand cannot be identified, drain out all of the remaining coolant and refill with a totally new brand of coolant mix.

1.3 Checking air cleaner element (If necessary)

1. Remove the dust cup in the air cleaner.
2. Check the dust in the dust cup and the element.



(1) Element
(2) Dust cap
(3) "TOP" mark

(When reassembling)
- Install the air cleaner dust cup with **[TOP]** indicated on the rear of the cup.

1.4 Cleaning air cleaner element (If necessary)

NOTE
- **The air cleaner uses a dry element. Never apply oil to it.**
- **Do not run the engine with filter element removed.**
- **Change the element once a year or every 6th cleaning.**

1. Remove the air cleaner element.
2. Use clean dry compressed air on the inside of the element.
   Pressure of compressed air must be under 205 kPa (2.1 kgf/cm^2, 30 psi).
   Keep reasonable distance between the nozzle and the filter.

1.5 Checking LPG / natural gas tank setting condition (If necessary)

WG1605-L-E3, WG1605-GL-E3

1. Check the setting condition of LPG / natural gas fuel tank.

1.6 Checking LPG / natural gas fuel connector

WG1605-L-E3, WG1605-GL-E3

1. Check the connector of LPG / natural gas line (hoses and clamps).

2. Check points of initial 50 hours

2.1 Changing engine oil

CAUTION

- **Be sure to stop engine before changing engine oil.**

IMPORTANT

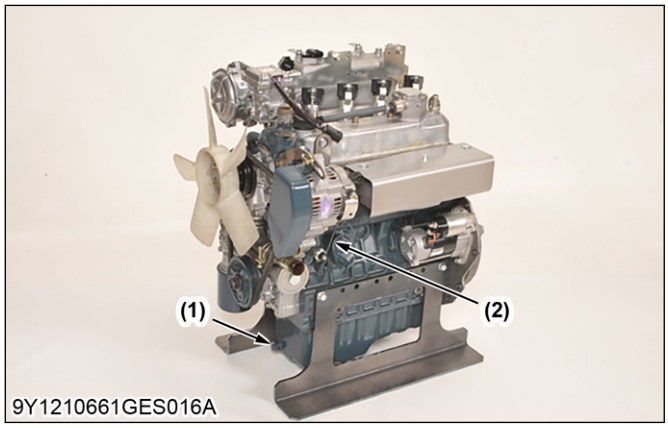
- **When using an oil of different maker or viscosity from the previous one, remove all of the old oil.**
- **Never mix two different types of oil.**
- **Engine oil should have properties of API classification better than SH.**
- **Use the proper SAE engine oil according to ambient temperature.**

Above 25 ℃ (77 ℉)	SAE30 or SAE10W-30 or SAE15W-40
0 ℃ to 25 ℃ (32 ℉ to 77 ℉)	SAE20 or SAE10W-30
0 ℃ to -20 ℃ (32 ℉ to -4 ℉)	SAE10W or SAE10W-30

1. Start and warm up the engine for approx. 5 minutes.
2. Place an oil pan underneath the engine.
3. To drain the used oil, remove the drain plug (1) at the bottom of the engine and drain the oil completely.

Engine oil capacity	6.0 L 1.6 U.S. gals

4. Screw the drain plug (1).
5. Fill new oil up to upper line on the dipstick (2).



(1) Drain plug (2) Dipstick

Tightening torque	Drain plug	32.4 to 37.3 N·m 3.31 to 3.80 kgf·m 23.9 to 27.5 lbf·ft

2.2 Replacing oil filter cartridge

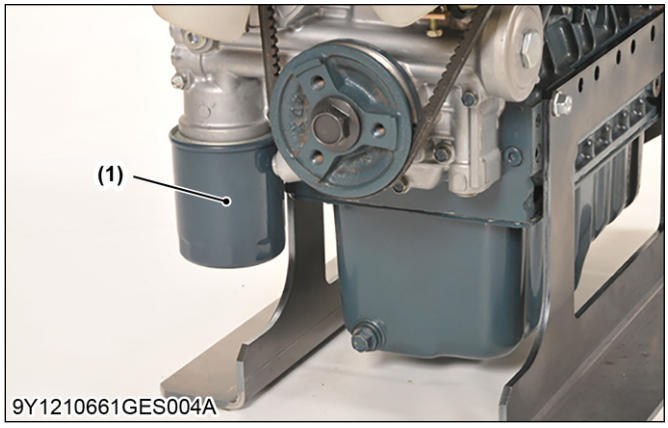
CAUTION

- **Be sure to stop the engine before changing the oil filter cartridge.**

IMPORTANT

- **To prevent serious damage to the engine, replacement element must be highly efficient. Use only a Kubota genuine filter or its equivalent.**

1. Remove the engine oil filter cartridge (1) with the filter wrench.



(1) Engine oil filter cartridge

2. Apply a slight coat of oil onto the new cartridge gasket.
3. To install the new cartridge, screw it in by hand. Over tightening may cause deformation of rubber gasket.

4. After the new cartridge has been replaced, the engine oil normally decrease a little. Thus see that the engine oil does not leak through the seal and be sure to read the oil level on the dipstick. Then, fill the engine oil up to the specified level.

3. Check points of every 50 hours

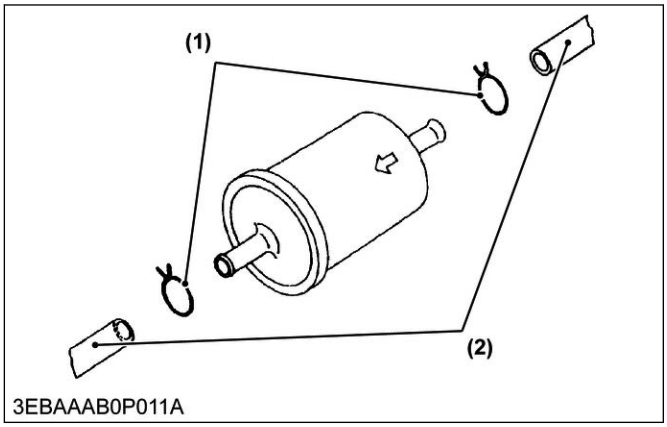
⚠ CAUTION

- **Stop the engine when trying the check and replace prescribed below.**
- **Make sure to check the fuel line periodically. The fuel line is subject to wear and aging, fuel may leak out onto the running engine, causing a fire.**

3.1 Checking gasoline fuel hose and clamp bands

Check the fuel hoses every 50 hours of operation.

1. Use good engineering judgment to ensure that all fuel-line fittings will remain securely connected to prevent fuel leakage throughout the useful life of the equipment.
   Replace the fuel hose together with the clamp every year.
2. If the fuel hose and clamp are found to be damaged or deteriorate earlier than year, then replace or remedy.
3. After the fuel hose and the clamp have been replaced, make sure that there is no fuel leakage.



(1) Clamp (2) Fuel hose

3.2 Checking LPG / natural gas fuel hose and clamp bands

WG1605-L-E3, WG1605-N-E3, WG1605-GL-E3, WG1605-LN-E3, WG1605-GLN-E3

■ IMPORTANT

- **Never test for gas leaks with a flame.**

■ NOTE

- **Check for fuel leakage with soapy water or gas-detector, if leakage is found, correct leakage or replace the hose.**

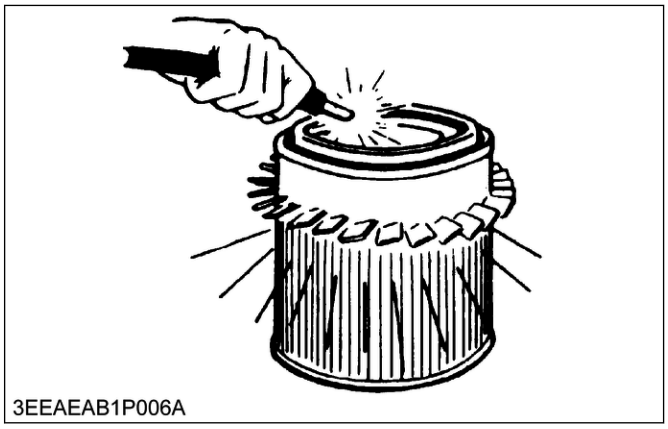
4. Check points of every 100 hours

4.1 Cleaning air cleaner element

■ NOTE

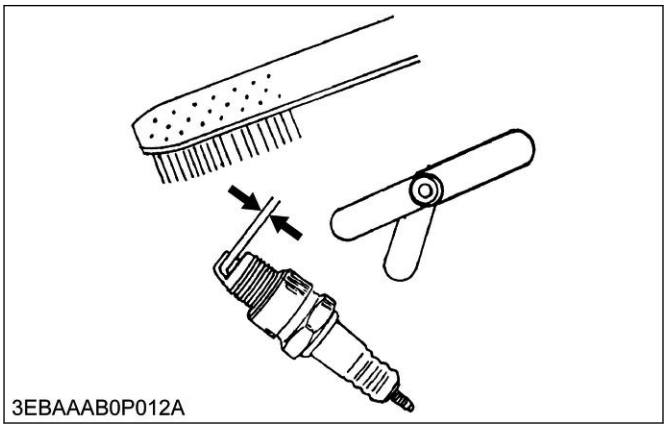
- **The air cleaner uses a dry element. Never apply oil to it.**
- **Do not run the engine with filter element removed.**
- **Change the element once a year or every 6th cleaning.**

1. Remove the air cleaner element.
2. Use clean dry compressed air on the inside of the element.
   Pressure of compressed air must be under 205 kPa (2.1 kgf/cm^2, 30 psi).
   Keep reasonable distance between the nozzle and the filter.



4.2 Cleaning spark plug (If necessary)

1. Remove the spark plug, and remove carbon from the electrode with a wire brush or other tools.



2. Measure the spark plug gap with a feeler gauge, and adjust or replace the spark plug if the measured gap differs from the Service specification.

Spark plug gap	Service specification	0.70 to 0.80 mm 0.028 to 0.031 in.

3. Replace the spark plug if the electrode or the insulator is deformed or cracked.
4. Tighten the spark plug with a plug wrench.

Spark plug	NGK IFR6F8DN

Tightening torque	Spark plug	24.5 to 29.4 N·m 2.50 to 2.99 kgf·m 18.1 to 21.6 lbf·ft

(When reassembling)

■ IMPORTANT

- **Put the ignition coil inside the spark plug terminal firmly.**
- **Make sure that the wiring and the ignition coil are correctly connected.**
- **Fix the ignition coil by screw / nut.**

Tightening torque	Ignition coil mounting screw / nut	9.81 to 11.3 N·m 1.00 to 1.15 kgf·m 7.24 to 8.33 lbf·ft

4.3 Checking fuel filter

⚠ CAUTION

- **Stop the engine when trying to check and clean the fuel filter.**
- **Gasoline fuel is extremely flammable, so avoid fires.**

1. Check the fuel filter.
2. If the fuel filter is dirty, clean it or replace it.

4.4 Checking fan belt tension

Tools required

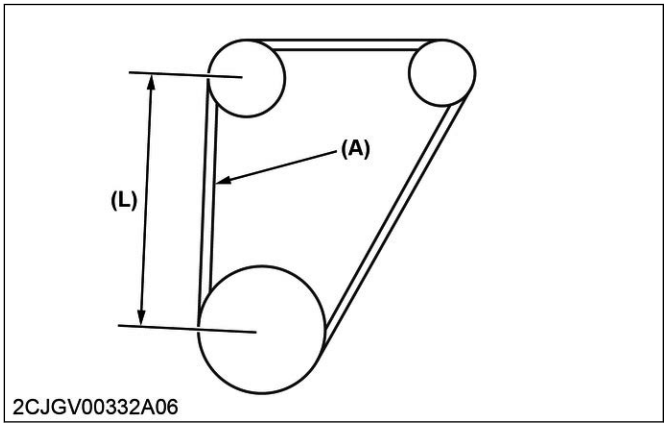
- Sonic belt tension meter

1. Check the tension of fan belt at the position (A) between the fan drive pulley and alternator pulley with sonic belt tension meter.

■ NOTE
- **If the measurement is out of the service specifications, loosen the alternator mounting screws and adjust its position.**

Sonic belt tension meter setting value	
Mass (Mass per 1 rib 1 m of belt)	75 g/rib/m
Width (Number of ribs)	1
Span L	Measure at location (A) in the figure with (L) as the distance between the fan drive pulley and alternator pulley.

Belt tension	Service specification	200 to 300 N 20.4 to 30.5 kgf 45.0 to 67.4 lbf



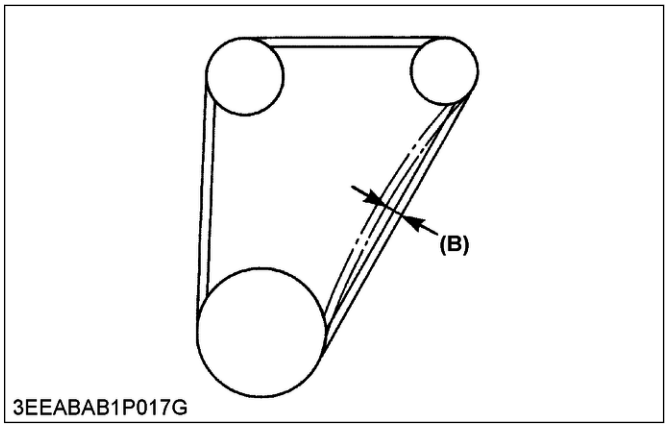
(A) Fan belt halfway

(Reference)
- If you can not prepare the sonic belt tension meter, check the fan belt tension by next procedure.

a. Push the belt halfway between the fan drive pulley and alternator pulley at a specified force to measure the deflection (1).

■ NOTE
- **If the measurement is out of the service specifications, loosen the alternator mounting screws and adjust its position.**

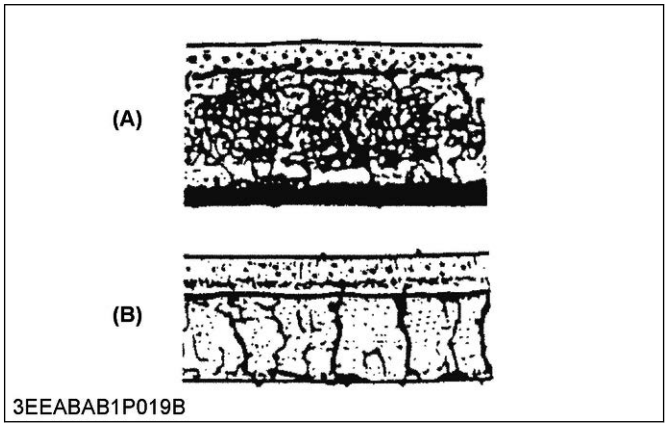
Deflection (B)	Service specification	10.0 mm 0.39 in. (Under load of 98 N (10 kgf, 22 lbf))



(B) Deflection

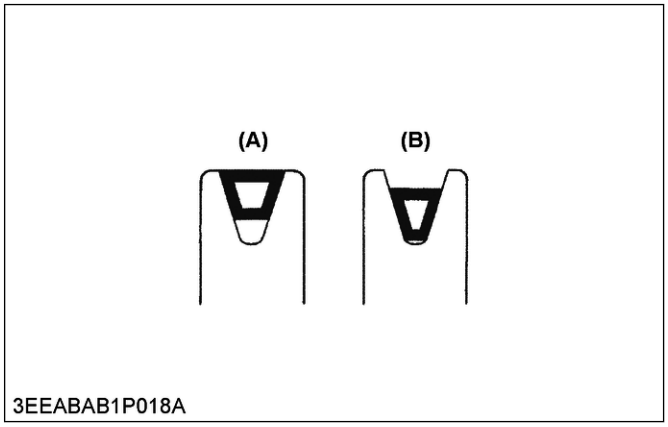
4.5 Checking fan belt damage and wear

1. Check the fan belt for damage.



(A) Good (B) Bad

2. If the fan belt is damaged, replace it.
3. Check if the fan belt is worn and sunk in the pulley groove.



(A) Good (B) Bad

4. If the fan belt is nearly worn out and deeply sunk in the pulley groove, replace it.

5. Check points of every 200 hours

5.1 Changing engine oil

CAUTION
- **Be sure to stop engine before changing engine oil.**

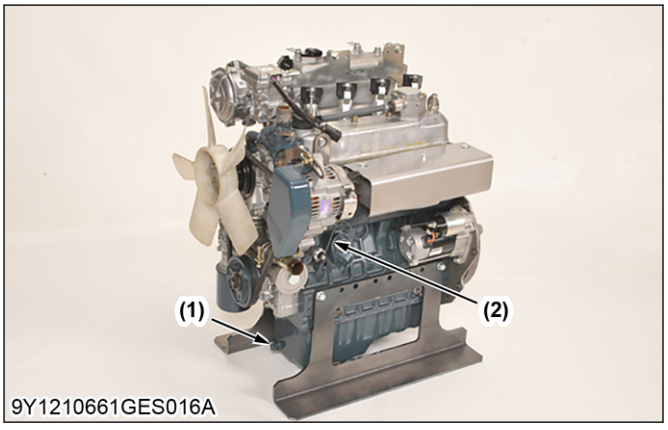
IMPORTANT
- **When using an oil of different maker or viscosity from the previous one, remove all of the old oil.**
- **Never mix two different types of oil.**
- **Engine oil should have properties of API classification better than SH.**
- **Use the proper SAE engine oil according to ambient temperature.**

Above 25 ℃ (77 ℉)	SAE30 or SAE10W-30 or SAE15W-40
0 ℃ to 25 ℃ (32 ℉ to 77 ℉)	SAE20 or SAE10W-30
0 ℃ to -20 ℃ (32 ℉ to -4 ℉)	SAE10W or SAE10W-30

1. Start and warm up the engine for approx. 5 minutes.
2. Place an oil pan underneath the engine.
3. To drain the used oil, remove the drain plug (1) at the bottom of the engine and drain the oil completely.

Engine oil capacity	6.0 L 1.6 U.S. gals

4. Screw the drain plug (1).
5. Fill new oil up to upper line on the dipstick (2).



(1) Drain plug (2) Dipstick

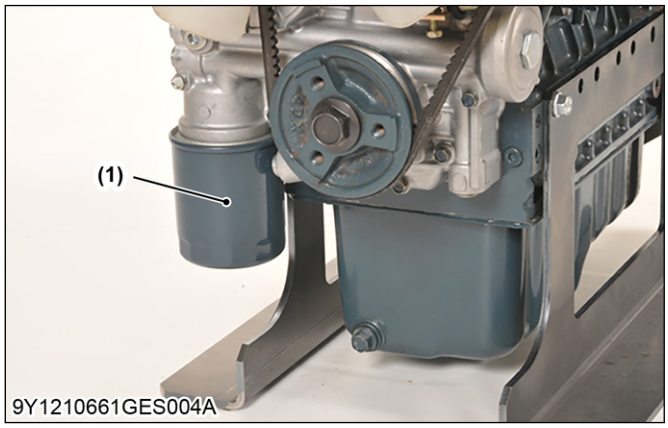
Tightening torque	Drain plug	32.4 to 37.3 N·m 3.31 to 3.80 kgf·m 23.9 to 27.5 lbf·ft

5.2 Replacing oil filter cartridge

CAUTION
- **Be sure to stop the engine before changing the oil filter cartridge.**

IMPORTANT
- **To prevent serious damage to the engine, replacement element must be highly efficient. Use only a Kubota genuine filter or its equivalent.**

1. Remove the engine oil filter cartridge (1) with the filter wrench.



(1) Engine oil filter cartridge

2. Apply a slight coat of oil onto the new cartridge gasket.
3. To install the new cartridge, screw it in by hand. Over tightening may cause deformation of rubber gasket.
4. After the new cartridge has been replaced, the engine oil normally decrease a little. Thus see that the engine oil does not leak through the seal and be sure to read the oil level on the dipstick. Then, fill the engine oil up to the specified level.

5.3 Checking LPG / natural gas tank setting condition

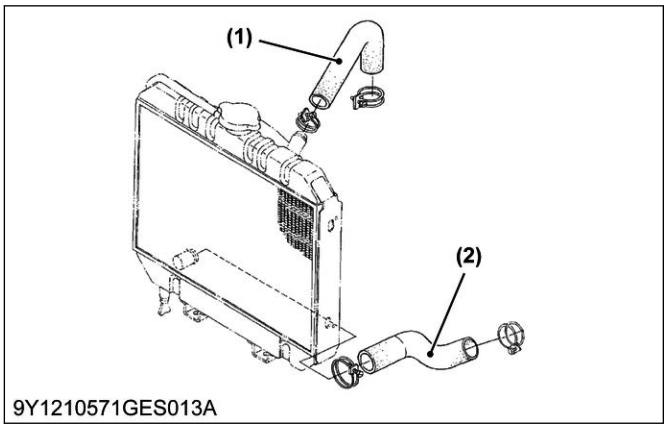
WG1605-L-E3,WG1605-N-E3, WG1605-GL-E3, WG1605-LN-E3, WG1605-GLN-E3

1. Check the setting condition of LPG / natural gas fuel tank.

5.4 Checking radiator hoses and clamp bands

1. Check to see if the radiator hoses are properly fixed every 200 hours of operation or every six months, whichever comes first.

2. If the clamp is loose, apply oil to the threads and retighten it securely.
3. The coolant hose is made of rubber and tends to age. It must be replaced every two years. Also replace the clamp and tighten it securely.

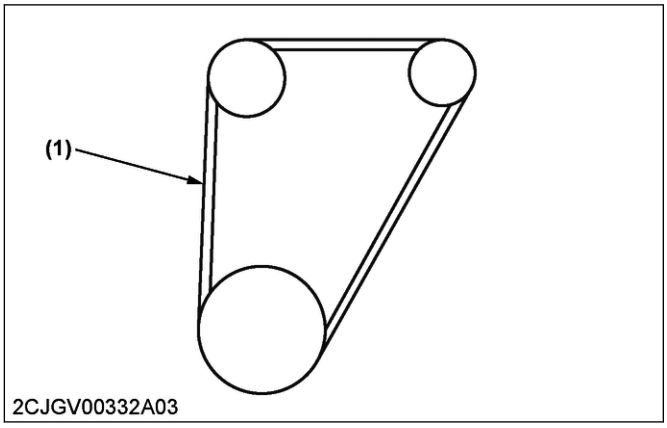


(1) Upper hose (2) Lower hose

6. Check points of every 500 hours

6.1 Replacing fan belt

1. Remove the alternator.
2. Remove the fan belt (1).

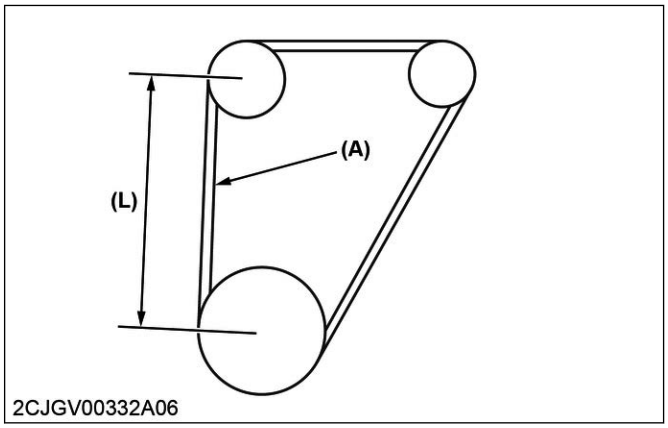


(1) Fan belt

3. Replace new fan belt.
4. Install the alternator.
5. Check and adjust the fan belt tension.

Sonic belt tension meter setting value	
Mass (Mass per 1 rib 1 m of belt)	75 g/rib/m
Width (Number of ribs)	1
Span L	Measure at location (A) in the figure with (L) as the distance between the fan drive pulley and alternator pulley.

Belt tension	Service specification	267 to 361 N 27.3 to 36.8 kgf 60.1 to 81.1 lbf



(A) Fan belt halfway

(Reference)

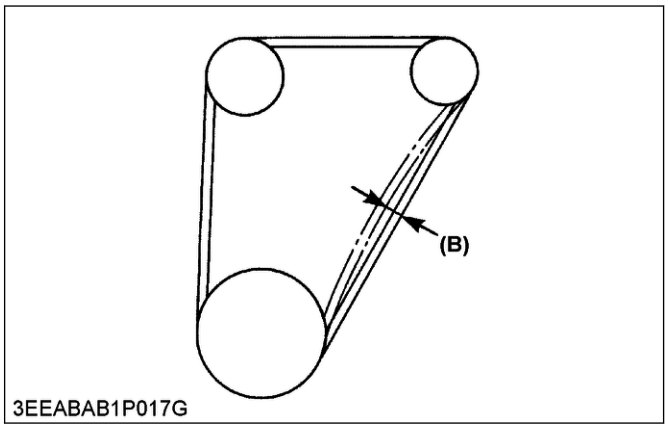
- If you can not prepare the sonic belt tension meter, check the fan belt tension by next procedure.

a. Push the belt halfway between the fan drive pulley and alternator pulley at a specified force to measure the deflection (1).

■ NOTE

- **If the measurement is out of the service specifications, loosen the alternator mounting screws and adjust its position.**

Deflection (B)	Service specification	10.0 mm 0.39 in. (Under load of 98 N (10 kgf, 22 lbf))

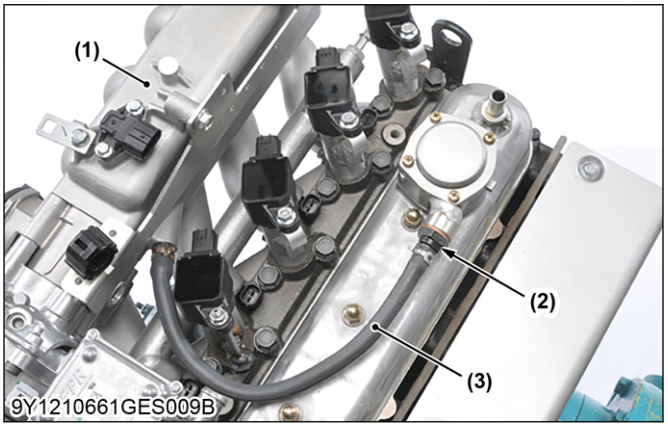


(B) Deflection

7. Check points of every 1000 hours

7.1 Checking PCV valve

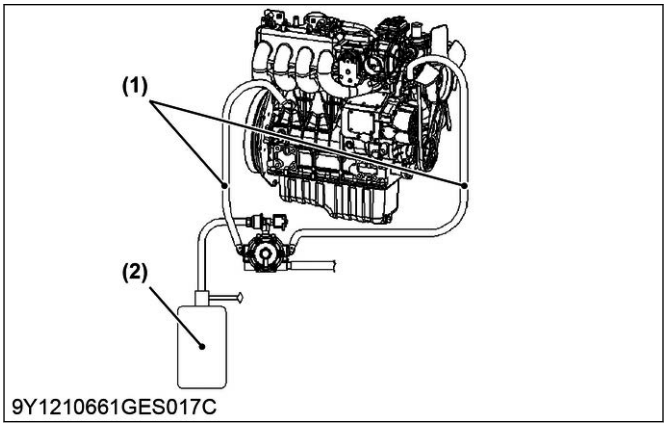
1. Disconnect the breather hose (3) from the intake manifold (1).
2. Blow into the breather hose (3).
3. Stop to blow.
4. Make sure that a slight operation sound is heard from the PCV valve.
   If there is no operation sound, replace the PCV valve (2).
5. Connect the breather hose (3) to the intake manifold (1).



(1) Intake manifold
(2) PCV valve
(3) Breather hose

7.2 Checking coolant hose of LPG/ natural gas vaporizer

1. Check the coolant hoses (1) for damage.



(1) Coolant hose
(2) LPG/natural gas tank

2. If the coolant hose is damaged, replace it.

7.3 Checking LPG / natural gas lock off valve

1. Start the engine.
2. Make sure that an operation sound of solenoid is heard from the LPG / natural gas lock off valve.
3. Make sure that there is no fuel leakage from the LPG / natural gas lock off valve.
   If there is no operation sound or fuel leakage, replace the LPG / natural gas lock off valve.

7.4 Checking valve clearance

IMPORTANT

- **The valve clearance must be checked and adjusted when engine is cold.**

NOTE

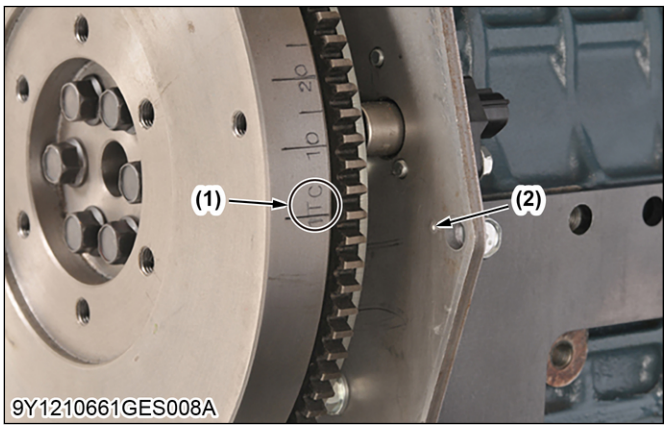
- **The sequence of cylinder numbers is given as No. 1, No. 2, No. 3 and No. 4 starting from the gear case side.**
- **After adjusting the valve clearance, secure the adjusting screw with the lock nut.**

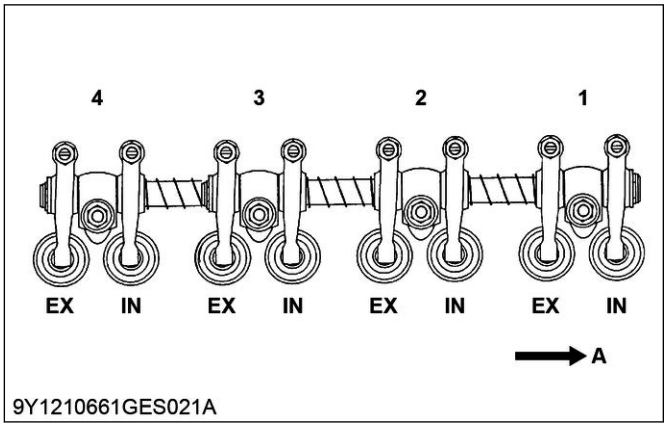
Tools required

- Feeler gauge

1. Remove the cylinder head cover.

2. Align the **[1TC]** mark (1) on the flywheel and alignment mark (2) on the rear end plate so that the No. 1 piston comes to the compression top dead center.

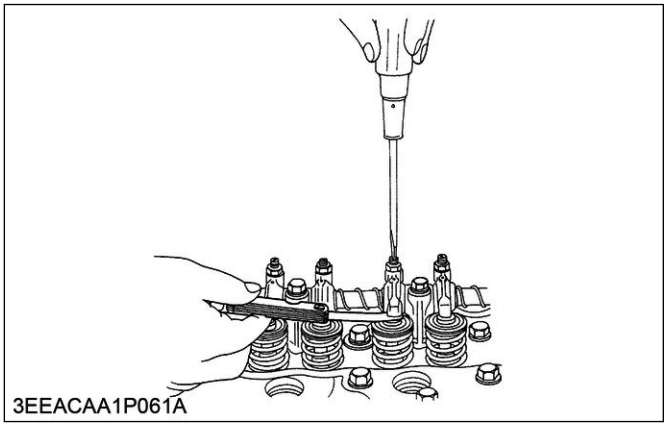




(1) **[1TC]** mark
(2) Alignment mark
A: Gear case side

3. Check the following valve clearance marked with "☆" using a feeler gauge.

Adjustable cylinder location of piston		Intake valve	Exhaust valve
When No. 1 piston is at compression top dead center.	1st	☆	☆
	2nd	☆	
	3rd		☆
	4th		



4. If the clearance is not within the service specifications, adjust with the adjusting screw.

Intake and exhaust valve clearance (Cold)	Service specification	0.145 to 0.185 mm 0.00571 to 0.00728 in.

5. Then turn the flywheel 6.28 rad (360°), and align the **[1TC]** mark (1) on the flywheel and alignment mark (2) on the rear end plate so that the No. 1 piston comes to the overlap position.
6. Check the following valve clearance marked with "☆" using a feeler gauge.

Adjustable cylinder location of piston		Intake valve	Exhaust valve
When No. 1 piston is at overlap position.	1st		
	2nd		☆
	3rd	☆	
	4th	☆	☆

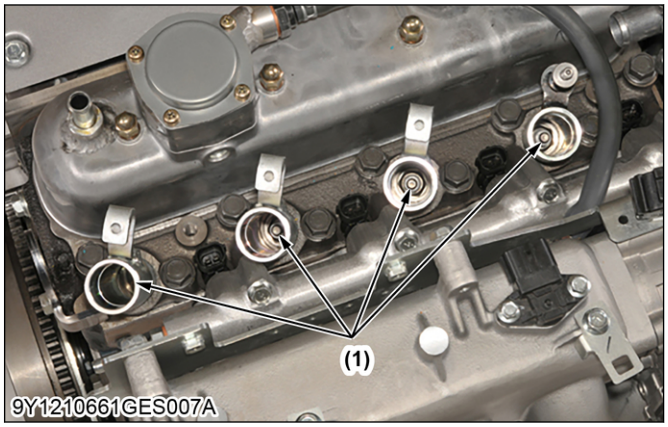
7. If the clearance is not within the service specifications, adjust with the adjusting screw.

Intake and exhaust valve clearance (Cold)	Service specification	0.145 to 0.185 mm 0.00571 to 0.00728 in.

8. Check points of every 2000 hours

8.1 Replacing spark plug

1. Disconnect the ignition coil.
2. Remove the spark plug (1).



(1) Spark plug

3. Replace the new spark plug.

4. Tighten the spark plug with a plug wrench.

Spark plug	NGK IFR6F8DN

Tightening torque	Spark plug	24.5 to 29.4 N·m 2.50 to 2.99 kgf·m 18.1 to 21.6 lbf·ft

(When reassembling)

■ IMPORTANT

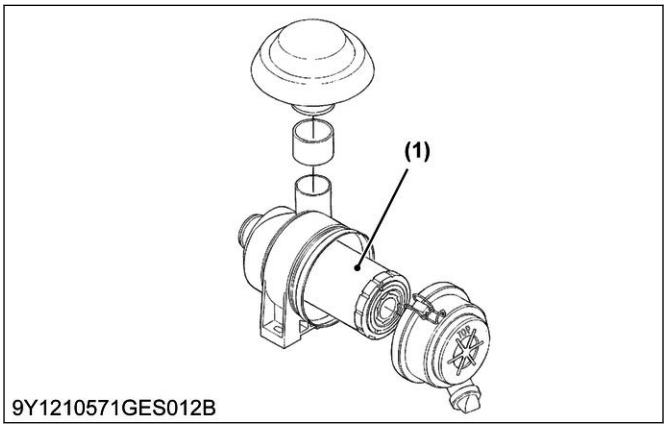
- **Put the ignition coil inside the spark plug terminal firmly.**
- **Make sure that the wiring and the ignition coil are correctly connected.**
- **Fix the ignition coil by screw / nut.**

Tightening torque	Ignition coil mounting screw / nut	9.81 to 11.3 N·m 1.00 to 1.15 kgf·m 7.24 to 8.33 lbf·ft

9. Check points of every 1 year

9.1 Replacing air cleaner element

1. Remove the dust cup from the air cleaner.
2. After cleaning the dust cup, remove the air cleaner element.
3. Replace new air cleaner element.



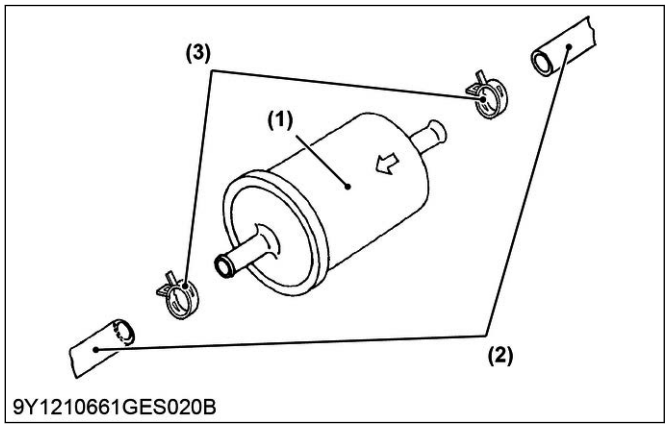
(1) Air cleaner element

9.2 Replacing gasoline fuel hose, clamp bands and fuel filter

⚠ CAUTION

- **In order to reduce the fuel pressure, do not remove the fuel hose at least 3 minutes after stopping the engine.**
- **Remove the hose after covering the hose with a waste to prevent scatter of fuel.**

1. Replace the fuel filter (1) with a new one.
2. Replace the hose (2) and clamp (3).



(1) Fuel filter
(2) Fuel hose
(3) Clamp

9.3 Cleaning fuel tank inside

1. Following the unit/machine's operators manual, drain the gasoline fuel in the fuel tank.
2. Clean the fuel tank inside.

9.4 Cleaning water jacket and radiator interior

⚠ CAUTION

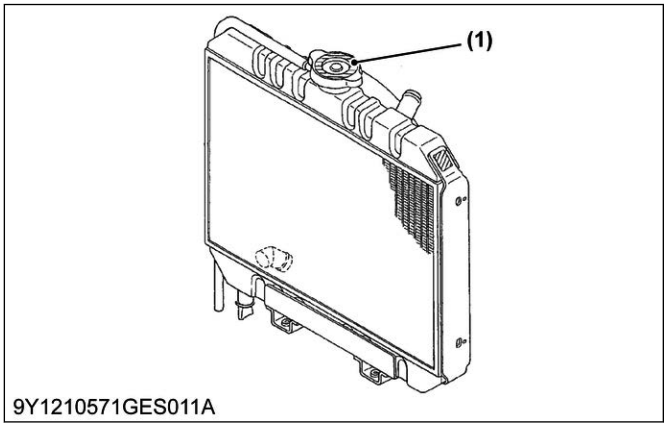
- **Do not remove the radiator cap when the engine is hot.**
  Then loosen cap slightly to the stop to relieve any excess pressure before removing cap completely.

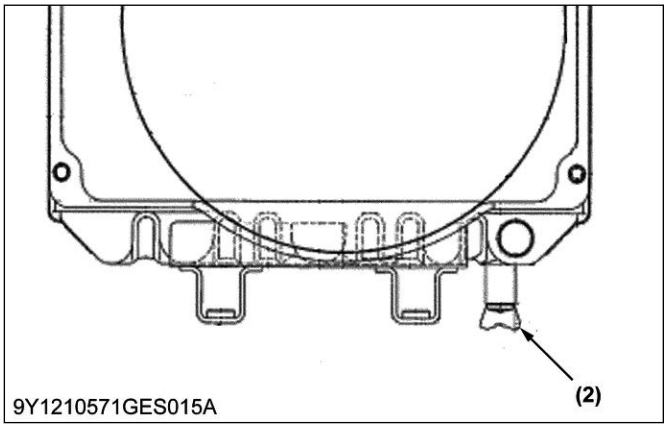
■ IMPORTANT

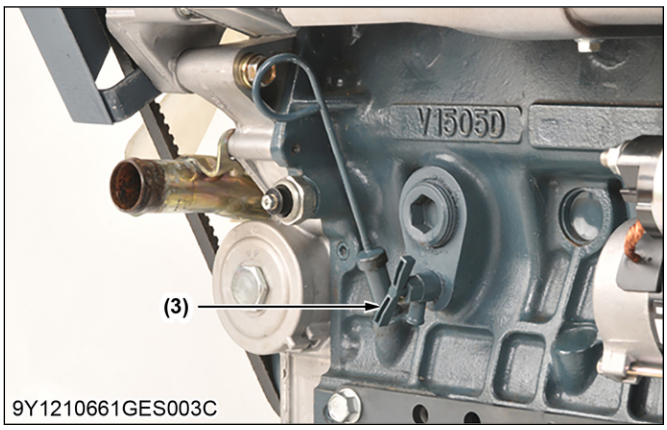
- **Do not start the engine without coolant.**
- **Use clean, fresh, soft water and anti-freeze to fill the radiator and recovery tank.**
- **When the anti-freeze is mixed with fresh, soft water, the anti-freeze mixing ratio must be less than 50 %.**
- **Securely tighten radiator cap.**
  If the cap is loose or improperly fitted, water may leak out and the engine could overheat.

1. Stop the engine and let cool down.

2. To drain the coolant, open the radiator drain plug (2) and remove the radiator cap (1). Then radiator cap (1) must be removed to completely drain the coolant. And open the drain valve (3) of engine body.

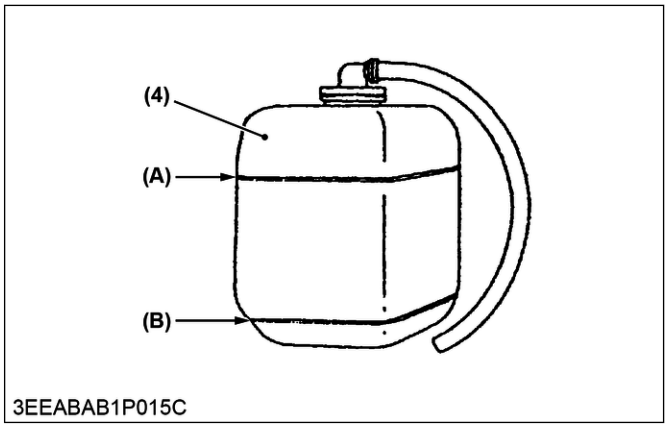






(1) Radiator cap
(2) Drain plug
(3) Drain valve

3. After all coolant is drained, close the drain plug.
4. Fill with clean water and cooling system cleaner.
5. Follow directions of the cleaner instruction.
6. After flushing, fill with clean water and anti-freeze until the coolant level is just below the port. Install the radiator cap (1) correctly.
7. Fill with the coolant up to **[FULL]** (A) mark on the reserve tank (4).



(4) Reserve tank
(A) **[FULL]**
(B) **[LOW]**

8. Start and operate the engine for a few minutes.

9. Stop the engine and let cool. Check coolant level of reserve tank (4) and add coolant if necessary.

Anti-freeze

- There are 2 types of anti-freeze available: use the permanent type (PT) for this engine.
- Before adding anti-freeze for the first time, clean the radiator interior by pouring fresh, soft water and draining it a few times.
- The procedure for mixing water and anti-freeze differs according to the make of the anti-freeze and the ambient temperature. Basically, it should be referred to SAE J1034 standard, more specifically also to SAE J814c.
- Mix the anti-freeze with fresh, soft water, and then fill into the radiator.

■ IMPORTANT

– When the anti-freeze is mixed with fresh, soft water, the anti-freeze mixing ratio must be less than 50 %.

■ NOTE

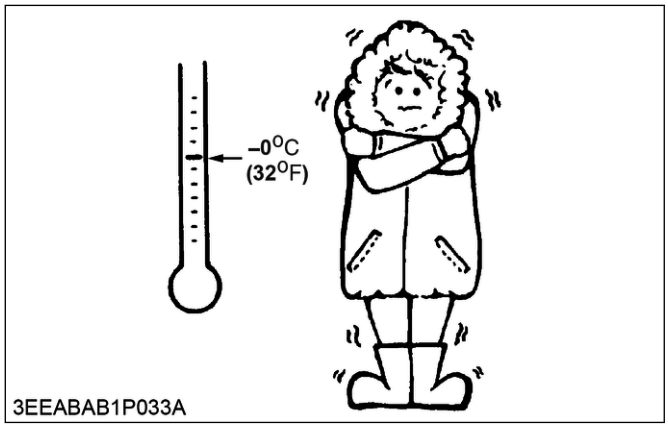
– Following data represents industrial standards that necessitate a minimum glycol content in the concentrated anti-freeze.

Vol % anti-freeze	Freezing point		Boiling point*	
	℃	℉	℃	℉
40	-24	-11	106	223
50	-37	-35	108	226

– When the coolant level drops due to evaporation, add fresh, soft water only to keep the anti-freeze mixing ratio less than 50 %. In case of leakage, add anti-freeze and fresh, soft water in the specified mixing ratio.

– Anti-freeze absorbs moisture. Keep unused anti-freeze in a tightly sealed container.

– Do not use radiator cleaning agents when anti-freeze has been added to the coolant.
(Anti-freeze contains an anti-corrosive agent, which will react with the radiator cleaning agent forming sludge which will affect the engine parts.)



* At 1.01 × 100000 Pa (760 mmHg) pressure (atmospheric). A higher boiling point is obtained by using a radiator pressure cap which permits the development of pressure within the cooling system.

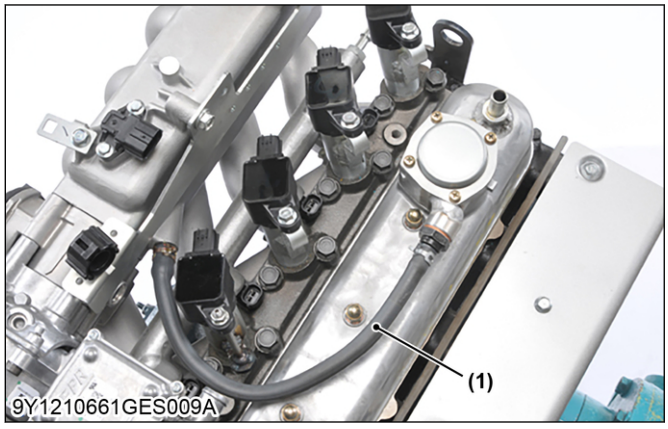
10. Check points of every 2 years

10.1 Replacing intake air line

1. Replace the intake hose and the clamps between the air cleaner and the electronic throttle body or gas mixer.

10.2 Replacing breather hose

1. Replace the breather hose (1) and the clamps between the head cover and the intake manifold.



(1) Breather hose

10.3 Replacing LPG / natural gas fuel hose and clamp bands

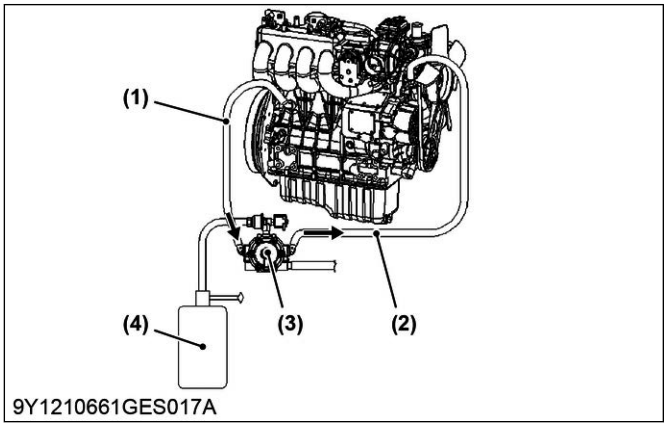
WG1605-L-E3, WG1605-N-E3, WG1605-GL-E3, WG1605-LN-E3, WG1605-GLN-E3

1. Replace the fuel hose and the clamps.

10.4 Replacing coolant hose of LPG/ natural gas vaporizer

WG1605-L-E3, WG1605-N-E3, WG1605-GL-E3, WG1605-LN-E3, WG1605-GLN-E3

1. Connect the new coolant hose (1) and (2) to the vaporizer (3).
2. Fill the coolant to radiator, and bleed the air from the vaporizer (3).

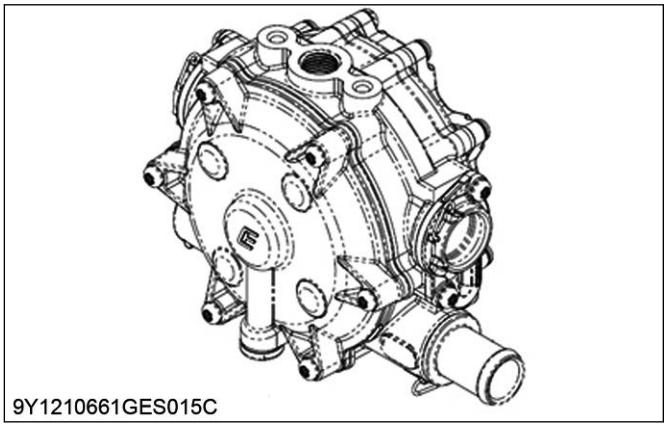


(1) Coolant hose
(2) Coolant hose
(3) Vaporizer
(4) LPG/natural gas tank

10.5 Checking LPG / natural gas vaporizer

WG1605-L-E3, WG1605-N-E3, WG1605-GL-E3, WG1605-LN-E3, WG1605-GLN-E3

1. Make sure that any fuel leaks at the inlet and outlet fittings.
2. Make sure that the mounting bracket to ensure the vaporizer is securely mounted.

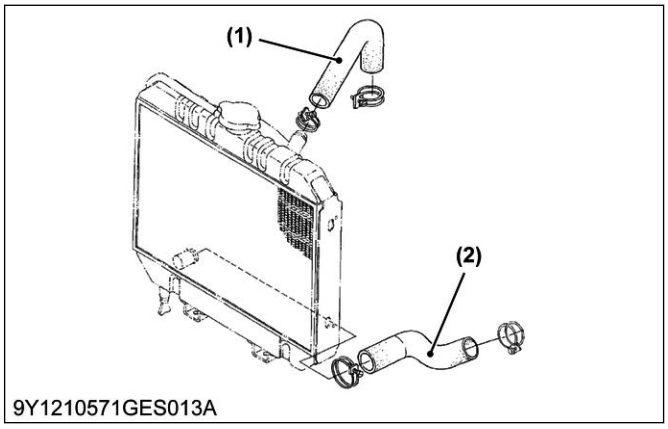


10.6 Replacing radiator hoses and clamp bands

⚠ CAUTION

- **Do not remove the radiator cap when the engine is hot. Then loosen cap slightly to the stop to relieve any excess pressure before removing cap completely.**

1. Drain the coolant.
2. Loosen the clamp bands.
3. Remove the upper hose (1) and lower hose (2).
4. Replace new upper / lower hose (1), (2) and clamp bands.



(1) Upper hose
(2) Lower hose

5. Tighten the clamp bands.
6. Fill with clean water and anti-freeze until the coolant level is just below the port. Install the radiator cap securely.

10.7 Replacing lockoff valve filter

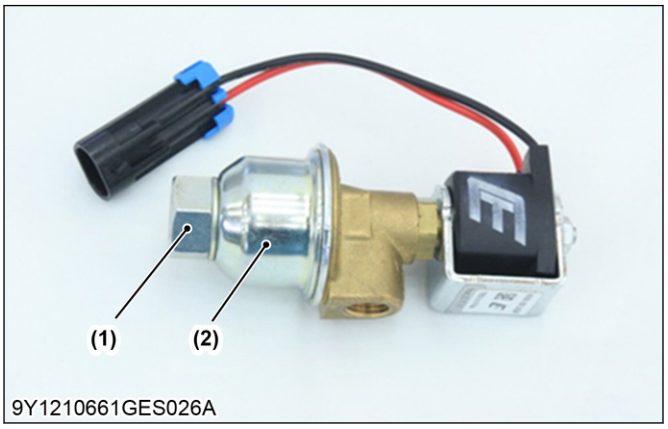
■ NOTE

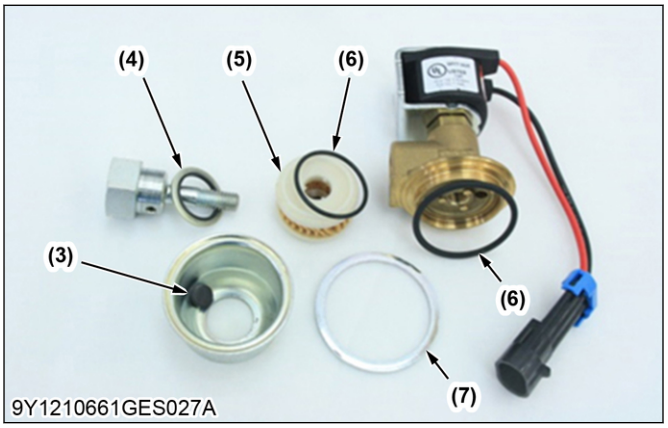
- **When reassemble the spacer ring, be careful of the direction.**

1. Remove the fitting union (1) and open the filter chamber (2).
2. Replace lockoff valve filter (5), magnet (3), seal (4) and O-rings (6).
3. Reassemble lockoff valve filter (5), magnet (3) , seal (4), O-rings (6) and the filter chamber (2).

4. Tighten the fitting union (1) at specific torque.

Tightening torque	Fitting union	11.2 to 12.8 N·m 1.15 to 1.30 kgf·m 8.26 to 9.44 lbf·ft





(1) Fitting union
(2) Filter chamber
(3) Magnet
(4) Seal
(5) Lockoff valve filter
(6) O-ring
(7) Spacer ring

10.8 Changing radiator coolant (L.L.C.)

CAUTION

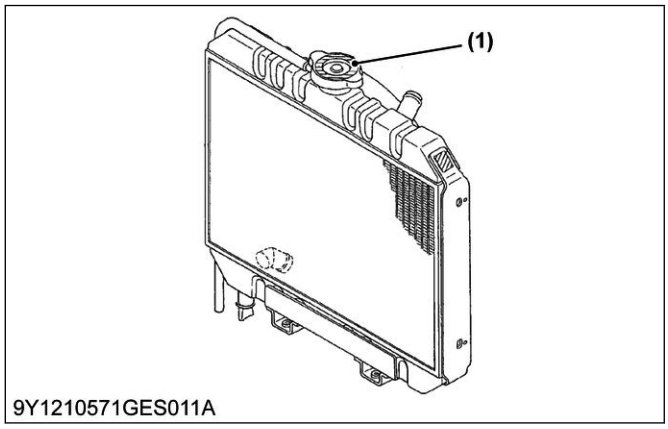
- **Do not remove the radiator cap when the engine is hot.**
  Then loosen cap slightly to the stop to relieve any excess pressure before removing cap completely.

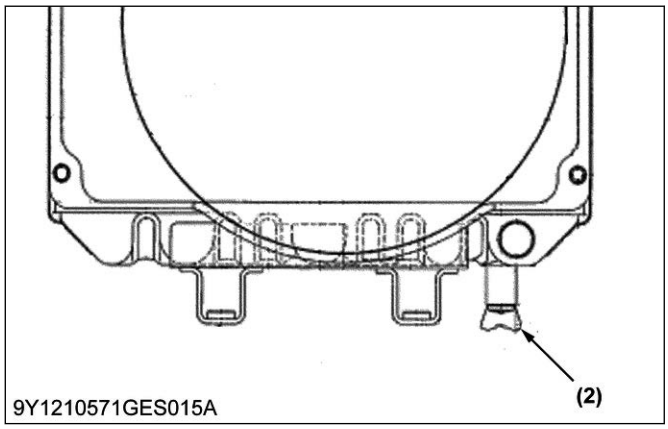
IMPORTANT

- **Do not start the engine without coolant.**
- **Use clean, fresh, soft water and anti-freeze to fill the radiator and recovery tank.**
- **When the anti-freeze is mixed with fresh, soft water, the anti-freeze mixing ratio must be less than 50 %.**
- **Securely tighten radiator cap.**

If the cap is loose or improperly fitted, water may leak out and the engine could overheat.

1. Stop the engine and let cool down.
2. To drain the coolant, open the radiator drain plug (2) and remove the radiator cap (1). Then radiator cap (1) must be removed to completely drain the coolant. And open the drain valve of engine body.

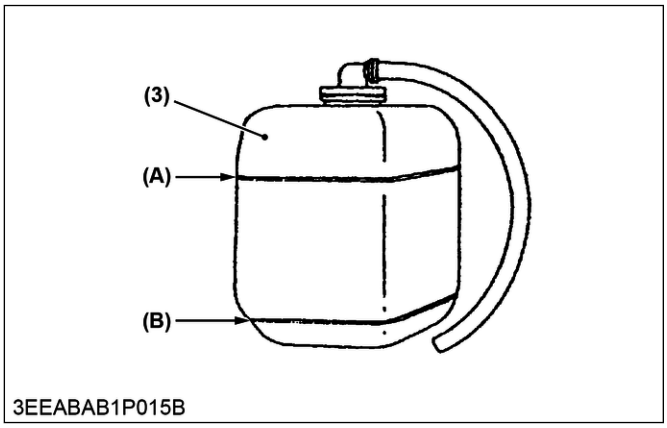




(1) Radiator cap
(2) Drain plug

3. After all coolant is drained, close the drain plug.
4. Fill with clean water and cooling system cleaner.
5. Follow directions of the cleaner instruction.
6. After flushing, fill with clean water and anti-freeze until the coolant level is just below the port. Install the radiator cap (1) correctly.

7. Fill with the coolant up to **[FULL]** (A) mark on the recovery tank (3).



(3) Reserve tank (B) LOW
(A) FULL

8. Start and operate the engine for a few minutes.
9. Stop the engine and let cool. Check coolant level of recovery tank (3) and add coolant if necessary.

Anti-freeze

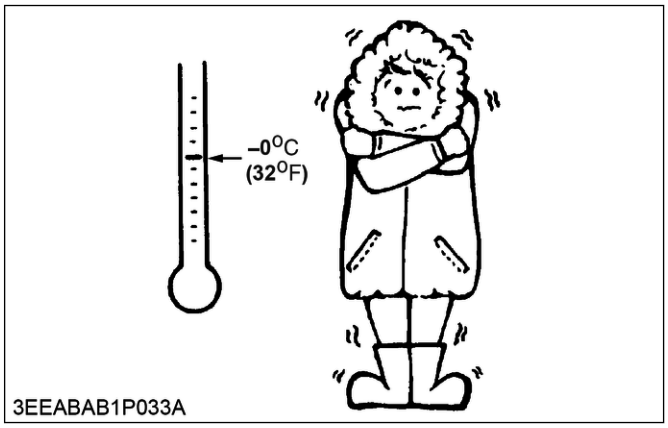
■ NOTE
- **There are 2 types of anti-freeze available: use the permanent type (PT) for this engine.**
- **Before adding anti-freeze for the first time, clean the radiator interior by pouring fresh, soft water and draining it a few times.**
- **The procedure for mixing water and anti-freeze differs according to the make of the anti-freeze and the ambient temperature. Basically, it should be referred to SAE J1034 standard, more specifically also to SAE J814c.**
- **Mix the anti-freeze with fresh, soft water, and then fill into the radiator.**

■ IMPORTANT
- **When the anti-freeze is mixed with fresh, soft water, the anti-freeze mixing ratio must be less than 50 %.**

Vol % anti-freeze	Freezing point		Boiling point*	
	℃	℉	℃	℉
40	-24	-11	106	223
50	-37	-35	108	226

* At 1.01 × 100000 Pa (760 mmHg) pressure (atmospheric). A higher boiling point is obtained by using a radiator pressure cap which permits the development of pressure within the cooling system.

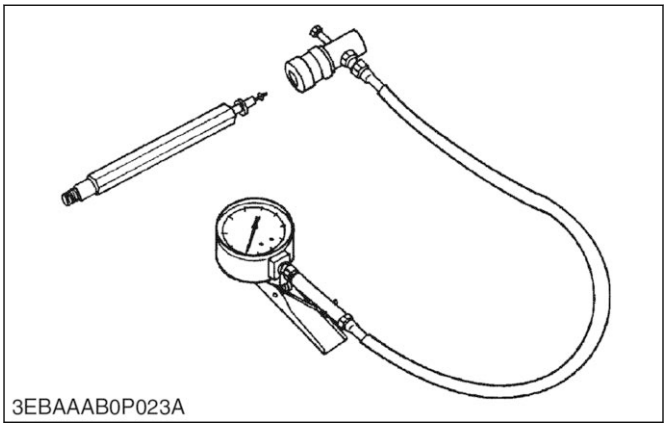
■ NOTE
- **The above data represents industrial standards that necessitate a minimum glycol content in the concentrated anti-freeze.**
- **When the coolant level drops due to evaporation, add fresh, soft water only to keep the anti-freeze mixing ratio less than 50 %. In case of leakage, add anti-freeze and fresh, soft water in the specified mixing ratio.**
- **Anti-freeze absorbs moisture. Keep unused anti-freeze in a tightly sealed container.**
- **Do not use radiator cleaning agents when anti-freeze has been added to the coolant. (Anti-freeze contains an anti-corrosive agent, which will react with the radiator cleaning agent forming sludge which will affect the engine parts.)**



SPECIAL TOOLS

1. Compression tester

Use to measure gasoline engine compression and diagnose the engine for a major overhaul.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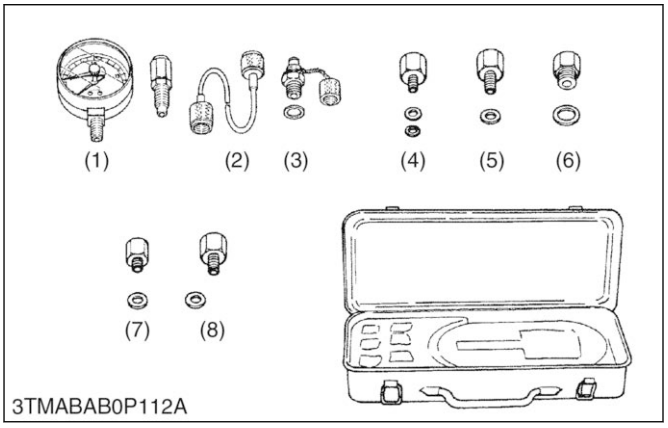
Code No.
07909-30251

2. Oil pressure tester

Use to measure lubricating oil pressure.



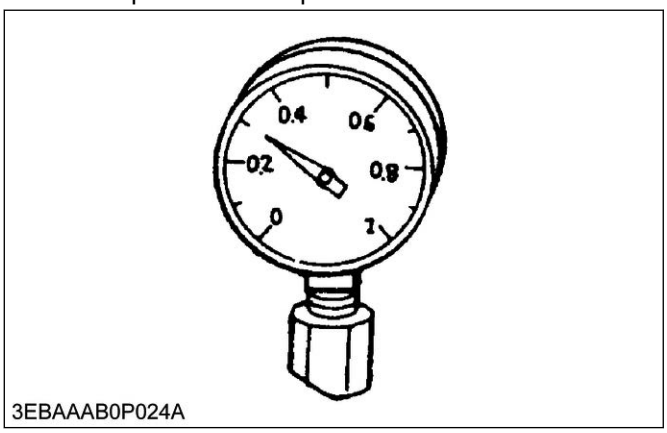
3TMABAB0P112A

(1) Gauge
(2) Cable
(3) Threaded joint
(4) Adaptor 1
(5) Adaptor 2
(6) Adaptor 3
(7) Adaptor 4
(8) Adaptor 5

Code No.
07916-32032

3. Pressure gauge

Check the pressure of vaporizer.



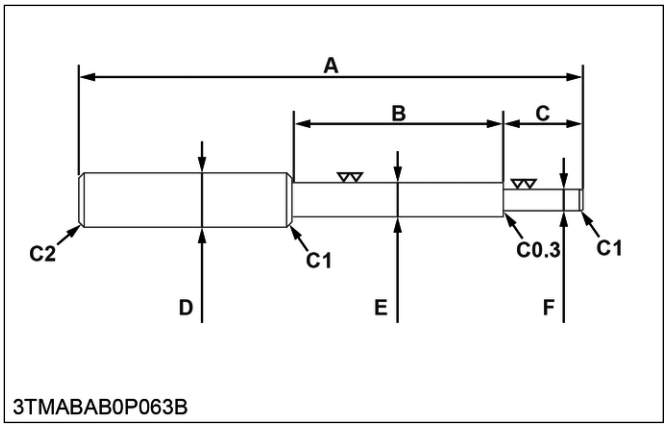
3EBAAAB0P024A

Specification
1745 kPa (17.79 kgf/cm^2, 253.1 psi)

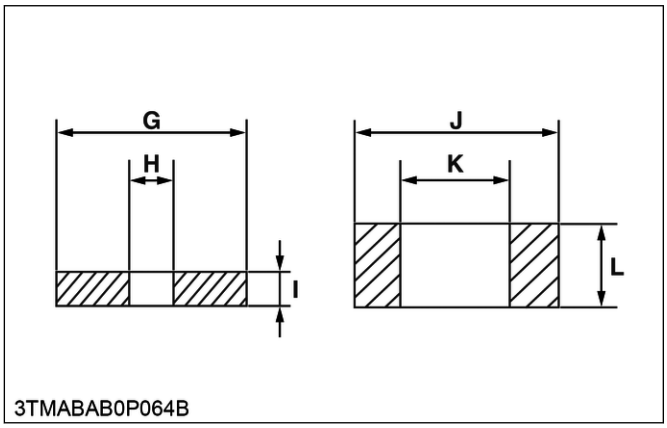
4. Valve guide replacing tool

Use for press out or press fit the valve guide.

NOTE
- **This special tool is not provided, so make it by referring to the figure.**



3TMABAB0P063B



3TMABAB0P064B

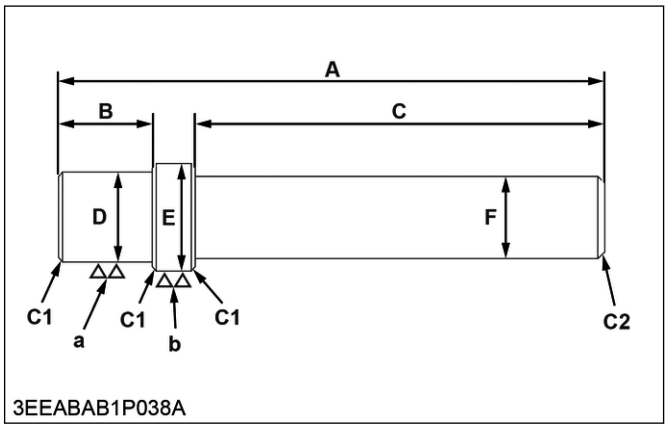
A	225 mm (8.86 in.)
B	70 mm (2.8 in.)
C	45 mm (1.8 in.)
D	20 mm dia. (0.79 in. dia.)
E	11.7 to 11.9 mm dia. (0.461 to 0.468 in. dia.)
F	6.50 to 6.60 mm dia. (0.256 to 0.259 in. dia.)
G	25 mm dia. (0.98 in. dia.)
H	6.70 to 7.00 mm dia. (0.264 to 0.275 in. dia.)
I	5.0 mm (0.20 in.)
J	20 mm dia. (0.79 in. dia.)
K	12.5 to 12.8 mm dia. (0.493 to 0.503 in. dia.)
L	8.90 to 9.10 mm (0.351 to 0.358 in.)
C1	Chamfer 1.0 mm (0.039 in.)
C2	Chamfer 2.0 mm (0.079 in.)
C0.3	Chamfer 0.3 mm (0.01 in.)
Material	SS400

5. Bushing replacing tool

Use for pressing out and pressing in the bushing.

NOTE

- **This special tool is not provided, so make it referring to the figure.**



3EEABAB1P038A

For small end bushing

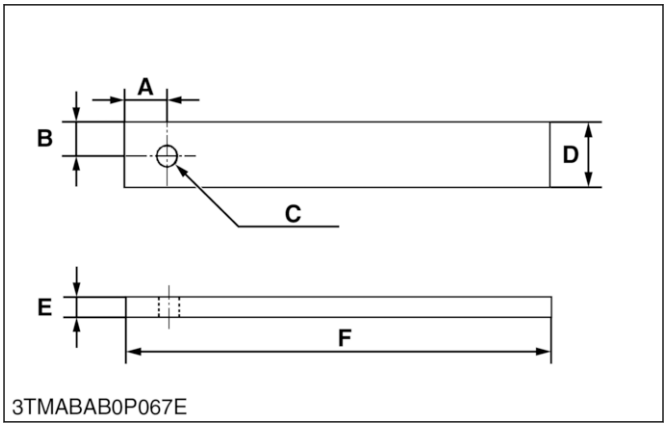
A	157 mm (6.18 in.)
B	24 mm (0.94 in.)
C	120 mm (4.72 in.)
D	21.8 to 21.9 mm dia. (0.859 to 0.862 in. dia.)
E	24.8 to 24.9 mm dia. (0.977 to 0.980 in. dia.)
F	20 mm dia. (0.79 in. dia.)
a	6.3 µm (250 µin.)
b	6.3 µm (250 µin.)
C1	Chamfer 1.0 mm (0.039 in.)
C2	Chamfer 2.0 mm (0.079 in.)

For idle gear bushing

A	196 mm (7.72 in.)
B	26 mm (1.0 in.)
C	150 mm (5.91 in.)
D	25.80 to 25.90 mm dia. (1.016 to 1.019 in. dia.)
E	28.80 to 28.90 mm dia. (1.134 to 1.137 in. dia.)
F	20 mm dia. (0.79 in. dia.)
a	6.3 µm (250 µin.)
b	6.3 µm (250 µin.)
C1	Chamfer 1.0 mm (0.039 in.)
C2	Chamfer 2.0 mm (0.079 in.)

6. Flywheel stopper

Use to loosen or tighten the flywheel screws.



3TMABAB0P067E

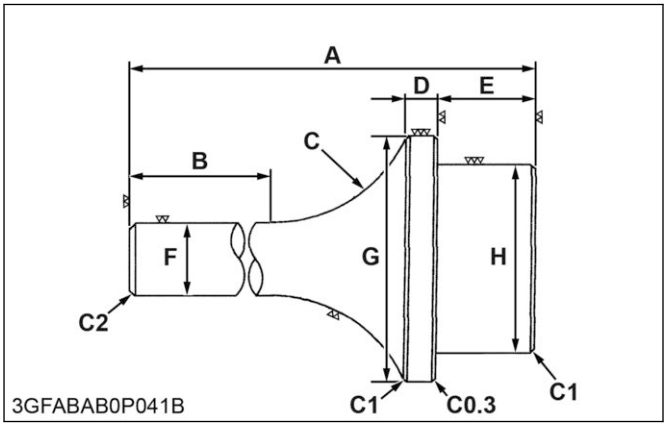
A	20 mm (0.79 in.)
B	15 mm (0.59 in.)
C	10 mm dia. (0.39 in. dia.)
D	30 mm (1.2 in.)
E	8.0 mm (0.31 in.)
F	200 mm (7.87 in.)
Material	SS400

7. Crankshaft bearing 1 replacing tool

Use to press out and press fit the crankshaft bearing 1.

NOTE

- **The special tools are not provided, so make them referring to the figure.**



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[Press out]

A	135 mm (5.31 in.)
B	72 mm (2.8 in.)
C	40 mm radius (1.6 in. radius)

(Continued)

D	10 mm (0.39 in.)
E	24 mm (0.94 in.)
F	20 mm dia. (0.79 in. dia.)
G	51.20 to 51.40 mm dia. (2.016 to 2.023 in. dia.)
H	47.30 to 47.50 mm dia. (1.863 to 1.870 in. dia.)
C1	Chamfer 1.0 mm (0.039 in.)
C2	Chamfer 2.0 mm (0.079 in.)
C0.3	Chamfer 0.30 mm (0.012 in.)

[Press fit]

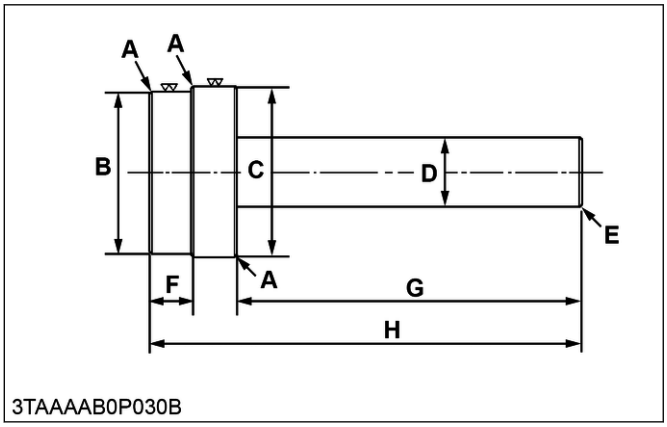
A	135 mm (5.31 in.)
B	72 mm (2.8 in.)
C	40 mm radius (1.6 in. radius)
D	10 mm (0.39 in.)
E	24 mm (0.94 in.)
F	20 mm dia. (0.79 in. dia.)
G	68 mm dia. (2.7 in. dia.)
H	47.30 to 47.50 mm dia. (1.863 to 1.870 in. dia.)
C1	Chamfer 1.0 mm (0.039 in.)
C2	Chamfer 2.0 mm (0.079 in.)
C0.3	Chamfer 0.30 mm (0.012 in.)

8. Governor gear holder bushing replacing tool

Use to press out and to press fit the governor gear holder bushing.

NOTE

- **The special tools are not provided, so make them referring to the figure.**



3TAAAAB0P030B

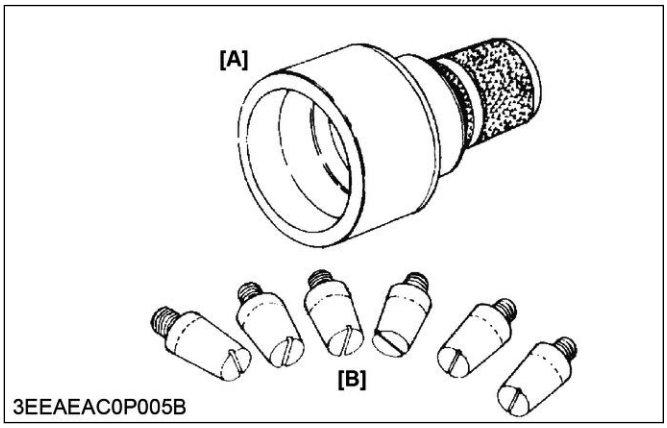
A	**C1:** Chamfer 1.0 mm (0.039 in.)
B	73.90 to 74.00 mm dia. (2.910 to 2.913 in. dia.)
C	69.80 to 69.90 mm dia. (2.748 to 2.751 in. dia.)
D	30 mm dia. (1.2 in. dia.)
E	**C2:** Chamfer 2.0 mm (0.079 in.)
F	18 mm (0.71 in.)
G	150 mm (5.91 in.)
H	188 mm (7.40 in.)

9. Crank sleeve setter

Use to fix the crankshaft sleeve.

NOTE

- **The special tools are not provided, so make them referring to the figure.**



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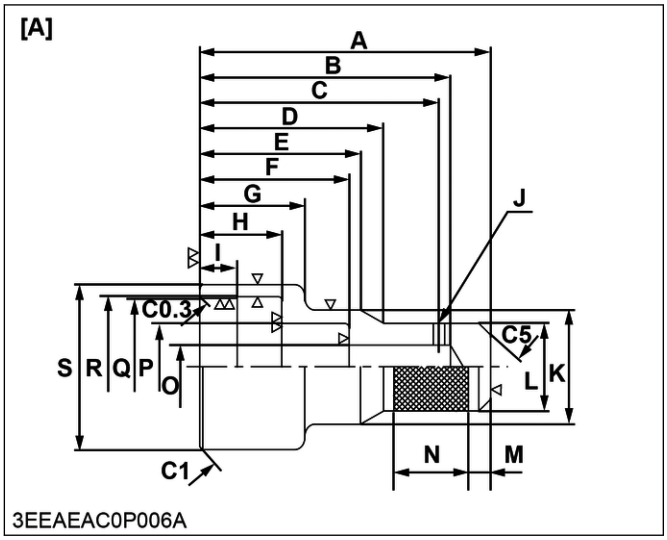


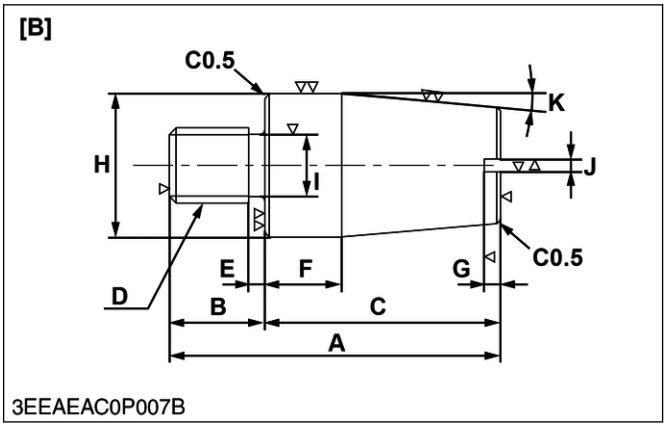
3EEAEAC0P006A

[A] Auxiliary socket for pushing

A	130 mm (5.12 in.)

(Continued)

B	112 mm (4.41 in.)
C	107 mm (4.21 in.)
D	82 mm (3.2 in.)
E	72 mm (2.8 in.)
F	67 mm (2.6 in.)
G	47 mm (1.8 in.)
H	36.00 to 36.20 mm (1.418 to 1.425 in.)
I	17 mm (0.67 in.)
J	5.0 mm dia. (0.20 in. dia.)
K	52 mm dia. (2.0 in. dia.)
L	40 mm dia. (1.6 in. dia.)
M	10 mm (0.39 in.)
N	33 mm (1.3 in.)
O	20 mm dia. (0.79 in. dia.)
P	40 mm dia. (1.6 in. dia.)
Q	72.10 to 72.15 mm dia. (2.839 to 2.840 in. dia.)
R	73 mm dia. (2.9 in. dia.)
S	83 mm dia. (3.3 in. dia.)
C0.3	Chamfer 0.30 mm (0.012 in.)
C1	Chamfer 1.0 mm (0.039 in.)
C5	Chamfer 5.0 mm (0.20 in.)



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[B] Sleeve guide

A	42 mm (1.7 in.)
B	12 mm (0.47 in.)
C	30 mm (1.2 in.)
D	M10 × Pitch 1.25
E	2.0 mm (0.079 in.)
F	10 mm (0.39 in.)
G	2.0 mm (0.079 in.)

(Continued)

H	17.90 to 17.95 mm dia. (0.7048 to 0.7066 in. dia.)
I	8.0 mm dia. (0.31 in. dia.)
J	1.8 mm (0.071 in.)
K	0.09 rad (5°)
C0.5	Chamfer 0.5 mm (0.02 in.)

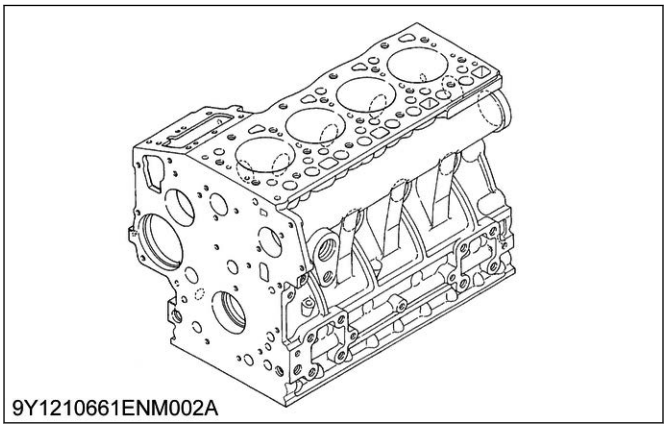
3. ENGINE

MECHANISM

1. Engine body

1.1 Cylinder block

The engine has a high durability tunnel-type cylinder block in which the crank bearing component is a constructed body. Furthermore, liner less type, allow effective cooling, less distortion, and greater wear resistance. The noise level is reduced to a minimum because each cylinder has its own chamber.
To increase the rigidity of the cylinder block, parts of engine block which support main bearing case has thicker rib for additional rigidness to improve noise and vibration.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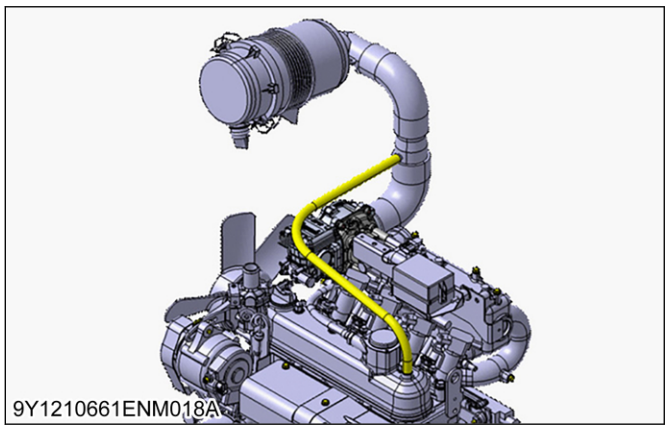
1.2 Positive crankcase ventilation (PCV) system

During normal compression stroke, a small amount of gases in the combustion chamber escapes past the piston. Approximately 70 % of these blowby gases are unburned fuel (HC) that can dilute and contaminate the engine oil, cause corrosion to critical parts, and contribute to sludge build up.
The purpose of the positive crankcase ventilation (PCV) system is to remove these harmful gases from the crankcase before damage occurs and combine them with the engine's normal incoming air / fuel charge.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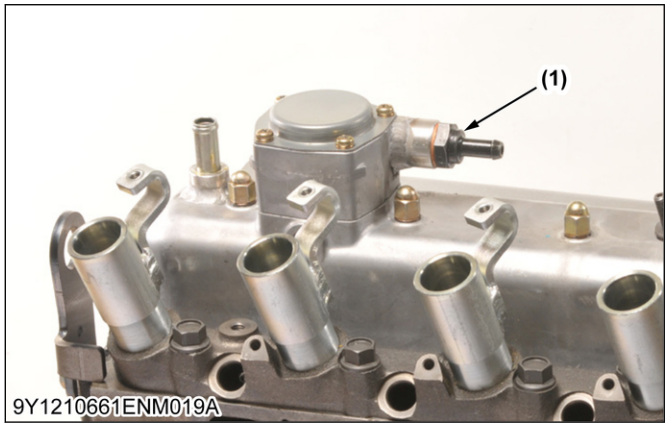
1.3 PCV valve

The PCV valve consists of a spring and a valve, and it is installed between an engine body and an intake manifold.
The PCV valve controls the inhalation volume of blow-by gas and the volume of fresh air according to the engine operation status.



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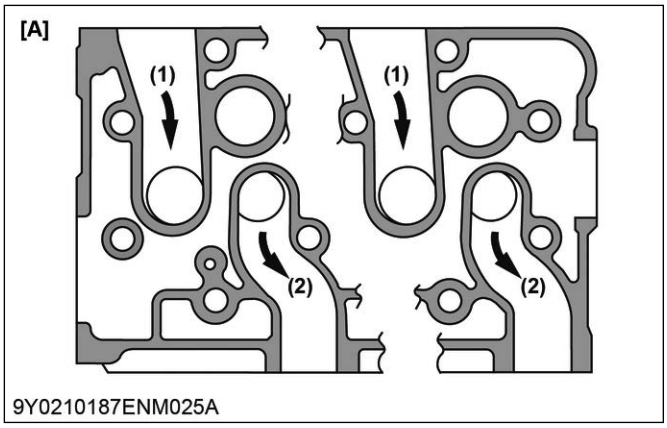
(1) PCV valve

1.4 Cylinder head

1.4.1 Intake and exhaust port

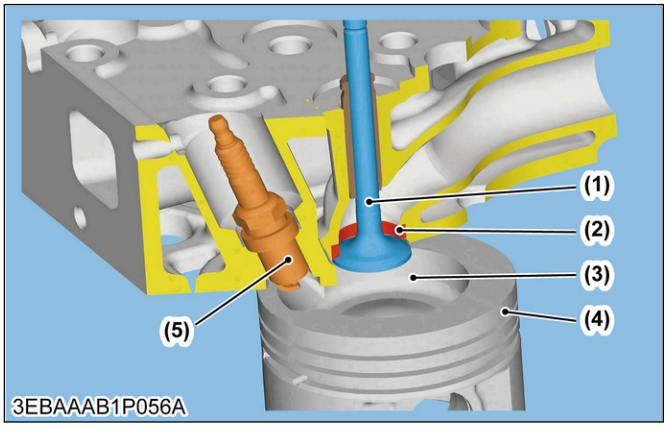
The cross-flow type intake / exhaust ports, which lower the heat conduction from the exhaust port to the intake port. The low heat conduction keeps the intake air from being heated and expanded by the exhaust gas.



(1) Intake port
(2) Exhaust port

1.4.2 Combustion system

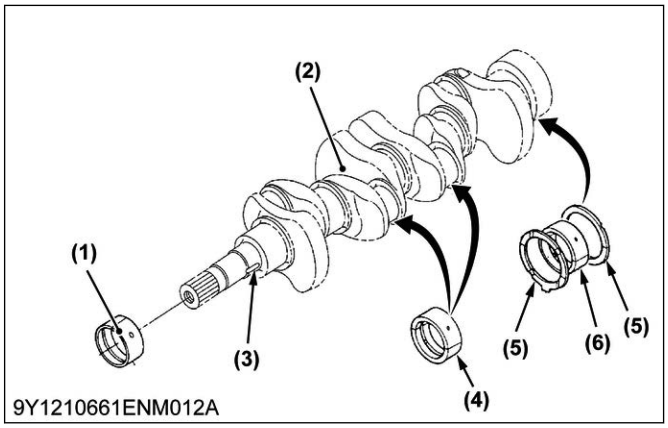
The Spark Ignition type combustion chamber, compactly placed on top of the piston head, successfully reduces emissions. To ensure even more reliable emission life, the intake / exhaust valve seats are fitted with special heat resistant stellite alloys.



(1) Valve
(2) Valve seat
(3) Main combustion chamber
(4) Piston
(5) Spark plug

1.5 Crankshaft

The crankshaft with the connecting rod converts the reciprocating motion of the piston into rotating motion. The crankshaft (2) has oil passages drilled so that oil can flow from the main bearings to the crank pin bearings.
The front journal is supported by a sleeve type bearing (crankshaft bearing 1) (1), the intermediate journal by a split type (crankshaft bearing 3) (4), and the rear by a split type (crankshaft bearing 2) (6) with thrust bearings (5).



(1) Crankshaft bearing 1
(2) Crankshaft
(3) Feather key
(4) Crankshaft bearing 3
(5) Thrust bearing
(6) Crankshaft bearing 2

1.6 Piston and piston ring

The piston has a slightly oval shape when cold (in consideration of thermal expansion) and a concave head.

Top ring

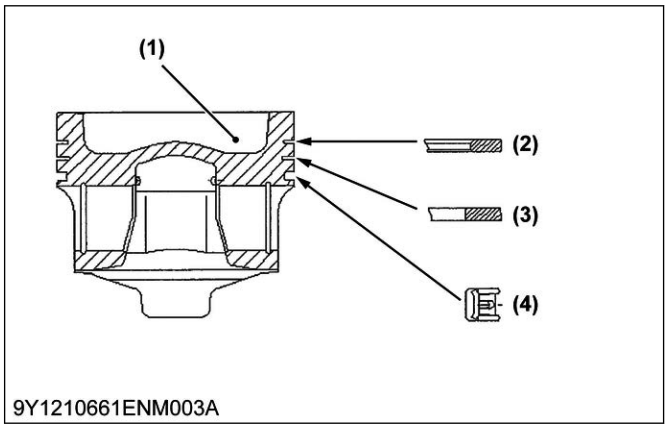
The top ring is of plain barrel face type. The barrel face type has an arc sliding surface easy to run in and prevents abnormal wears by providing a maintained oil film against the lined wall.

Second ring

For the second ring, the tapered outer surface area that comes in contact with the lined wall is reduced to obtain a high surface pressure for the prevention of gas leakage, compression leakage and oil spillage.

Oil ring

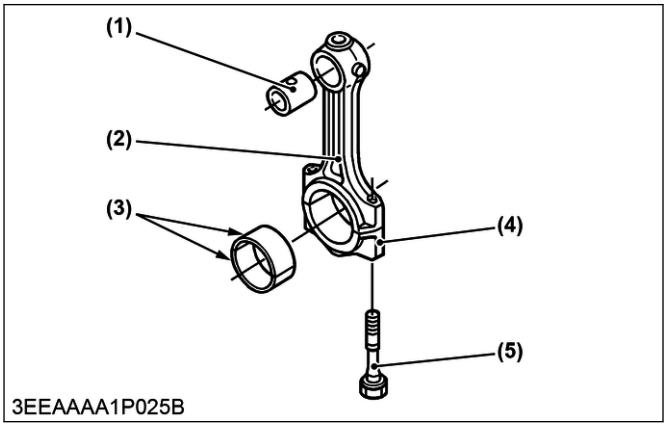
Oil ring consists of three steel components, that is upper and lower rails and one spacer being held between two rails. This function is particularly effective in preventing oil-up because of high boost at the time of engine coasting.



(1) Combustion chamber
(2) Top ring
(3) Second ring
(4) Oil ring

1.7 Connecting rod

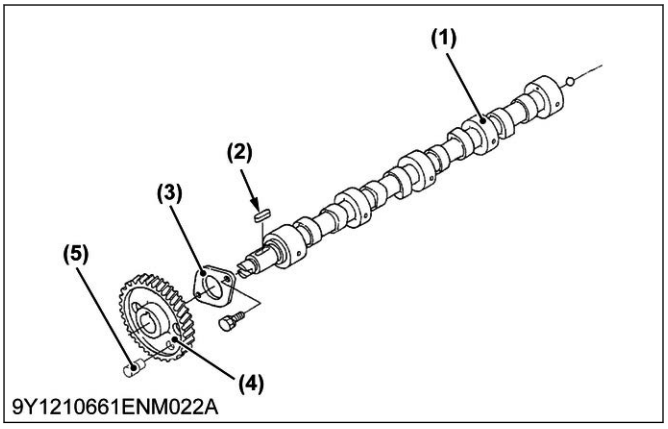
The connecting rod (2) is used to connect the piston with the crankshaft. The big end of the connecting rod has a crankpin bearing (3) (split type) and the small end has a small end bushing (1) (solid type).



(1) Small end bushing
(2) Connecting rod
(3) Crankpin bearing
(4) Connecting rod cap
(5) Connecting rod screw

1.8 Camshaft

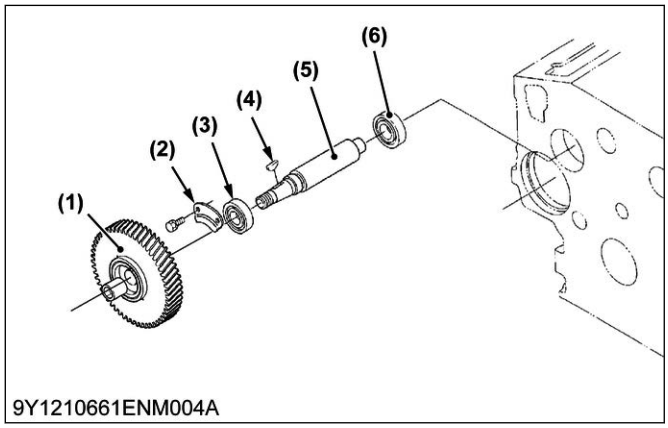
The camshaft (1) is made of special cast iron, and the journal and cam sections are chilled to resist wear.
The cams on the camshaft cause the intake and exhaust valves to open as the camshaft rotates. The bearing and journals are force-lubricated.
A rotation detective pin is attached to the cam gear.



(1) Camshaft
(2) Feather key
(3) Camshaft stopper
(4) Cam gear
(5) Pin

1.9 Gear shaft

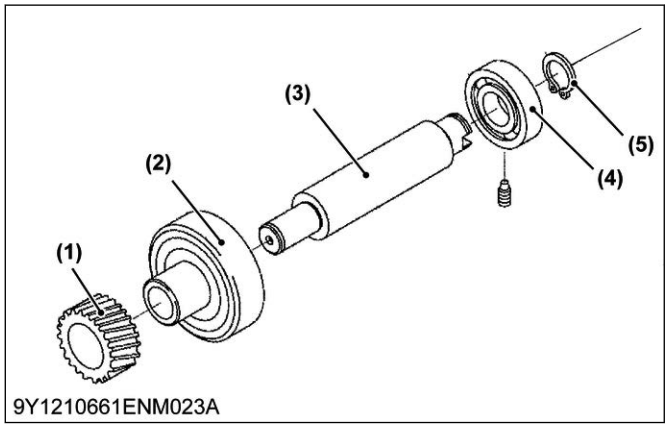
The gear shaft is a shaft that was changed from the fuel camshaft for 05-E3B engine to the shaft with no cam.



(1) Injection pump gear
(2) Stopper
(3) Ball bearing
(4) Feather key
(5) Gear shaft
(6) Ball bearing

1.10 PTO shaft

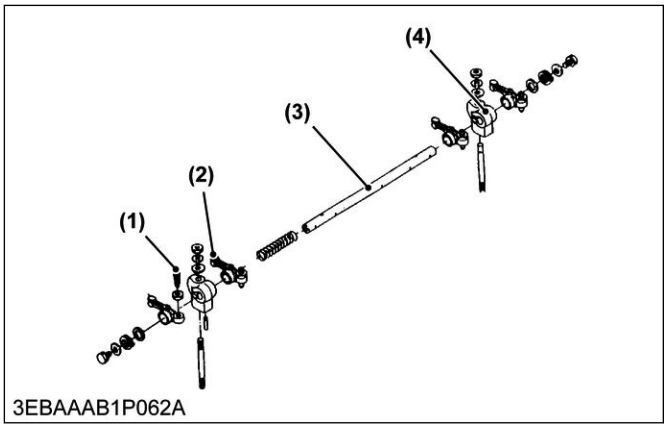
It is possible to takeoff the power of hydraulic pump drive from the PTO shaft.



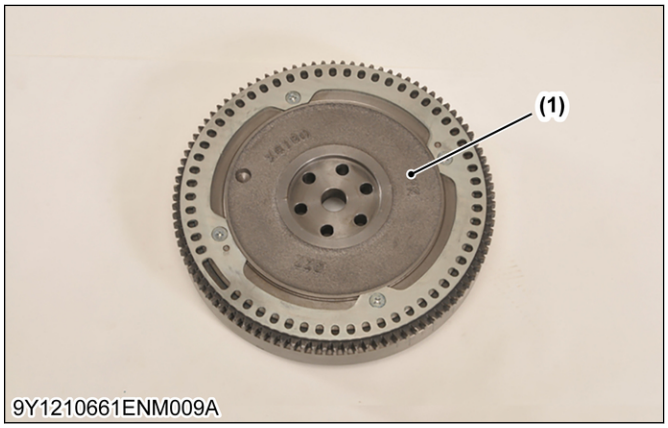
(1) Governor gear
(2) Governor gear holder
(3) PTO shaft
(4) Bearing
(5) Circlip

1.11 Rocker arm assembly

The rocker arm assembly includes the rocker arms (2) and adjusting screws (1), the end of which rests on the push rods, rocker arm brackets (4) and rocker arm shaft (3).
The rocker arms swing and transmits the reciprocating motion of the push rods to the inlet and exhaust valves to open and close them.



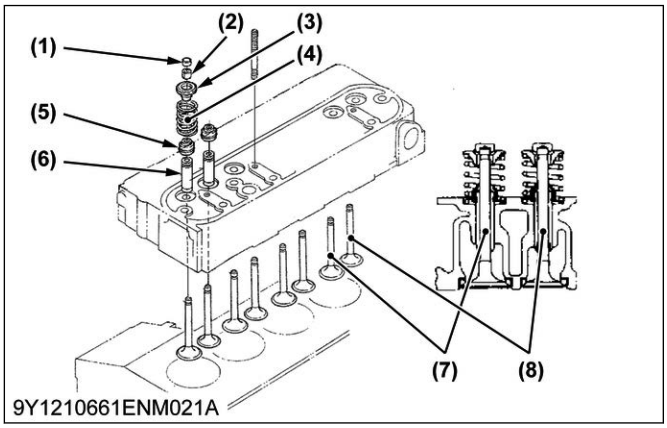
(1) Adjusting screw
(2) Rocker arm
(3) Rocker arm shaft
(4) Rocker arm bracket



(1) Flywheel

1.12 Inlet and exhaust valves

The valve and its guide for the inlet are different from those for the exhaust.
Other parts, such as the spring (4), spring retainer (3), collet (2), stem seal (5), and cap (1) are the same for both the inlet and exhaust.



(1) Valve cap
(2) Collet
(3) Spring retainer
(4) Spring
(5) Stem seal
(6) Valve guide
(7) Inlet valve
(8) Exhaust valve

1.13 Flywheel

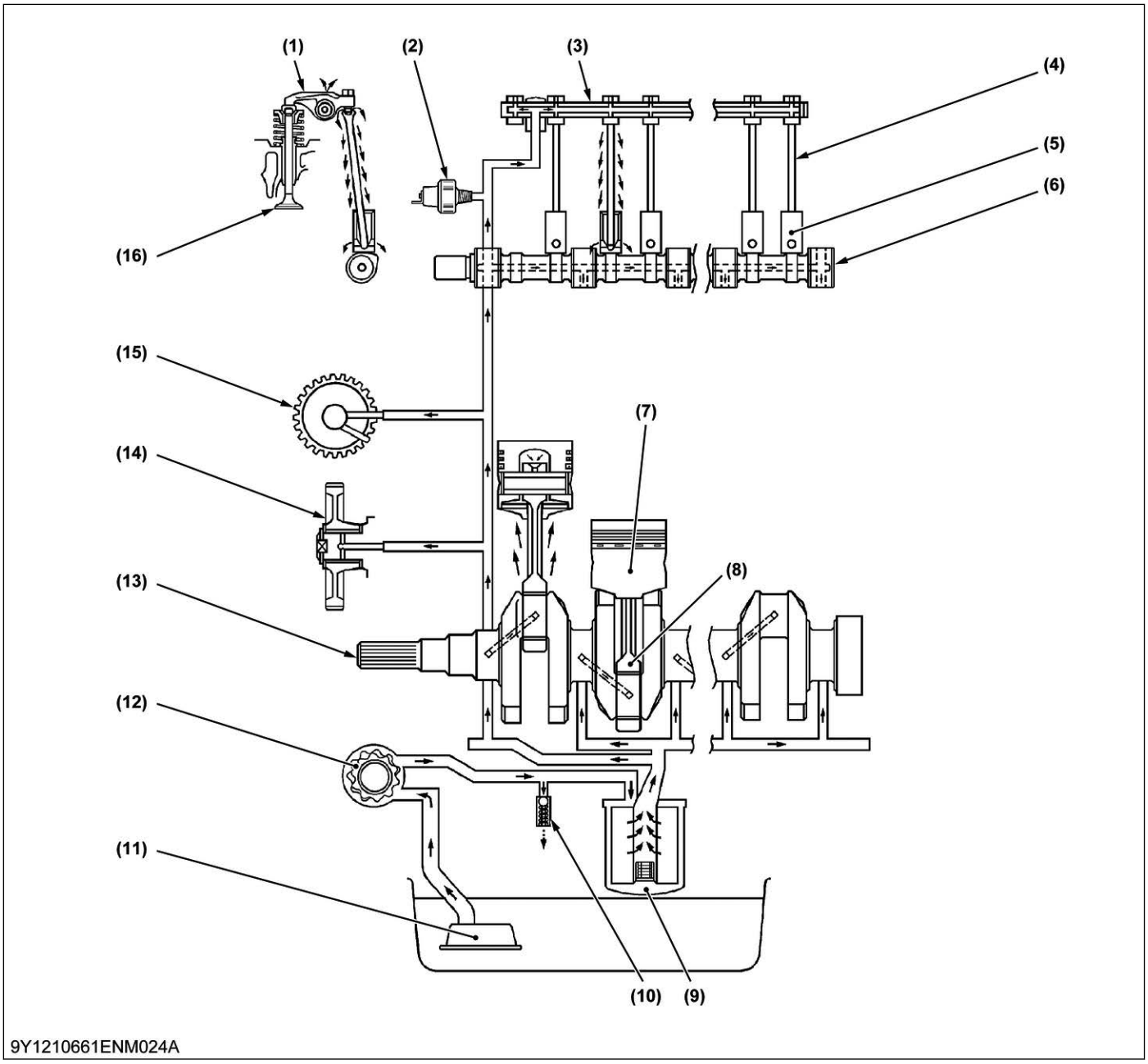
The flywheel (1) is connected with the crankshaft, it stores the rotating force in the combustion stroke as inertial energy to rotate the crankshaft smoothly.
The flywheel periphery is provided with marks showing fuel injection timing and top dead center.
The flywheel has gear teeth around its outer rim, which mesh with the drive pinion of the starter. Also, a rotor for determining the ignition timing is attached to the flywheel.

2. Lubricating system

2.1 General

Engine lubricating system may be classified as:
- Full pressure feed type
- Pressure feed and splash type

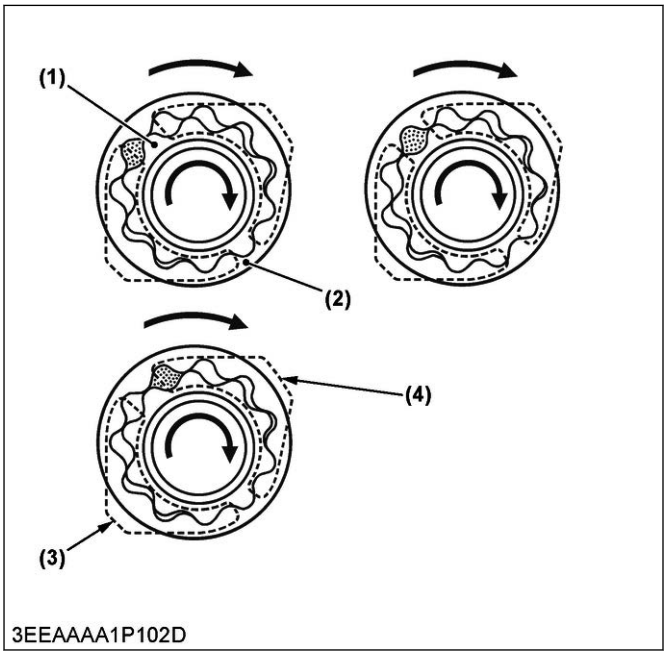
KUBOTA engines have lubricating system of full pressure feed type.
This system consists of an oil strainer (11), oil pump (12), relief valve (10), oil filter cartridge (9) and oil pressure switch (2).
The oil pump sucks lubricating oil from the oil pan through the oil strainer and the oil flows down to the oil filter, cartridge where it is further filtered. Then the oil is forced to crankshaft (13), connecting rods (8), idle gear (14), PTO shaft (15), camshaft (6) and rocker arm shaft (3) to lubricate each part through the oil gallery.
Some part of oil, splashed by the crankshaft or leaking and dropping from gaps of each part, lubricates following parts.
- Pistons (7)
- Cylinder walls
- Small ends of connecting rods
- Tappets (5)
- Push rods (4)
- Intake and exhaust valves (16)
- Timing gears



(1) Rocker arm
(2) Oil pressure switch
(3) Rocker arm shaft
(4) Push rod
(5) Tappet
(6) Camshaft
(7) Piston
(8) Connecting rod
(9) Oil filter cartridge
(10) Relief valve
(11) Oil strainer
(12) Oil pump
(13) Crankshaft
(14) Idle gear
(15) PTO shaft
(16) Valve

2.2 Oil pump

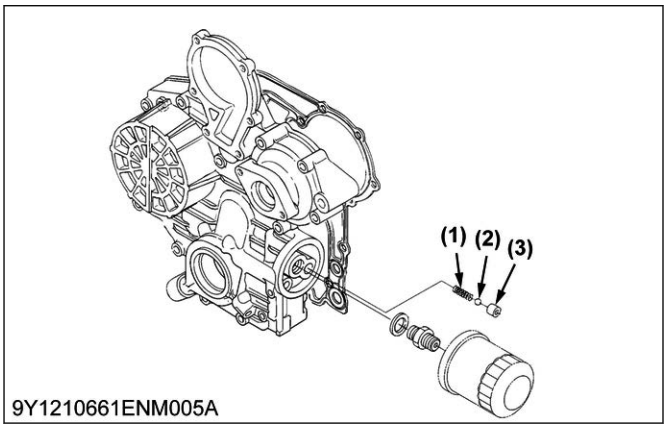
This oil pump has an inner rotor (1) and an outer rotor (2).
The inner rotor (1), which is driven by crankshaft, rotates the outer rotor (2) in the same direction.
The inner rotor (1) has one less lobe than the outer rotor (2), and they are eccentrically engaged with each other.
This allows the other lobes to slide over the outer lobes, making a seal to prevent back-up of oil. As the lobes slide up and over the lobes on the outer rotor (2), oil is drawn in. As the lobes fall into the outer rotor's cavities, oil is squeezed out.



(1) Inner rotor
(2) Outer rotor
(3) Inlet port
(4) Outlet port

2.3 Relief valve

The relief valve prevents the damage to the lubricating system due to the high pressure of the oil.
This relief valve is a ball direct acting type, and is best suited for low pressures.
When the pressure of the oil, forced by the pump, exceeds the specified value, the oil pushes back the ball (2) and escapes to the oil pan.

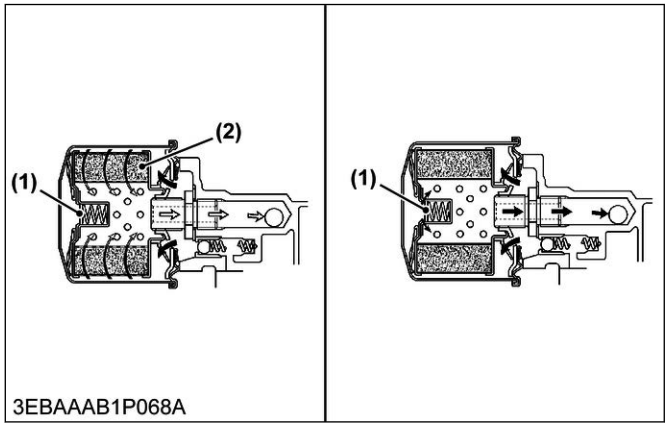


(1) Spring
(2) Ball
(3) Valve seat

2.4 Oil filter cartridge

After lubricating, the lubricating oil brings back various particles of grit and dirt to the oil pan. Those particles and the impurities in the lubricating oil can cause wear or seizure of the engine parts. It may also impair the physical and chemical properties of the oil itself.
The lubricating oil which is force-fed by the pump, is filtered by the filter cartridge with the filter element (2).

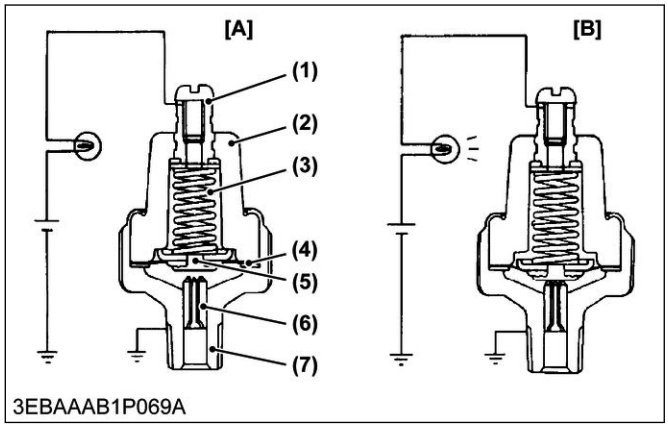
When the filter element accumulates on excessive amount of dirt and the oil pressure in the inlet line builds up by 98 kPa (1.0 kgf/cm^2, 14 psi) more than the outlet line, the bypass valve (1) opens to allow the oil to flow from the inlet into the outlet line, bypassing the filter element.



(1) Bypass valve
(2) Filter element

2.5 Oil pressure switch

The oil pressure switch is mounted on the cylinder block and is led to the lubricating oil passage.
When the oil pressure falls below the specified value, the oil pressure warning lamp lights.



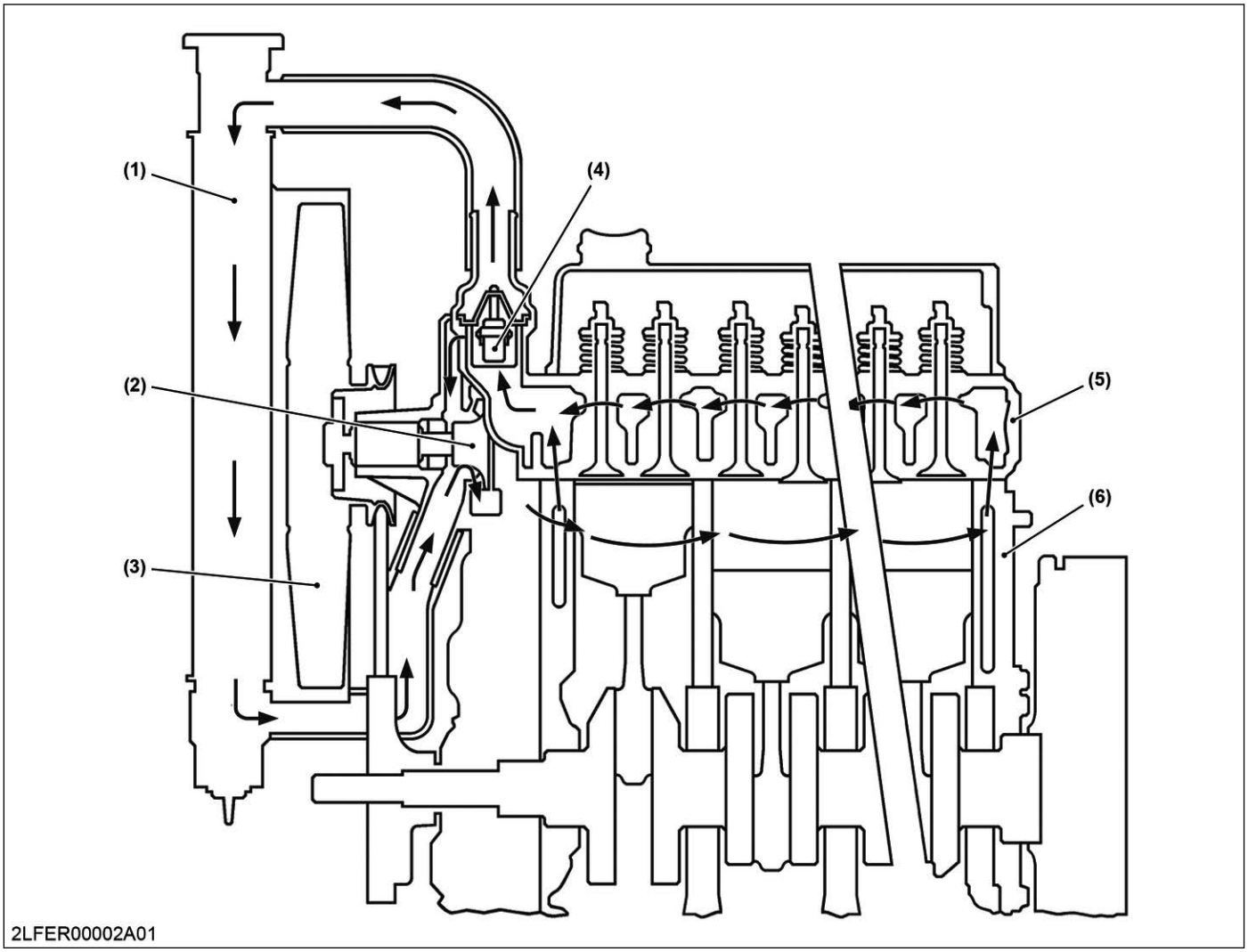
(1) Terminal
(2) Insulator
(3) Spring
(4) Rubber gasket
(5) Contact rivet
(6) Contact
(7) Oil switch body
[A] At the proper oil pressure
[B] At lower oil pressure, 50 kPa (0.5 kgf/cm^2, 7 psi) or less

3. Cooling system

3.1 General

The cooling system consists of a radiator (1), a centrifugal water pump (2), a cooling fan (3) and a thermostat (4).
The coolant is cooled through the radiator core, and the fan behind the radiator pulls the cooling air through the core to improve cooling.
The water pump sucks the coolant from the radiator or from the cylinder head and forces it into the cylinder block.
The thermostat opens or closes according to the coolant temperature, to allow the coolant to flow from the cylinder block to the radiator while open, or only to the water pump while closed.

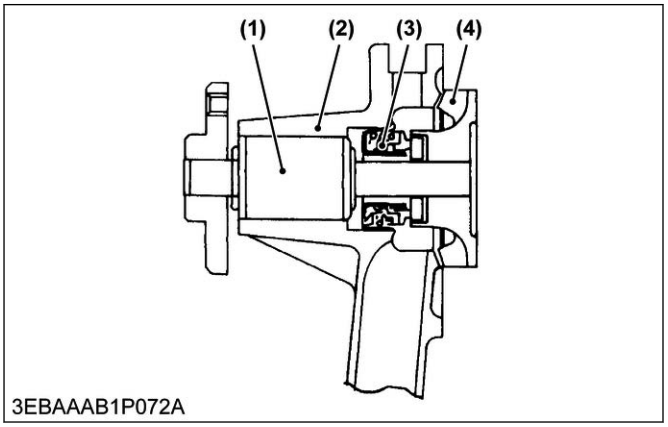
Thermostat's valve opening temperature	Service specification	69.5 to 72.5 ℃ 157.1 to 162.5 ℉



(1) Radiator
(2) Water pump
(3) Cooling fan
(4) Thermostat
(5) Cylinder head
(6) Cylinder block

3.2 Water pump

The water pump is driven by the crankshaft and a V belt. The rotating impeller (4) in the water pump sucks the coolant from the radiator and sends it into the water jacket in the cylinder block.
The mechanical seal (3) prevents the water from entering the bearing unit (1).



(1) Bearing unit
(2) Water pump body
(3) Mechanical seal
(4) Impeller

3.3 Thermostat

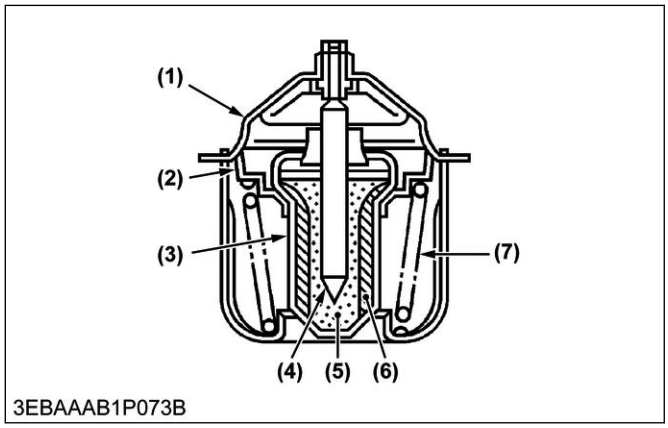
The thermostat is of the wax pellet type.
The thermostat controls the flow of the coolant to the radiator to keep the proper temperature.
The case, which serves as a valve seat, has a spindle inserted in the pellet (3) which is installed to the valve (2). The spindle is covered with the synthetic rubber (5) in the pellet.
The wax is charged between the pellet and the rubber.

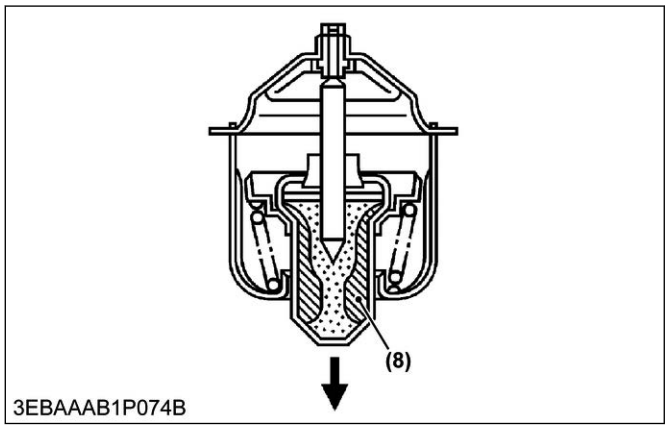
- At low temperature (lower than valve opening temperature (at beginning))

The valve (2) is seated by the spring (7) and the coolant circulates in the engine through the water return hose without running into the radiator. Only the air in the water jacket escapes to the radiator through the leak hole of the thermostat.

- At high temperature (higher than valve opening temperature (opened completely))

As the coolant temperature rises, the wax in the pellet (3) turns liquid and expands, repelling the spindle, which causes the pellet to lower. The valve (2) opens to send the coolant to the radiator.

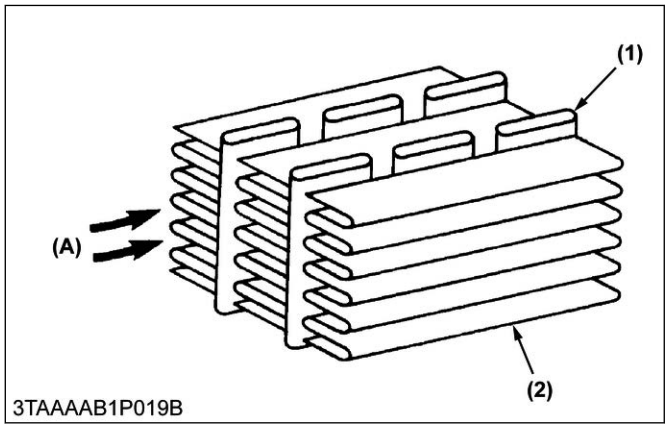




(1) Seat
(2) Valve
(3) Pellet
(4) Spindle
(5) Synthetic rubber
(6) Wax (Solid)
(7) Spring
(8) Wax (liquid)

3.4 Radiator

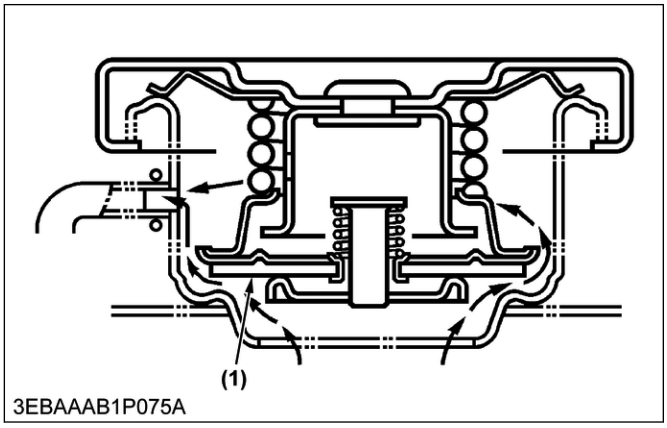
The radiator core consists of coolant carrying tubes (1) and fins (2) meeting at a right angle with the tubes. The fin is a louverless, corrugated type which is light in weight, high in heat exchange ratio and less apt to clog.

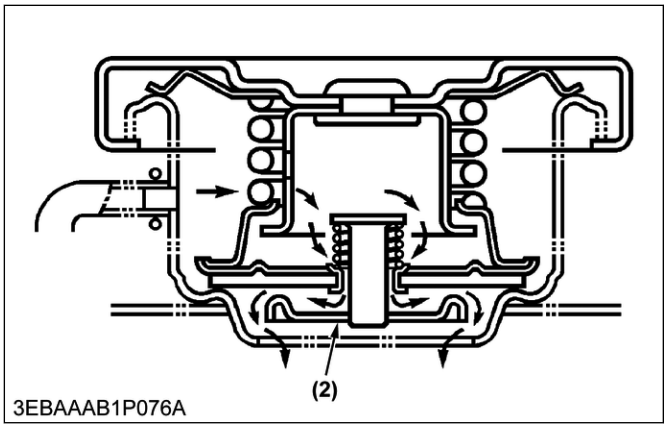


(1) Tube
(2) Fin
(A) Cooling air

3.5 Radiator cap

The pressure type radiator cap prevents differences in pressure between the inside and the outside of the radiator from deforming the radiator.
When the coolant temperature rises and the pressure in the radiator increases above the specified pressure, the pressure valve (1) opens to reduce the internal pressure.
When the coolant temperature falls and a vacuum forms in the radiator, the vacuum valve (2) opens to introduce the air into the radiator.





(1) Pressure valve (Opening pressure 88 kPa (0.90 kgf/cm^2, 13 psi))
(2) Vacuum valve

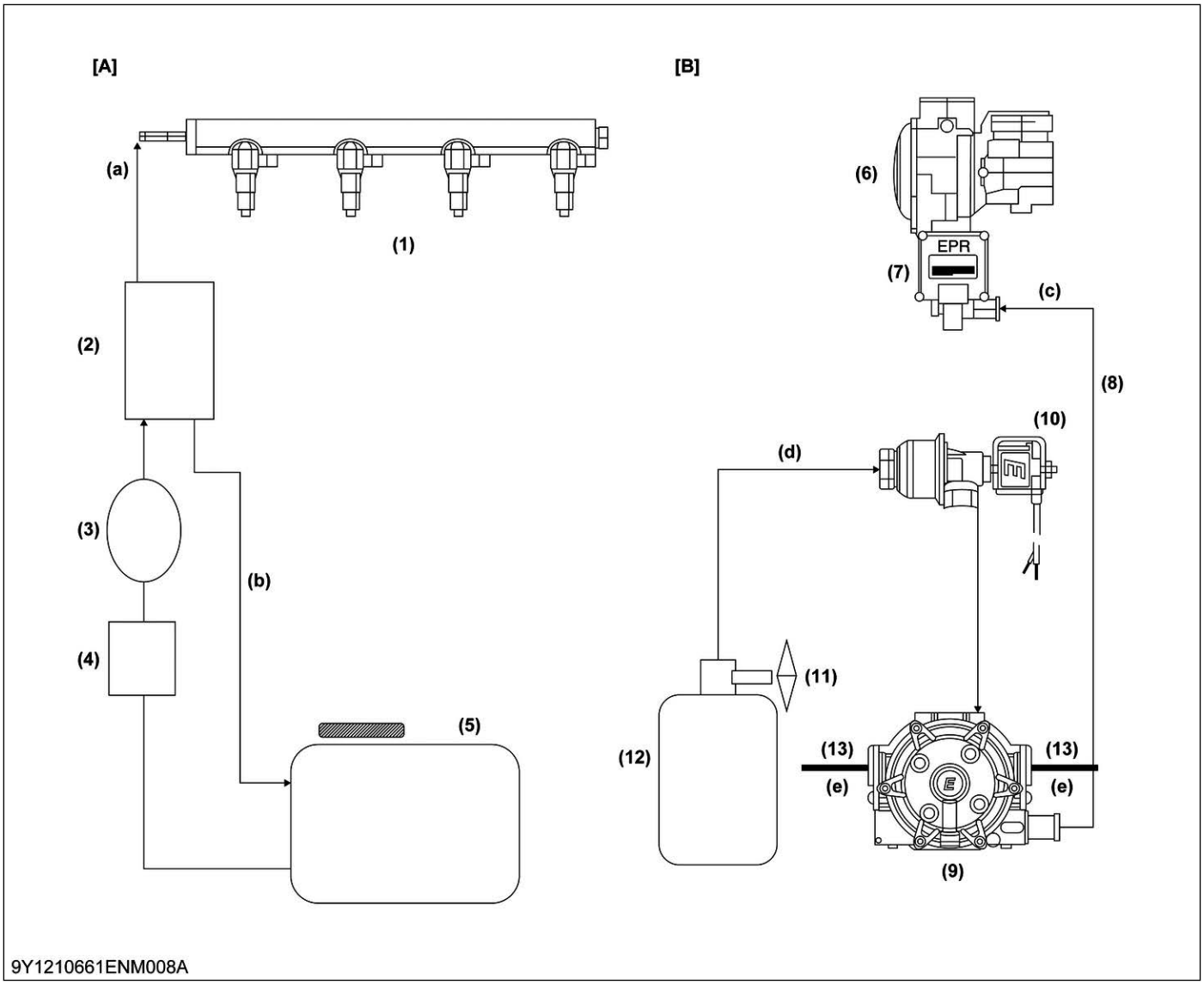
4. Fuel system

4.1 General

WG1605-G-E3
The fuel is fed from the gasoline tank (5) through the fuel filter (4) to the delivery pipe (1) by the fuel pump (3).

WG1605-L-E3, WG1605-N-E3, WG1605-LN-E3
The LPG/natural gas fuel stored in the LPG/natural gas tank (12) is sent to vaporizer (9) by pressure in the gaseous phase in the tank through the lock off valve (10).
The LPG/natural gas fuel is evaporated in vaporizer (9) and is sent to the regulator (7) as a gaseous fuel of gas pressure near the atmospheric pressure.
The regulator (7) mixes the gas and air is supplied in the cylinder.

WG1605-GL-E3, WG1605-GLN-E3
This fuel system has 2 ways (gasoline fuel and LPG/natural gas fuel).



(1) Delivery pipe
(2) Fuel pressure manifold (FPM)
(3) Fuel pump
(4) Fuel filter
(5) Gasoline tank*
(6) Mixer
(7) Regulator (D-EPR)
(8) Vapor hose*
(9) Vaporizer (DSR)
(10) Lock off valve
(11) LPG/natural gas manual valve*
(12) LPG/natural gas tank*
(13) Coolant hose*

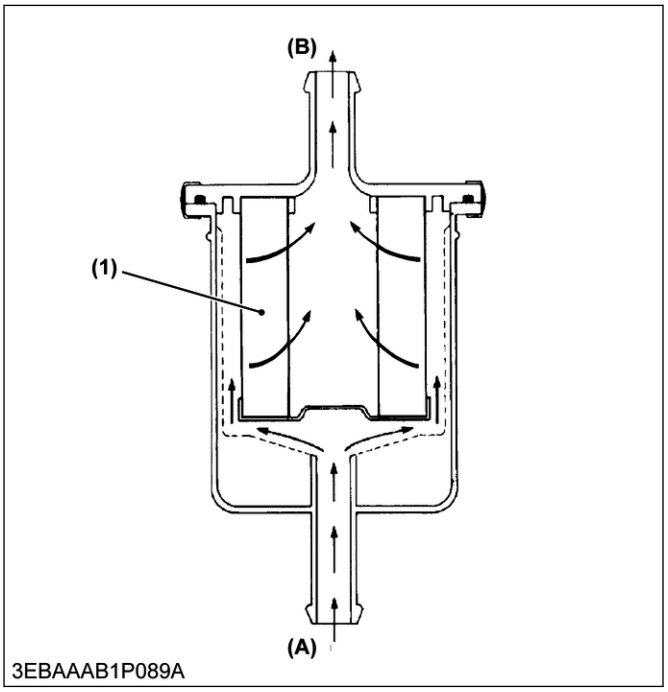
[A] Gasoline fuel
[B] LPG/natural gas fuel
(a) Gasoline line*
(b) Bleed/return circuit*
(c) Gaseous propane or natural gas line*
(d) Liquid propane or natural gas line*
(e) Hot coolant inlet or outlet line*

* Component Marked * is Not Provided by KUBOTA

4.2 Fuel filter (WG1605-G-E3, WG1605-GL-E3, WG1605-GLN-E3)

The fuel filter is installed in the fuel line between the fuel tank and the feed pump.
As the fuel flows from the inlet *"A"* through the filter element (1), the dirt and impurities in the fuel are filtered, allowing only clean fuel to penetrate the inside of the filter element. The cleaned fuel flows out from the outlet *"B"*.

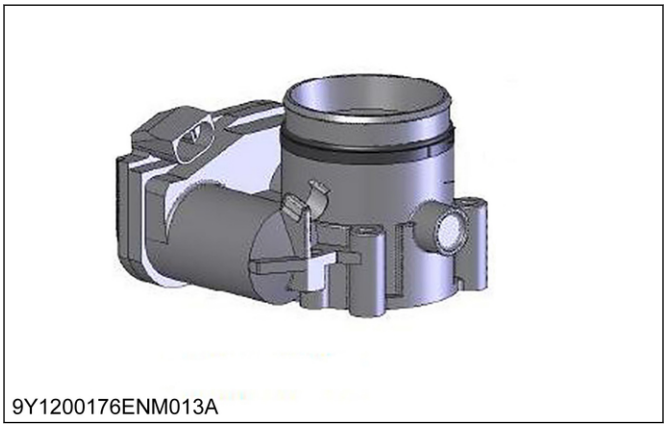
Type of filter element	Accordion-pleated paper type
Material of filter element	Cotton fiber
Filter mesh	15 µm (0.00059 nin.)



(1) Filter element (B) Outlet
(A) Inlet

4.3 Electronic throttle body (ETB)

The ETB is connected to the intake manifold of the engine. The ETB uses an electric motor connected to the throttle shaft. In addition, an accelerator position sensor (a foot pedal position sensor) is located in the operator's compartment. When the engine is running, electrical signals are sent from the accelerator position sensor (the foot pedal position sensor) to the Engine Control Unit (ECU) when the operator depresses or releases the accelerator. The ECU then sends an electrical signal to the motor on the ETB to increase or decrease the angle of the throttle blade, thus increasing or decreasing the air flow to the engine.

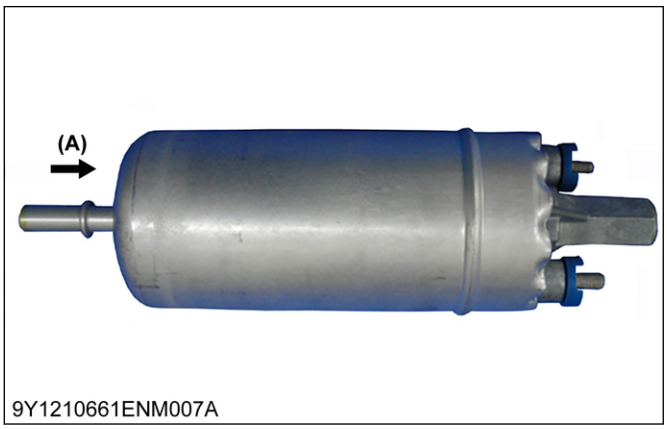


4.4 Fuel pump (WG1605-G-E3, WG1605-GL-E3, WG1605-GLN-E3)

The gasoline system will use an external electric gasoline fuel pump. The pump will be mounted in the chassis of the vehicle, or equipment near the fuel tank. Gasoline rated fuel hose and securing devices supplied by the OEM, will be used to transfer the pumped fuel to the gasoline fuel pressure manifold assembly. The OEM may have installed a fuel filtration device ahead of the electric pump, which may be located in the tank or an external filter. Most industrial equipment will be exposed to dusty and dirty environments, therefore use caution when opening the gasoline tank, to prevent dirt and debris from falling in the tank. For filter maintenance, refer to "3. MAINTENANCE CHECK LIST".

The electric gasoline fuel pump, used on USA emission certified engines are a critical part of the certified emissions system, and do not require any periodic adjustment.

The pump will be mounted in the chassis of the vehicle, or equipment near the fuel tank. Gasoline rated fuel hose and securing devices supplied by the OEM, will be used to transfer the pumped fuel to the gasoline fuel pressure manifold.

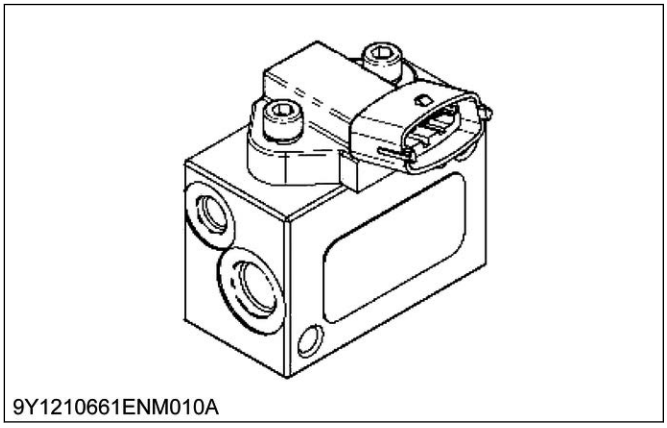


(A) From fuel tank

4.5 Fuel pressure manifold (FPM) (WG1605-G-E3, WG1605-GL-E3, WG1605-GLN-E3)

The gasoline fuel system, uses a fuel pressure manifold assembly, to control the delivery pressure to the delivery pipe. The manifold is mounted to the chassis, between the electric fuel pump and the delivery pipe. The manifold is equipped with a sensor, which provides the ECU with the gasoline fuel temperature, and pressure being regulated to the delivery pipe. The ECU uses the fuel temperature and pressure, to calculate the precise amount of gasoline, to be injected to the engine during operation. The manifold is designed into the system, to control

pressure, as well as the amount of gasoline, to be returned to the fuel tank. In normal gasoline delivery systems, the electric fuel pump, delivers a constant pressure to the delivery pipe, and allows a significant amount of fuel to be recycled to the tank, thus causing the gas to heat and vaporize, and requiring the use of a vapor recovery system to control the excess vapor. The system manages the fuel pressure at the manifold and minimizes the amount of returned fuel, thus reducing the vapor fuel in the tank.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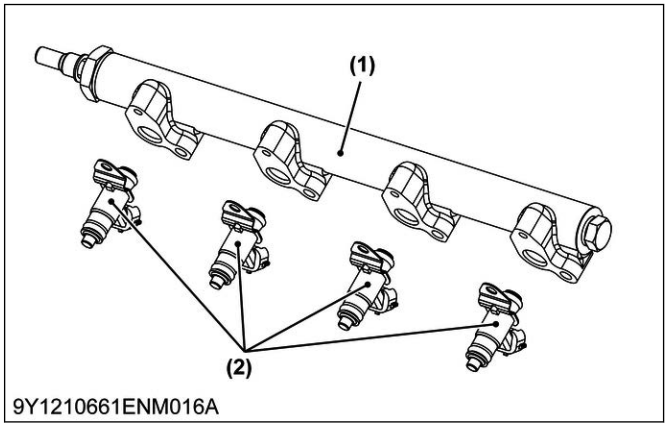
engine control unit (ECU) will use the gasoline fuel delivery calibrations, to pulse width modulate each injector (2), to deliver the correct amount of gasoline, for optimized performance and emission control. The injector pulsing or "firing" is accomplished by supplying a 12 volt supply, to the positive side of the injector coil, and switching the ground circuit side, using the injector drivers, internal to the ECU. Injectors (2) are an emissions control device, and do not require periodic adjustment.



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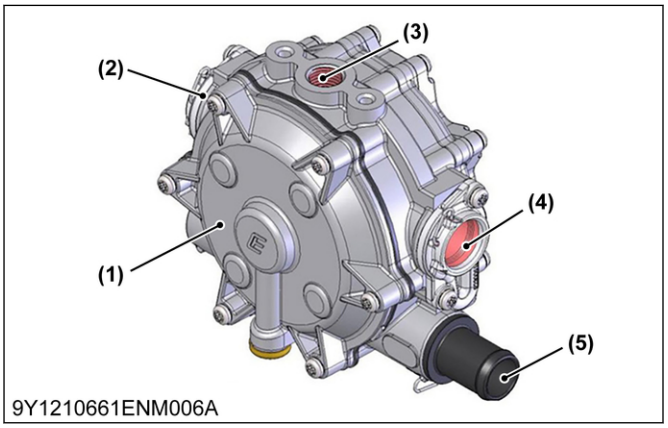
(1) Delivery pipe (2) Injector

4.6 Injectors and delivery pipe (WG1605-G-E3, WG1605-GL-E3, WG1605-GLN-E3)

The gasoline fuel delivery system, uses a delivery pipe (1) mounted with injectors (2), for each cylinder. The

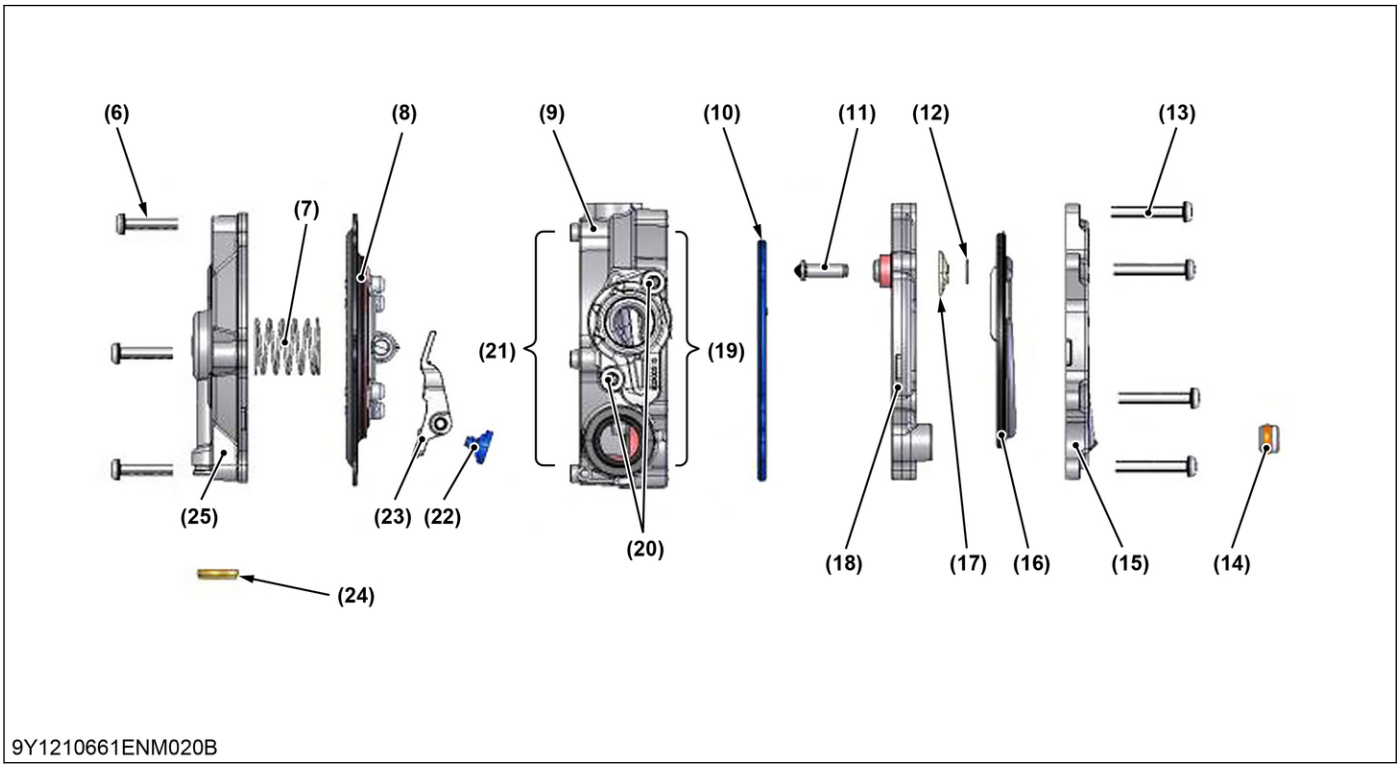
4.7 Vaporizer (Dual stage regulator (DSR)) (WG1605-G-E3, WG1605-L-E3, WG1605-N-E3, WG1605-LN-E3, WG1605-GLN-E3)

When evaporating by primary chamber of vaporizer liquid propane or natural gas needs the evaporation heat.
This vaporizer installs the water jacket, throws the coolant of engine, heats primary chamber, promotes evaporation.
The DSR is a combination vaporizer, pressure regulating device. The DSR is a two stage regulator that is normally closed, when the engine is not running. When the engine is cranking or running, a partial vacuum is created in the fuel line, which connects the regulator to the direct electronic pressure regulators (DEPR), and mixer. This partial vacuum opens the second stage regulator, permitting fuel to flow to the DEPR, and mixer.



(1) Delivery pipe
(2) Hot coolant in/out
(3) Fuel in
(4) Hot coolant out/in
(5) Fuel out

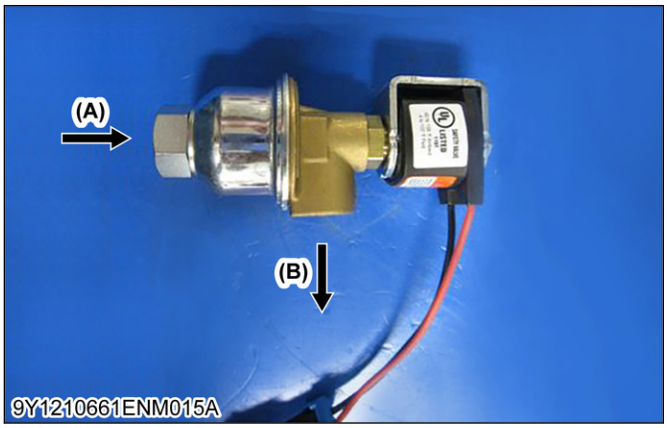
As the propane or natural gas passes through the heat exchanger (9), the fuel expands, and creates pressure inside the primary chamber (19). The pressure rises as the fuel expands, when the pressure rises above 10.34 kPa (0.1054 kgf/cm^2, 1.500 psi); sufficient pressure is exerted on the primary diaphragm (16), and press against the primary pin (11), thus closing off the flow of fuel. This action causes the flow of fuel, into the regulator to be regulated. When the engine is cranking, sufficient vacuum will be introduce into the secondary chamber (21), from the EPR/ mixer, drawing the secondary diaphragm (8) down onto the secondary lever (23), allowing vaporized fuel, to pass to the mixer. Increased vacuum, in the secondary chamber (21), increases the downward action on the secondary lever (23), allowing more fuel to flow to the mixer.



(6) Secondary cover screw
(7) Secondary spring
(8) Secondary diaphragm
(9) Heat exchanger
(10) Coolant gasket
(11) Primary pin
(12) Primary spring retaining clip
(13) Primary cover screw
(14) Primary test port plug
(15) Primary cover
(16) Primary diaphragm
(17) Primary spring
(18) Primary plate
(19) Primary chamber
(20) Coolant fitting housing retaining screw
(21) Secondary chamber
(22) Secondary seat
(23) Secondary lever
(24) Secondary cover vent
(25) Secondary cover

4.8 Lock off valve (WG1605-L-E3, WG1605-N-E3, WG1605-LN-E3, WG1605-GLN-E3)

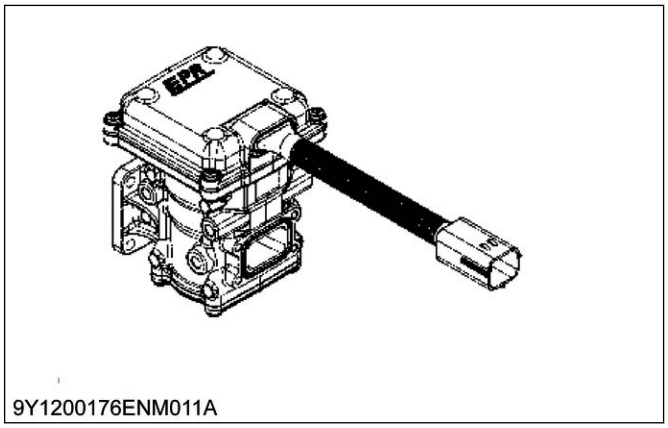
Vaporizer requires a normally-closed electrically controlled fuel lock off valve that is close coupled to the vaporizer and off when ignition switch is off or when the engine is not running normally. In operation without a lock off upstream the vaporizer will flow fuel with the engine off. The vaporizer is not a fuel shut-off safety device.



(A) From LPG/natural gas tank (B) To vaporizer

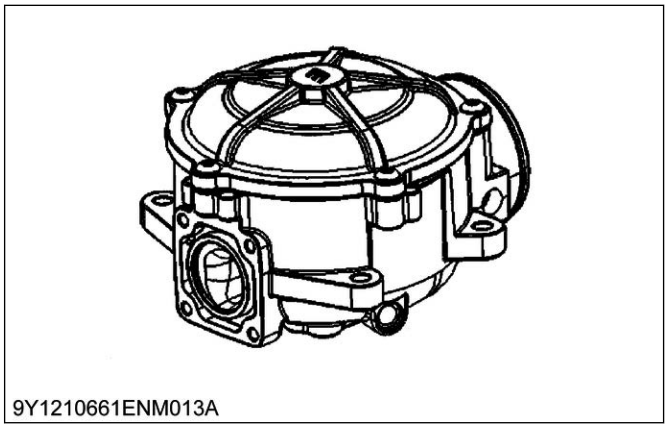
4.9 Direct electronic pressure regulator (DEPR) (WG1605-L-E3, WG1605-N-E3, WG1605-LN-E3, WG1605-GLN-E3)

The direct electronic pressure regulator (DEPR) is the primary fuel control device, used to keep both performance and emissions control. The DEPR contains an internal computer, which communicates to the engine control unit (ECU), via a communications area network (CAN), high speed connection.
The DEPR precisely controls the fuel flow required to ensure stoichiometric (correct air/fuel mixture for complete burn) fuel delivery to the engine combustion chambers. The DEPR also contains internally mounted fuel pressure and temperature sensors, which provide input across the CAN link, to the ECU, for fuel calculation. The ECU will process this information and command changes back across the CAN link, to the DEPR, to adjust fueling.



4.10 Mixer (WG1605-L-E3, WG1605-N-E3, WG1605-LN-E3, WG1605-GLN-E3)

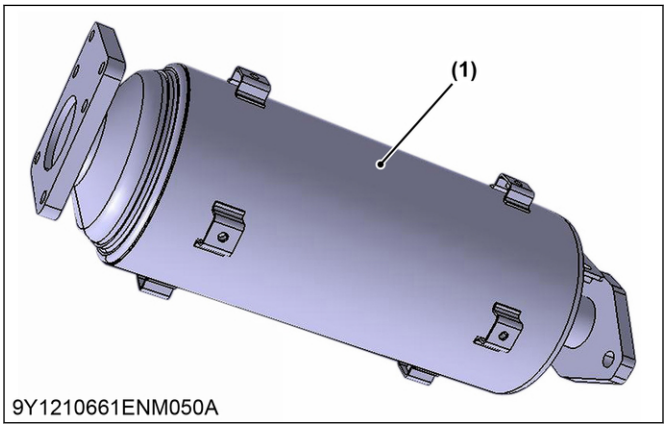
The air valve mixer is an air-fuel metering device, and is completely self-contained. The mixer is an air valve design, utilizing a relatively constant pressure drop, to draw fuel into the mixer from cranking, to full load. The mixer is mounted in the air stream, ahead of the throttle control device.

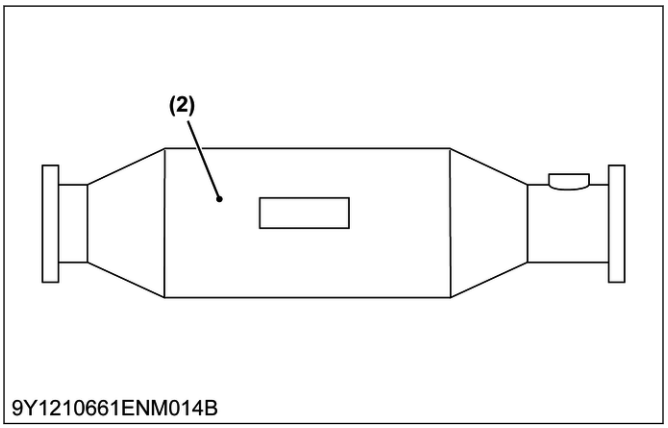


5. Exhaust system

5.1 Three-way catalyst

A three-way catalyst is a catalyst that oxidizes HC to CO_2 and H_2O and also CO to CO_2 respectively and at the same time reduces NOx to N_2 near the stoichiometric ratio.
The main basic component of an exhaust gas purification system that uses a three-way catalyst is feedback control of air-fuel ratio by means of an oxygen sensor for the purpose of maximizing the emission purification efficiency characteristic with reference to the intake air-fuel ratio of the three-way catalyst.
KUBOTA engines have two kinds of catalytic devices, catalytic muffler and catalytic converter.





(1) Catalytic muffler (2) Catalytic converter

5.2 Oxygen sensor

CAUTION

- **When you have to exchange O_2 sensor, please attached it immediately after opening from package.**

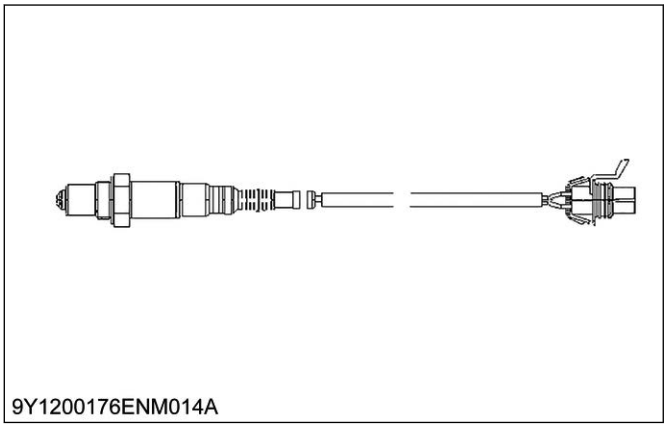
An oxygen sensor is an essential element of a feedback control of air-fuel ratio. The sensor has a mechanism in which a zirconia tube, which is a solid electrolyte, is exposed into the exhaust gas and the outside of a zirconia tube to an exhaust gas, the inside to an atmosphere with a known oxygen concentration respectively. Any difference produced between the two sides of the zirconia tube causes electromotive force to be generated. Oxygen sensor should be installed at the catalyst inlet and outlet each.

[Pre-catalyst oxygen sensor]

When the air-fuel ratio is rich, HC, CO, H_2, etc. react with the oxygen (O_2) that remains in the exhaust gas. This causes a significant reduction of the concentration of the remaining oxygen, which considerably increases the ratio of it to the concentration of oxygen contained in the atmosphere inside, increasing the electromotive force. When the air-fuel ratio is lean, the process is the other way around, resulting in a significant drop in the electromotive force near the stoichiometric ratio. That is, the feedback control functions as electronic control that reduces the air-fuel ratio when it is judged to be on the rich side based on the electromotive force and increases the ratio when it is on the lean side.

[Post-catalyst oxygen sensor]

A post-catalyst oxygen sensor provides information that can be used 1) to diagnose how efficiently a catalyst is using the available oxygen to react and 2) to adjust or trim pre-catalyst equivalence ratio (air-fuel ratio) to a desired level to optimize catalyst conversion efficiency.



6. Electrical system

6.1 Starting system

6.1.1 General

The starting device consists of the starter, starter switch, fuse, battery etc., and the outline of the basic operation is as the followings;

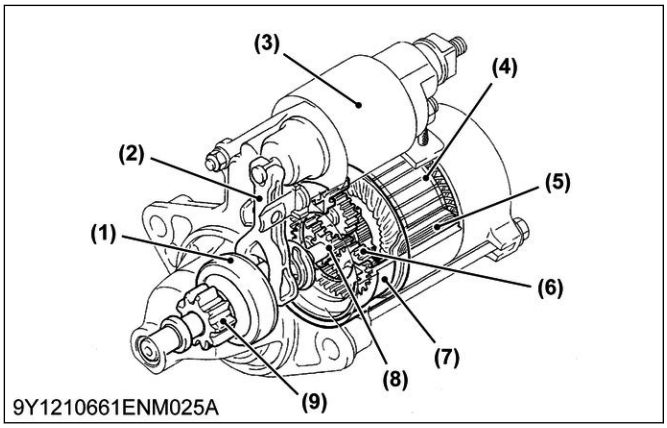
1. Voltage from battery is added to the B terminal of starter switch through the fuse.
2. If the starter switch is turned on, B terminal will be connected to AC, and the electrical current will flow to each load.
3. If the starter switch is turned to the starting position, B terminal will be connected to AC, 19, and 50 will be connected to the ST terminal of starter (in case of the type with safety relay, it shall be connected via relay) to start the engine.
4. After the engine is started, if you have let your hand off the starter switch, it automatically returns to ON position.

6.1.2 Starter

6.1.2.1 P type starters

- The P type starters are reduction type starters that uses a planetary gears. The P types use the same type of compact, high-speed motor as the reduction type, and have planetary gears between the clutch and armature.
  As a result, a more compact and lightweight starter design has been achieved.

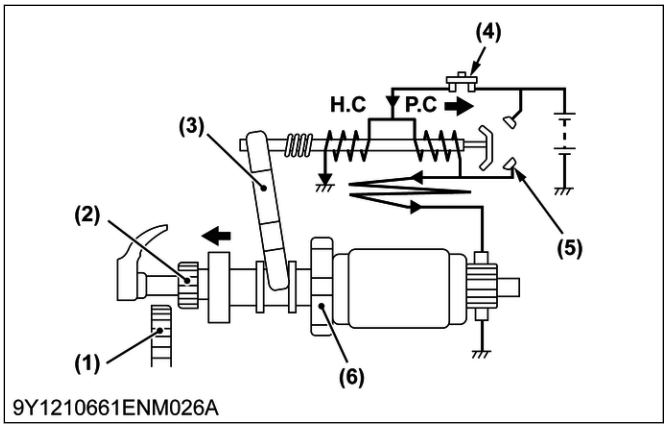
- To engage with the engine, the magnetic switch moves the clutch forward via the drive lever. The clutch slides along a shaft (planetary carrier shaft) connected to the planetary gears.
- The P type starters are equipped with shock absorbers that reduce the shock generated during starter actuation.



(1) Clutch
(2) Drive lever
(3) Magnetic switch
(4) Armature
(5) Field coil
(6) Planetary gear
(7) Internal gear
(8) Sun gear
(9) Pinion gear

6.1.2.1.1 Starter switch on

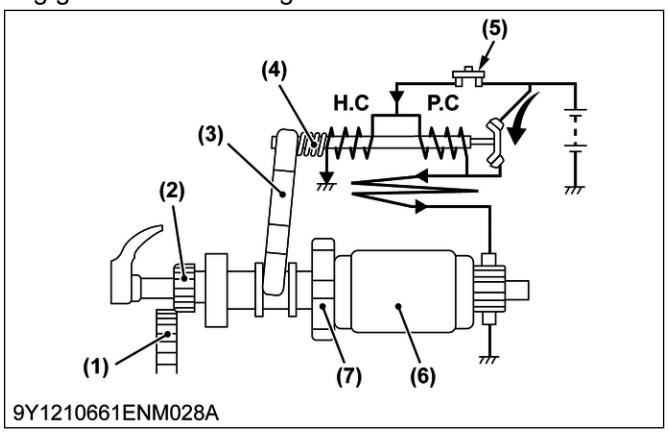
When the starter switch is on, current flows to both the pull-in coil PC and holding coil HC, and the plunger is pulled in by the electromagnetic force generated in both coils.
The pinion gear is thus pushed out to the left, and engages with the ring gear.



(1) Ring gear
(2) Pinion gear
(3) Drive lever
(4) Starter switch
(5) Plunger
(6) Planetary gear

6.1.2.1.2 When the pinion gear engages with the ring gear without collision

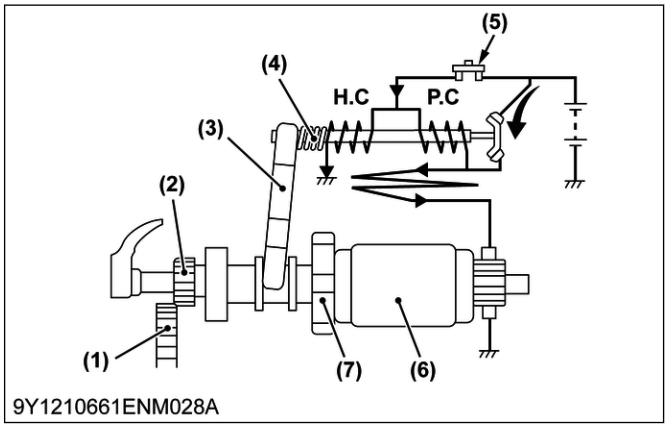
When the pinion gear engages with the ring gear at a certain position, the magnetic switch main contact closes, and a large current flows through the main contact to the armature.
The force of the armature spiral spline pushes the pinion gear forward, engaging the pinion gear with the ring gear to start the engine.



(1) Ring gear
(2) Pinion gear
(3) Clutch
(4) Starter switch
(5) Armature

6.1.2.1.3 When the pinion gear and ring gear collide

If the pinion gear and ring gear teeth contact, the pinion gear cannot move any further. If this happens, the magnetic switch drive spring compresses, and the magnetic switch contact closes. As a result, the armature rotates at high torque, and the teeth alignment position slides. The compression force of the drive spring and the force of the armature spiral spline move the pinion gear forward, engaging the pinion gear with the ring gear to start the engine.



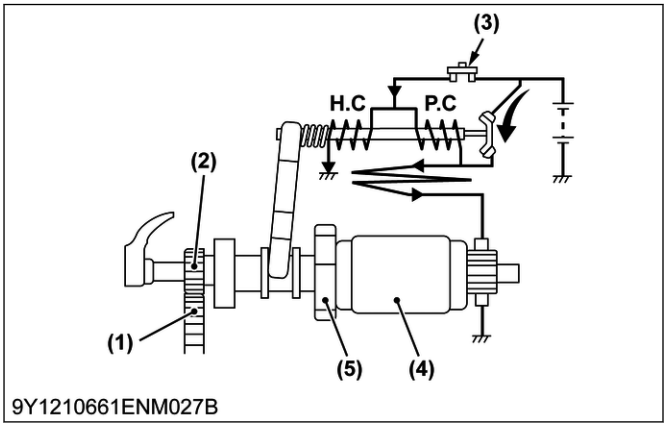
(1) Ring gear
(2) Pinion gear
(3) Drive gear
(4) Drive spring
(5) Starter switch
(6) Armature
(7) Planetary gear

6.1.2.1.4 When the engine is started

When the engine starts, the clutch idles to prevent the ring gear from driving the armature in reverse.

6.1.2.1.5 Starter switch off

When the starter switch is turned OFF, the magnetic switch attraction is cancelled and the pinion gear is returned by the magnetic switch return spring.
The main contact then opens, interrupting the flow of current to the armature.



(1) Ring gear
(2) Pinion gear
(3) Starter switch
(4) Armature
(5) Planetary gear

6.1.2.2 Overrunning clutch

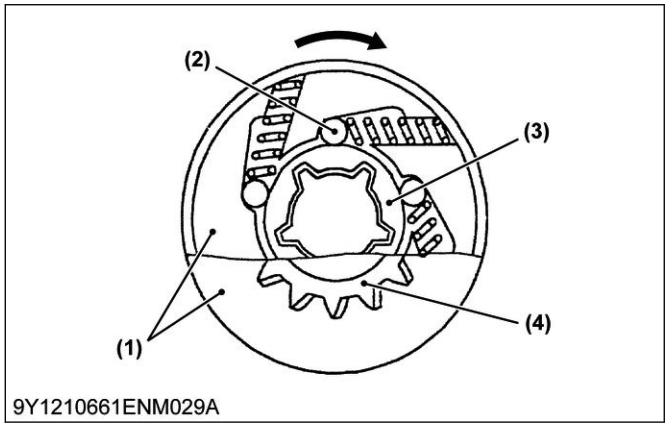
6.1.2.2.1 Function

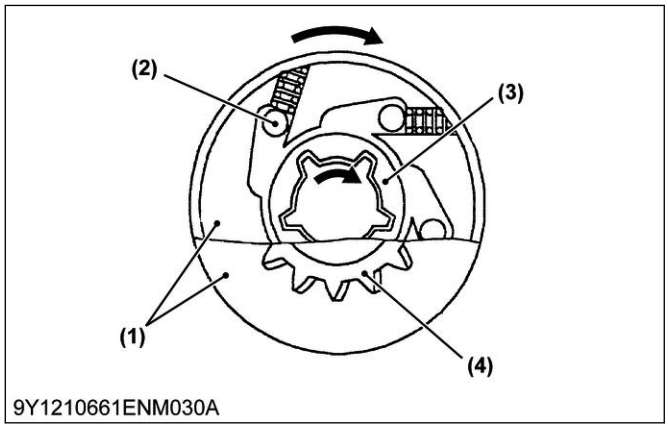
In case that the pinion gear and ring gear are still inter meshed even when the engine is started, the motor will be forced to run in abnormal rotation, and the armature, brush, etc. will be damaged.In order to prevent such an error, the overrunning clutch will function as the device to let the pinion race against the armature shaft when the engine is started, and to shut off transmission of rotation of the engine to the motor.

6.1.2.2.2 Action

When starting:
If the outer is rotated in the arrow mark direction receiving rotation of the armature, the clutch roller will be pushed toward the narrower side of clearance between the outer concave side and the inner so that the outer and inner will be locked. The roller will function as a wedge between the inner and outer, and will transmit the rotation of the outer to the inner,and both will rotate in the same speed.

After the engine is started:
When the pinion is forced to rotate by the ring gear, rotation of the inner (rotation of engine x gear ratio) will become faster than that of the outer (a number of rotation of armature), and the clutch roller will move toward the direction that compresses the spring.
Consequently, clearance between the outer concave side and the inner becomes wide to prevent overrunning of the armature.
(It is required to decrease the contact pressure of the pinion gear and ring gear to realize smooth separation of the pinion gear, and for the sake of this, the pinion gear must be in the state of racing.)

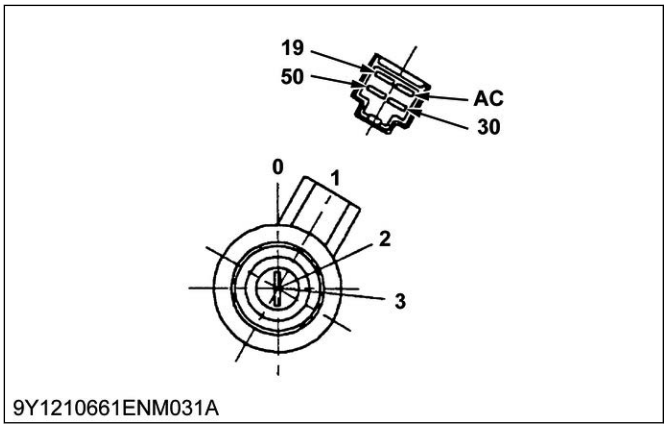




(1) Outer (Integral structure with spline tube)
(2) Clutch roller
(3) Inner (Integral structure with pinion tube)
(4) Pinion gear

6.1.3 Starter switch

Starter switch is an important part comprising of the starting device of engine. Particularly, as seizing of the starter may be incurred due to failure of the starter switch, careful consideration is required for the installation position, place, and direction, so that rain or cleaning water should not directly splash on the starter switch.
As the standard part of KUBOTA engine, the starter switch in below figure is recommended.



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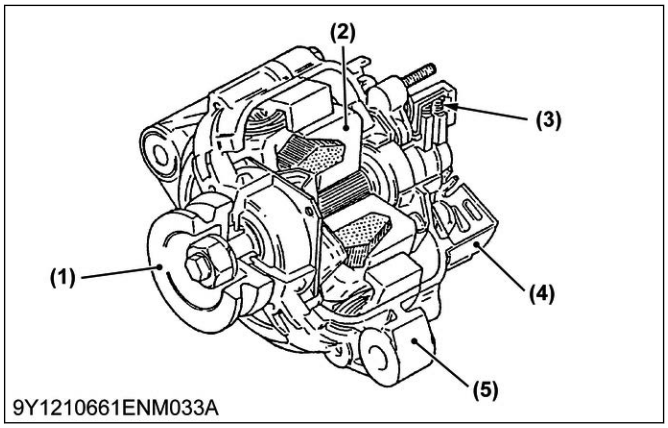
[Connection Diagram]

Position	19	30	50	AC
0				
1		●		●
2	●	●		●
3	●	●	●	●

9Y1210661ENM032enUS



9Y1210661ENM033A

(1) Pulley
(2) Rotor
(3) Brush
(4) Cover
(5) Drive and frame

6.1.4 Starter safety system

The ECU can be configured for either auto cranking (crank until starting) or crank limiting (maximum crank time and disabling of starter if frequency and number of tries is too high).

6.2 Charging system

6.2.1 General

The function of the charging device is to charge batteries.

6.2.2 IC regulator built-in type alternator

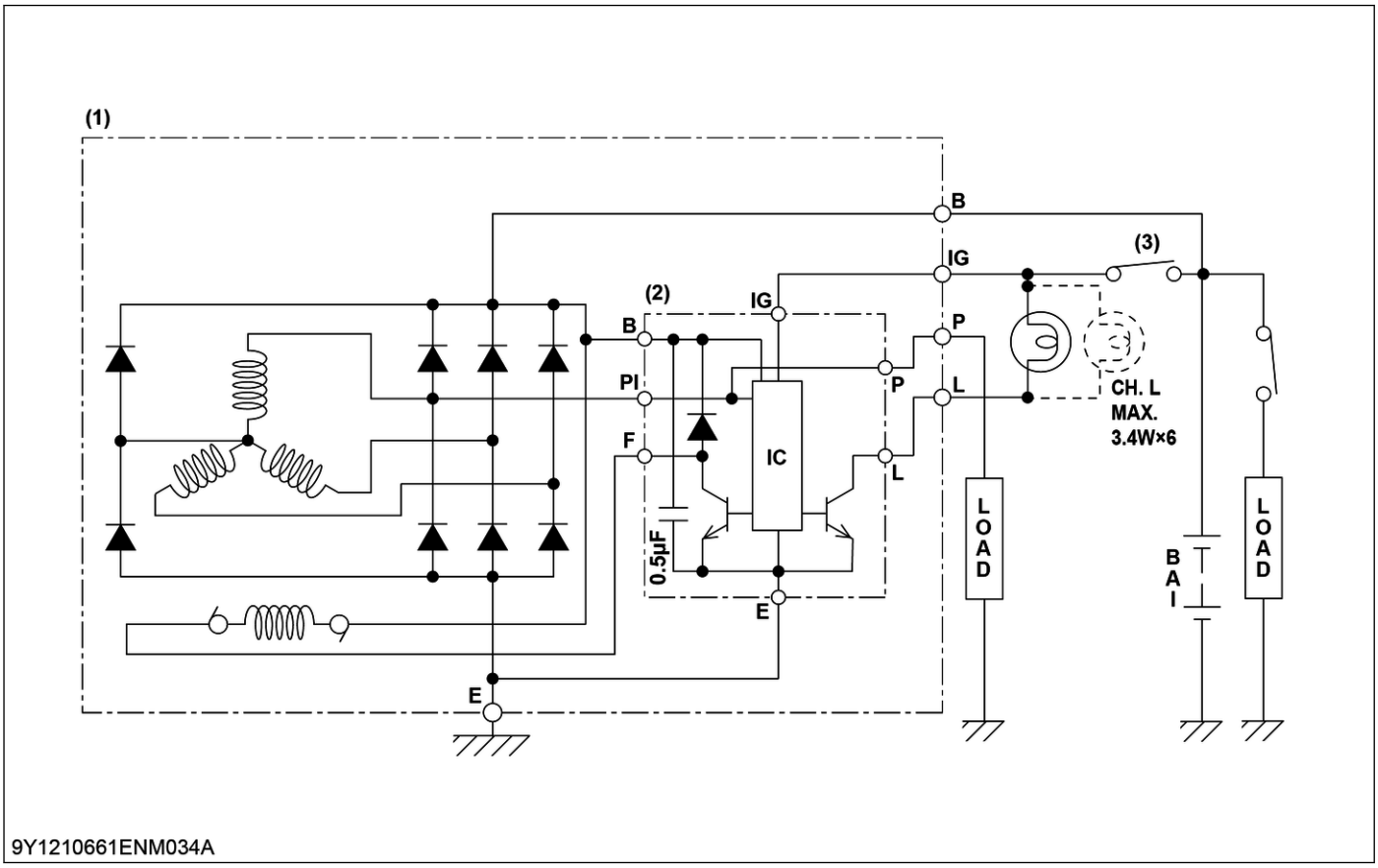
The alternator is the incorporated with an IC regulator, this has been made small size and light weight by the semiconductor technique of the IC regulator.
The cooling property and safety is improved by incorporating the cooling fan and roller that is an integral structure.
Further, the serviceability is also improved by facilitating mounting and removal of the rectifier and IC regulator.

6.2.2.1 D2 type regulator

IC regulator has a special feature that makes it possible to interrupt field current by using the transistor or IC instead of the contact-point-type regulator.
IC regulator has the special features as follows:

1. Readjustment for this regulator is unnecessary because the control voltage does not change over time. Further, vibration-proof property and durability is excellent because IC regulator has no moving parts.
2. Since IC regulator has over-temperature compensation property, which makes the control voltage low if the temperature is increased, it makes it possible to properly charge the batteries.

The circuit inside IC regulator is as shown in the following figure.
It consists of the monolithic IC-incorporated hybrid IC. (Since the inside circuit of the monolithic IC is extremely complex, it is described as "M.IC" circuit.)
"Tr1" has the function as the contact point to control field electrical current, and as the charging lamp relay to light the charging lamp.
"M.IC" controls "Tr1" and "Tr2" by detecting decrease of the output voltage of alternator, decrease of the "L" terminal voltage, disconnection of the rotor coil, and so on.



(1) Alternator assembly (2) IC regulator (3) Key switch

6.2.2.2 Charge light control

Turns the charge light ON and OFF in accordance with alternator power generation.

6.2.2.3 Specification of alternator with IC (Incorporated with) regulator

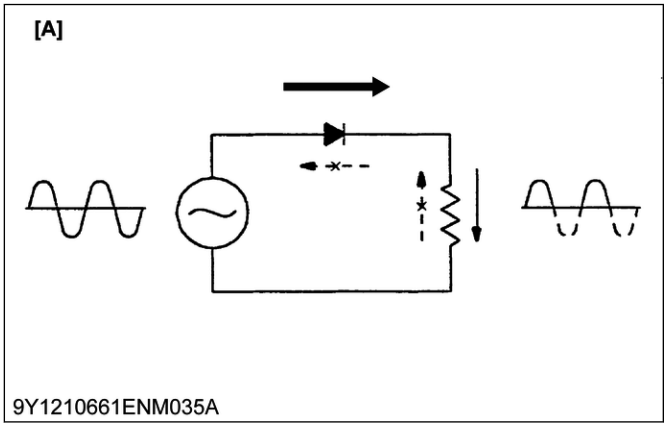
Generating capacity will be determined by rpm of engine and pulley ratio.

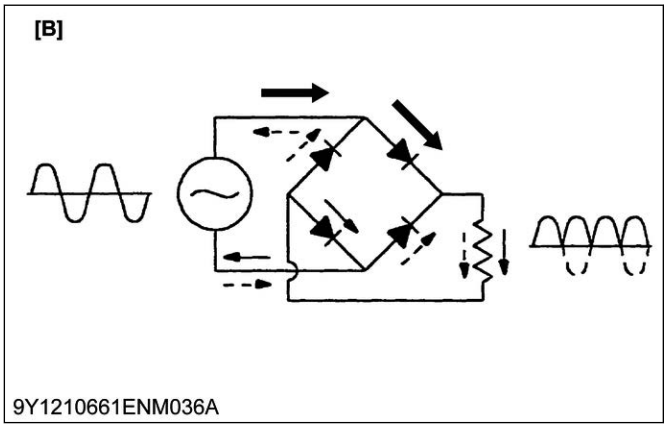
Nominal voltage	12 V
Maximum output	40 A, 60 A
Rotational direction	Right as seen from pulley side
Armature wiring	3 phase, Y wiring
Rectifying system	Total wave rectification
min^{-1} (rpm) at no load (when cold)	14 V at 0 A 1050 to 1350 min^{-1} (rpm)
min^{-1} (rpm) at max. output (when cold)	14 V at maximum output below 4000 min^{-1} (rpm)

6.2.2.4 Total wave rectification

In case of the generator for mobile equipment of which purpose is to charge the batteries, alternating current cannot be used as it is. Because of this, it is required to conduct the action called rectification so that the alternating current can be changed to direct current. Alternator conducts rectification by means of diode.

If the voltage is applied to diode in the normal direction, enough electrical current can flow even by small voltage, however if applied in the reverse direction, it inhibits the reserve flow of electrical current.
Using this property, alternate current generated in the stator coil is changed to the direct current.
As for the rectification using diode, there are two methods, i.e., "half-wave rectification" that takes out only positive portion of alternate current, and 'total-wave rectification' that rectifies both positive and negative current and change to the direct current.





[A] Half-wave rectification [B] Total-wave rectification

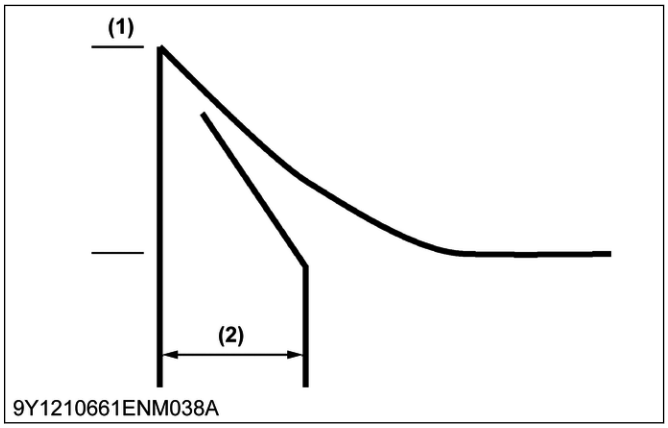
6.2.2.5 Alternator P terminal

NOTE

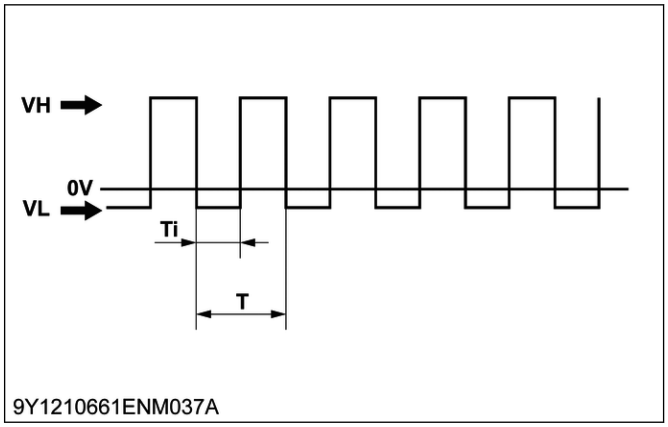
- **As with the B terminal waveform, the P terminal waveform includes noise, which varies depending on the number of revolutions, output and wiring (see the waveform in a separate material).**
- **Surge voltage may be generated by any charging cable disconnection (especially with high number of revolutions/high output), and so on.**

P terminal waveform: The alternator P terminal outputs rotation signals required by a tachometer, and so on.
The P terminal corresponds with one phase of the alternator stator and the output waveform during power generation is a waveform equivalent to the rectangular wave with a frequency in proportion to the number of revolutions of the alternator.

Frequency (1/T)	Number of revolutions of alternator (rpm)/10 Hz
Duty (Ti/T)	Approx. 50 %
VH	About +0 to 2 V with reference to the alternator B terminal voltage (Average)
VL	About −2 to 0 V

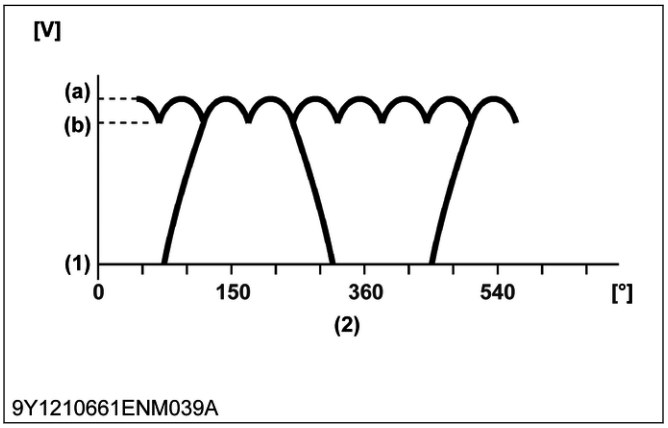


(1) Approx. 150 V (2) Approx. 180 ms



Surge voltage waveform with any charging cable disconnection.

- May be VHmin = 6.5 V in high electric load shedding or unloaded condition with the battery fully charged.



(1) Voltage
(2) Angle of rotation (°)
(a) VH max
(b) VH min

6.2.2.6 Load connected to the P terminal

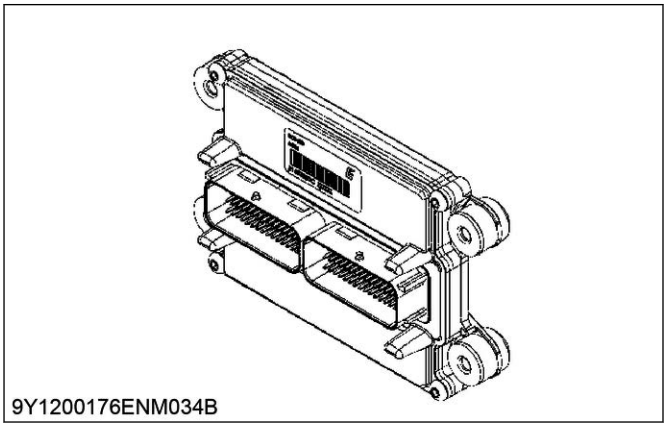
NOTE

- **Ensure that there is no load short circuit or wrong wiring.**
- **Do not connect inductive or capacitive load (connection of such load subject to discussion of the specification).**
- **When detecting a waveform, take the noise and VHmin into consideration.**
- **Take the surge voltage into consideration for the input of the load.**
- **Use the actual equipment for sufficient check of the operation of the load.**

P terminal output current: 0.5 A max (average current).

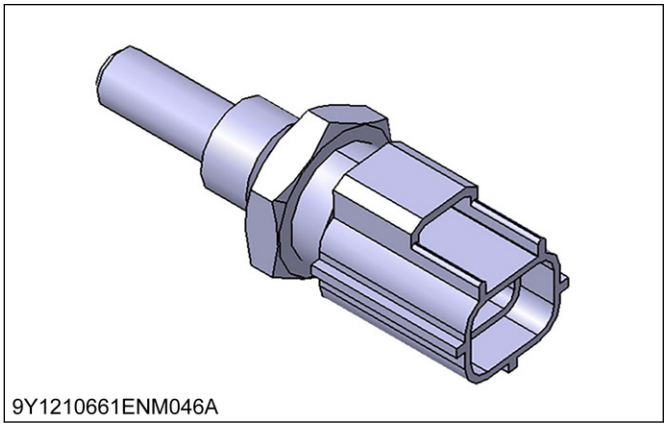
6.2.3 Engine control unit (ECU)

The ECU will use signal inputs, from the engine sensors, to control the fuel metering and speed control, while the engine is running. As well, the ECU will provide diagnostic control, over the fuel system.



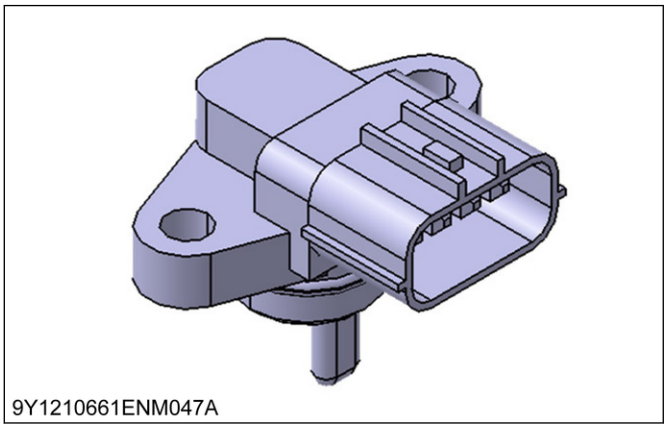
6.2.4 Water temperature sensor

Ignition timing, fuel rate, and boost levels can be configured to vary with engine coolant temperature. This is typically done at very cold or very hot conditions. Coolant temperature is also used in the airflow models in the ECU.



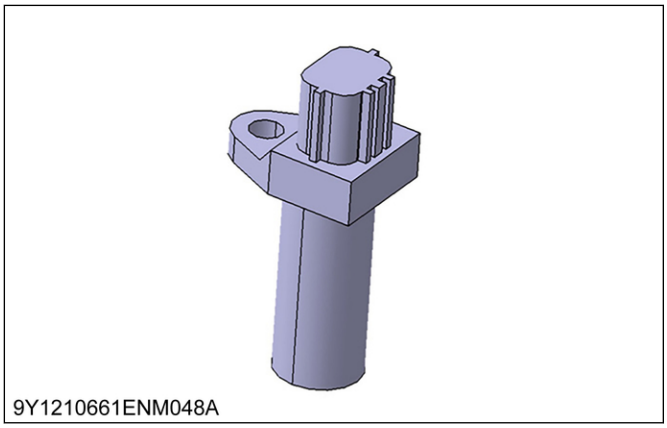
6.2.5 Temperature and manifold absolute pressure sensor (Tmap sensor)

Tmap sensor is mounted in the intake manifold and measures the absolute pressure as well as the temperature of the air / fuel stream. map data is used by the ECU for calculating airflow pressure. The temperature information from the tmap is used for a density correction in the mass air flow calculation.



6.2.6 Crankshaft position sensor

The Crankshaft Position Sensor provides engine speed information.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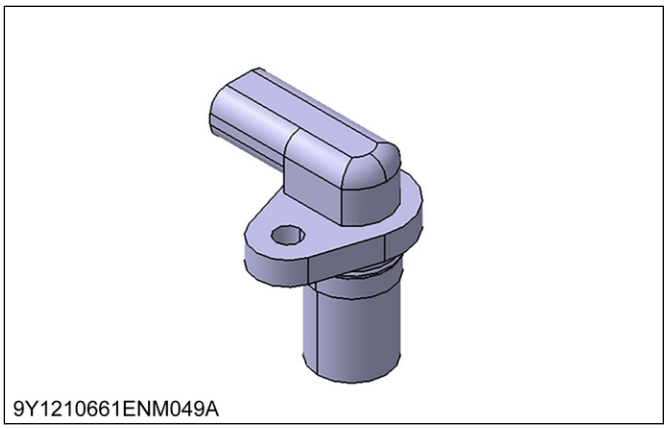
9Y1210661ENM017A

6.2.7 Camshaft position sensor

The Camshaft Position sensor informs the ECU which cylinders are in compression to signal spark timing.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6.2.8 Knock sensor

The knock sensor is used to detect detonation through mechanical vibration in the engine block and / or cylinder heads and provide feedback for the ignition system to retard spark to reduce knock intensity. In most applications the knock sensor is used to protect the engine from damage that can be caused from detonation or knock based on fixed spark advance.
The knock Sensor is a 5 volt reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the engine control unit (ECU) to use. The knock sensor sends a base or "no knock" signal to the ECU, when knocking does occur the sensor detects the increased vibration, and increases the voltage output to the ECU. When the ECU receives the voltage change, the ECU will slightly retard the timing, until such time, the knocking no longer exists.

6.2.9 Ignition coil

Ignition coil is a transformer to generate high electric voltage necessary for the ignition. Around the iron core of multi-layer thin crude steel plates, secondary coil is wound, on whose outside, in the same direction, primary coil is wound. The empty space in the case is filled with resin for electric insulation and good heat radiation.
The ignition timing is controlled by ECU and the high voltage is applied to the spark plugs by the ECU signals.


9Y1210661ENM044A

SERVICING

1. Troubleshooting

1.1 Troubleshooting for general

Symptom	Probable cause	Solution	Reference page
Engine will not turn over	1. Engine jammed	Check engine to find the problem and repair it	–
	2.Battery discharged	Charge	–
	3.Starter malfunctioning	Repair or replace	3-45
	4.Wires disconnected	Reconnect	–
Engine turns over slowly but does not start	1. Increased resistance of moving parts	Repair or replace	–
	2. Excessively high viscosity engine oil at low temperature	Use specified engine oil	2-11
Engine turns over at normal speed but does not start	1. Compression leak	Check the compression pressure and repair	3-36
	2. Improper valve clearance	Adjust	3-36
	3. Damaged ignition coil	Replace	3-43
	4. Damaged spark plug	Adjust spark plug gap or replace	2-15
	5. Clogged air cleaner	Clean or replace	2-14
Rough low-speed running and idling	1. Damaged ignition coil	Replace	3-43
	2. Damaged spark plug	Adjust spark plug gap or replace	2-15
	3. Improper valve clearance	Adjust	3-36
Rough high-speed running	1. Damaged spark plug	Adjust spark plug gap or replace	2-15
	2. Damaged ignition coil	Replace	3-43
Engine speed does not increase	1. Clogged air cleaner	Clean or replace	–
	2. Damaged ignition coil	Replace	3-43
	3. Damaged throttle body	Replace	–
	4. Breather tube has separated	Attach correctly	–
	5. Improper input signal to ECU	Check the wire harness	–
Deficient output	1. Improper intake or exhaust valve sealing	Replace	3-66
	2. Improper valve clearance	Adjust	3-36
	3. Piston ring and cylinder worn	Replace	3-73 3-79

(Continued)

Symptom	Probable cause	Solution	Reference page
Deficient output	4. Clogged air cleaner	Clean or replace	2-14
Engine noise	1. Improper valve clearance	Adjust	3-36
	2. Spark knock due to low-octane fuel or carbon	Use higher-octane fuel and remove carbon	–
	3. Rattles from loosely mounted external components	Retighten	–
Exhaust flames	1. Damaged ignition coil	Replace	3-43
	2. Damaged spark plug	Adjust spark plug or replace	2-15
	3. Wires disconnected or damaged wire	Reconnect / replace	–
	4. Bad connection of ignition coil and spark plug	Reconnect	–

1.2 Troubleshooting for gasoline fuel

Symptom	Probable cause	Solution	Reference page
Engine turns over at normal speed but does not start	1. No fuel	Fill fuel	–
	2.Damaged fuel system	Check fuel line and electronic throttle body and repair	–

1.3 Troubleshooting for LPG / natural gas fuel

Symptom	Probable cause	Solution	Reference page
Engine will not turn over	1. Damaged vaporizer	Replace	–
	2. Damaged lock off valve	Replace	–
Engine turns over at normal speed but does not start	1. No LPG / natural gas fuel	1. Fill LPG / natural gas fuel	–
		2. Check LPG / natural gas tank valve	
		3. Check lock off valve	
Rough low-speed running and idling	1. Shortage of gas supply	1. Fill LPG / natural gas fuel	–
		2. Check lock off valve	
Defection output	1. LPG / natural gas density is rich or lean	1. Repair or replace of fuel system	–
		2. Replace vaporizer	

2. Service specifications for engine

Engine body

Item		Service specification	Service limit
Valve clearance (Cold)		0.145 to 0.185 mm 0.00571 to 0.00728 in.	—
Compression pressure	—	1.27 MPa 13.0 kgf/cm^2 185 psi	0.88 MPa 9.0 kgf/cm^2 130 psi
	Variance among cylinder	—	10 % or less
Top Clearance		1.2 to 1.5 mm 0.048 to 0.059 in.	—
Cylinder head surface	Flatness	—	0.05 mm 0.002 in.
Valve recessing (Intake and exhaust)		−0.050 to 0.25 mm −0.0020 to 0.0098 in.	0.40 mm 0.016 in.
Valve stem to valve guide	Clearance	0.035 to 0.065 mm 0.0014 to 0.0025 in.	0.10 mm 0.0039 in.
• Valve stem	O.D.	6.960 to 6.975 mm 0.2741 to 0.2746 in.	—
• Valve guide	I.D.	7.010 to 7.025 mm 0.2760 to 0.2765 in.	—
Valve face	Angle (Intake)	1.0 rad 60°	—
	Angle (Exhaust)	1.0 rad 60°	—
Valve seat	Angle (Intake)	1.0 rad 60°	—
	Angle (Exhaust)	1.0 rad 60°	—
	Width	2.12 mm 0.0835 in.	—
Valve timing (Intake valve)	Open	0.38 rad 22° Before T.D.C.	—
	Close	0.82 rad 47° After B.D.C.	—
Valve timing (Exhaust valve)	Open	0.91 rad 52° Before B.D.C.	—
	Close	0.30 rad 17° After T.D.C.	—
Valve spring	Free length	35.1 to 35.6 mm 1.39 to 1.40 in.	34.8 mm 1.37 in.
	Tilt	—	1.0 mm 0.039 in.
	Setting load/setting length	74 N/31.0 mm 7.5 kgf/31.0 mm 17 lbf/1.22 in.	63 N/31.0 mm 6.4 kgf/31.0 mm 14 lbf/1.22 in.
Rocker Arm Shaft to Rocker Arm	Oil clearance	0.016 to 0.045 mm 0.00063 to 0.0017 in.	0.10 mm 0.0039 in.

(Continued)

Item		Service specification	Service limit
• Rocker arm shaft	O.D.	11.973 to 11.984 mm 0.47138 to 0.47181 in.	—
• Rocker arm	I.D.	12.000 to 12.018 mm 0.47244 to 0.47314 in.	—
Push rod	Alignment	—	0.25 mm 0.0098 in.
Tappet to tappet guide bore	Oil clearance	0.020 to 0.062 mm 0.00079 to 0.0024 in.	0.07 mm 0.003 in.
• Tappet	O.D.	19.959 to 19.980 mm 0.78579 to 0.78661 in.	—
• Tappet guide bore	I.D.	20.000 to 20.021 mm 0.78741 to 0.78822 in.	—
Timing gear • Crank gear to idle gear 1	Backlash	0.0320 to 0.115 mm 0.00126 to 0.00452 in.	0.15 mm 0.0059 in.
• Idle gear 1 to cam gear	Backlash	0.0360 to 0.114 mm 0.00142 to 0.00448 in.	0.15 mm 0.0059 in.
• Idle gear 1 to injection pump gear	Backlash	0.0340 to 0.116 mm 0.00134 to 0.00456 in.	0.15 mm 0.0059 in.
• Idle gear 1 to idle gear 2	Backlash	0.0330 to 0.117 mm 0.00130 to 0.00460 in.	0.15 mm 0.0059 in.
• Idle gear 2 to governor gear	Backlash	0.0300 to 0.117 mm 0.00119 to 0.00460 in.	0.15 mm 0.0059 in.
Idle gear • Idle gear 1	Side clearance	0.20 to 0.51 mm 0.0079 to 0.020 in.	0.80 mm 0.031 in.
• Idle gear 2	Side clearance	0.20 to 0.51 mm 0.0079 to 0.020 in.	0.80 mm 0.031 in.
Camshaft	Side clearance	0.0700 to 0.220 mm 0.00276 to 0.00866 in.	0.30 mm 0.012 in.
	Alignment	—	0.01 mm 0.0004 in.
Cam height	Intake	28.80 mm 1.134 in.	28.75 mm 1.132 in.
	Exhaust	29.00 mm 1.142 in.	28.95 mm 1.140 in.
Camshaft journal to cylinder block bore	Oil clearance	0.050 to 0.091 mm 0.0020 to 0.0035 in.	0.15 mm 0.0059 in.
• Camshaft journal	O.D.	35.934 to 35.950 mm 1.4148 to 1.4153 in.	—
• Cylinder block bore	I.D.	36.000 to 36.025 mm 1.4174 to 1.4183 in.	—
Idle gear shaft to gear bushing • Idle gear 1	Oil clearance	0.020 to 0.054 mm 0.00079 to 0.0021 in.	0.10 mm 0.0039 in.
• Idle gear bushing	I.D.	26.000 to 26.021 mm 1.0237 to 1.0244 in.	—
• Idle gear shaft 1	O.D.	25.967 to 25.980 mm 1.0224 to 1.0228 in.	—
• Idle gear 2	Oil clearance	0.020 to 0.054 mm 0.00079 to 0.0021 in.	0.10 mm 0.0039 in.
• Idle gear bushing	I.D.	26.000 to 26.021 mm 1.0237 to 1.0244 in.	—

(Continued)

Item		Service specification	Service limit
• Idle gear shaft 2	O.D.	25.967 to 25.980 mm 1.0224 to 1.0228 in.	—
Piston pin bore	I.D.	22.000 to 22.013 mm 0.86615 to 0.86665 in.	22.03 mm 0.8673 in.
Piston pin to small end bushing	Oil clearance	0.014 to 0.038 mm 0.00056 to 0.0014 in.	0.15 mm 0.0059 in.
• Piston pin	O.D.	22.002 to 22.011 mm 0.86622 to 0.86657 in.	—
• Small end bushing	I.D.	22.025 to 22.040 mm 0.86713 to 0.86771 in.	—
Piston pin to small end bushing (Spare parts)	Oil clearance	0.0650 to 0.144 mm 0.00256 to 0.00566 in.	0.15 mm 0.0059 in.
• Small end bushing	I.D.	22.076 to 22.146 mm 0.86914 to 0.87188 in.	—
Piston ring gap	Top ring	0.30 to 0.45 mm 0.012 to 0.017 in.	1.25 mm 0.0492 in.
	Second ring	0.30 to 0.45 mm 0.012 to 0.017 in.	1.25 mm 0.0492 in.
	Oil ring	0.20 to 0.70 mm 0.0079 to 0.027 in.	1.25 mm 0.0492 in.
Piston ring to piston ring groove	Top ring (Clearance)	0.040 to 0.080 mm 0.0016 to 0.0031 in.	0.2 mm 0.008 in.
	Second ring (Clearance)	0.030 to 0.070 mm 0.0012 to 0.0027 in.	0.2 mm 0.008 in.
	Oil ring (Clearance)	0.020 to 0.19 mm 0.00079 to 0.0074 in.	0.2 mm 0.008 in.
Connecting rod	Alignment	—	0.05 mm 0.002 in.
Crankshaft	Side clearance	0.15 to 0.31 mm 0.0059 to 0.012 in.	0.50 mm 0.020 in.
	Alignment	—	0.02 mm 0.0008 in.
Crankpin to crankpin bearing	Oil clearance	0.065 to 0.091 mm 0.0026 to 0.0035 in.	0.20 mm 0.0079 in.
• Crankpin	O.D.	39.959 to 39.975 mm 1.5732 to 1.5738 in.	—
• Crankpin bearing	I.D.	40.040 to 40.050 mm 1.5764 to 1.5767 in.	—
Crankshaft journal to crankshaft bearing 1	Oil clearance	0.0340 to 0.114 mm 0.00134 to 0.00448 in.	0.20 mm 0.0079 in.
• Crankshaft journal	O.D.	47.934 to 47.950 mm 1.8872 to 1.8877 in.	—
• Crankshaft bearing 1	I.D.	47.984 to 48.048 mm 1.8892 to 1.8916 in.	—
Crankshaft journal to crankshaft bearing 2	Oil clearance	0.034 to 0.095 mm 0.0014 to 0.0037 in.	0.20 mm 0.0079 in.
• Crankshaft journal	O.D.	47.934 to 47.950 mm 1.8872 to 1.8877 in.	—
• Crankshaft bearing 2	I.D.	47.984 to 48.029 mm 1.8892 to 1.8909 in.	—

(Continued)

Item		Service specification	Service limit
Crankshaft journal to crankshaft bearing 3	Oil clearance	0.0340 to 0.103 mm 0.00134 to 0.00405 in.	0.20 mm 0.0079 in.
• Crankshaft journal	O.D.	51.921 to 51.940 mm 2.0442 to 2.0448 in.	—
• Crankshaft bearing 3	I.D.	51.974 to 52.024 mm 2.0463 to 2.0481 in.	—
Cylinder liner [Standard]	I.D.	79.000 to 79.019 mm 3.1103 to 3.1109 in.	79.15 mm 3.116 in.
Cylinder liner [Oversize: 0.5 mm (0.02 in.)]	I.D.	79.500 to 79.519 mm 3.1300 to 3.1306 in.	79.65 mm 3.136 in.

Lubricating system

Item		Service specification	Service limit
Engine oil pressure	At idle speed	49 kPa 0.50 kgf/cm^2 7.1 psi	—
	At rated speed	196 to 441 kPa 2.00 to 4.49 kgf/cm^2 28.5 to 63.9 psi	147 kPa 1.50 kgf/cm^2 21.3 psi
Inner rotor to outer rotor	Clearance	0.060 to 0.18 mm 0.0024 to 0.0071 in.	—
Outer rotor to pump body	Clearance	0.100 to 0.180 mm 0.00394 to 0.00708 in.	—
Inner rotor to cover	Clearance	0.025 to 0.075 mm 0.00099 to 0.0029 in.	—

Cooling system

Item		Service specification	Service limit
Fan belt	Tension (After replace)	267 to 361 N 27.3 to 36.8 kgf 60.1 to 81.1 lbf	—
	Tension (Adjusting)	200 to 300 N 20.4 to 30.5 kgf 45.0 to 67.4 lbf	
	Deflection	10 mm 0.39 in. (under load of 98 N (10 kgf, 22 lbf))	
Thermostat	Valve opening temperature (At beginning)	69.5 to 72.5 ℃ 157.1 to 162.5 ℉	—
	Valve opening temperature (Opened completely)	85 ℃ 185 ℉	—
Radiator cap	Pressure falling time	10 seconds or more 88 → 59 kPa 0.89 → 0.61 kgf/cm^2 12 → 8.6 psi	—
Radiator	Weak Leakage Test Pressure (210 kPa, 2.14 kgf/cm^2, 30.5 psi)	No leak at specified pressure	—

Ignition system

Item		Service specification	Service limit
Ignition timing	Gasoline fuel	0.45 rad (26°) Before T.D.C./3000 min^{-1} (rpm)	—
		0.17 rad (10°) Before T.D.C./800 min^{-1} (rpm)	—
	LPG/natural gas fuel	0.35 rad (20°) Before T.D.C./3000 min^{-1} (rpm)	—
		0.17 rad (10°) Before T.D.C./800 min^{-1} (rpm)	—
Crank sensor	Resistance	1.85 to 2.45 kΩ at 20 ℃ (68 ℉)	—
Cam sensor	Resistance	470 to 530 Ω at 20 ℃ (68 ℉)	—
Spark plug (NGK: IFR6F8DN)	Plug gap	0.70 to 0.80 mm 0.028 to 0.031 in.	—
Resistance of ignition coil	Primary (+) - (−)	0.63 to 0.77 Ω at 25 ℃ (77 ℉)	—
	Secondary side (Primary (+) - Plug cap)	7.29 to 8.91 Ω at 25 ℃ (77 ℉)	—

Electrical system

Item		Service specification	Service limit
Starter	Commutator (O.D.)	28.0 mm 1.10 in.	27.0 mm 1.06 in.
	Difference (O.D.)	Less than 0.05 mm 0.002 in.	0.4 mm 0.02 in.
	Mica (Undercut)	0.50 to 0.80 mm 0.020 to 0.031 in.	0.20 mm 0.0079 in.
	Brush (Length)	16.0 mm 0.630 in.	10.5 mm 0.413 in.
Alternator	No-load voltage	14.2 V to 14.8 V at 5000 min^{-1} (rpm), 25 ℃ (77 ℉)	—
	Stator (Resistance)	Less than 1.0 Ω	—
	Rotor (Resistance)	2.9 Ω	—
	Slip ring (O.D.)	14.4 mm 0.567 in.	14.0 mm 0.551 in.
	Brush (Length)	10.0 mm 0.394 in.	8.4 mm 0.33 in.

3. Tightening torque

3.1 Tightening torques of screws, bolts and nuts for special use

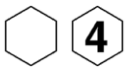
■ NOTE

- **For "*" marked screws, bolts and nuts on the table, apply engine oil to their threads and seats before tightening.**
- **The letter "M" in Size × Pitch means that the screw, bolt or nut dimension stands for metric. The size is the nominal outside diameter in mm of the threads. The pitch is the nominal distance in mm between two threads.**

Item	Dimension × Pitch	N·m	kgf·m	lbf·ft
Cylinder head screw	M10 × 1.25	63.7 to 68.6	6.50 to 6.99	47.0 to 50.5
*Connecting rod screw	M8 × 1.0	41.2 to 46.1	4.21 to 4.70	30.4 to 34.0
*Flywheel screw	M10 × 1.25	53.9 to 58.8	5.50 to 5.99	39.8 to 43.3
*Fan drive pulley screw	M14 × 1.5	235 to 245	24.0 to 24.9	174 to 180
*Main bearing case screw 1	M8 × 1.25	29.4 to 34.3	3.00 to 3.49	21.7 to 25.2
*Main bearing case screw 2	M9 × 1.25	49.0 to 53.9	5.00 to 5.49	36.2 to 39.7
*Cylinder head cover cap nut	M7 × 1.0	6.9 to 8.8	0.71 to 0.89	5.1 to 6.4
Oil pressure switch	PT 1/8	14.7 to 19.6	1.50 to 1.99	10.9 to 14.4
Bearing case cover mounting screw	M6 × 1.0	9.81 to 11.3	1.00 to 1.15	7.24 to 8.33
*Rocker arm bracket nut	M7 × 1.0	21.6 to 26.5	2.21 to 2.70	16.0 to 19.5
*Idle gear shaft mounting screw	M6 × 1.0	9.81 to 11.3	1.00 to 1.15	7.24 to 8.33
Injection pump gear cap nut	M12 × 1.5	58.8 to 68.6	6.00 to 6.99	43.4 to 50.5
Drain plug	M12 × 1.25	32.4 to 37.3	3.31 to 3.80	23.9 to 27.5
Rotation sensor mounting screw	M6 × 1.0	3.0 to 6.0	0.31 to 0.61	2.3 to 4.4
Spark plug	M14 × 1.25	24.5 to 29.4	2.50 to 2.99	18.1 to 21.6
Ignition coil mounting screw/nut	M6 × 1.0	9.81 to 11.3	1.00 to 1.15	7.24 to 8.33
Knock sensor mounting screw	M6 × 1.0	15.0 to 25.0	1.53 to 2.54	11.1 to 18.4
Water temperature sensor	M12 × 1.5	16.7 to 19.6	1.71 to 1.99	12.4 to 14.4
PCV valve	M16 × 1.5	16.0 to 24.0	1.64 to 2.44	11.8 to 17.7
Exhaust manifold mounting nut	M7 × 1.0	15.7 to 18.6	1.60 to 1.89	11.6 to 13.7
Outlet of exhaust manifold nut	M8 × 1.25	29.4 to 34.3	3.00 to 3.49	21.7 to 25.2
Starter B terminal nut	M8 × 1.25	5.88 to 11.8	0.600 to 1.20	4.34 to 8.70
Alternator's pulley nut	—	58.4 to 78.9	5.95 to 8.05	43.1 to 58.2
Inlet of catalytic muffler/converter mounting screw/nut	M10 × 1.25	48.1 to 55.9	4.91 to 5.70	35.5 to 41.2
Outlet of catalytic muffler/converter mounting screw/nut	M12 × 1.25	77.5 to 90.2	7.91 to 9.19	57.2 to 66.5
LPG/natural gas in	—	19.6 to 39.2	2.00 to 3.99	14.5 to 28.9
Lock off valve fitting union	PT 1/4	11.2 to 12.8	1.15 to 1.30	8.26 to 9.44

3.2 Tightening torques for general use screws, bolts

If the tightening torque is not specified, refer to the table below for the none specified torques values.

Indication on top of bolt	 [No-grade or 4T]		
Unit	**N·m**	**kgf·m**	**lbf·ft**
M6	7.9 to 9.3	0.80 to 0.95	5.8 to 6.8
M8	18 to 20	1.8 to 2.1	13 to 15
M10	40 to 45	4.0 to 4.6	29 to 33
M12	63 to 72	6.4 to 7.4	47 to 53

Indication on top of bolt	 [7T]		
Unit	**N·m**	**kgf·m**	**lbf·ft**
M6	9.81 to 11.2	1.00 to 1.15	7.24 to 8.31
M8	24 to 27	2.4 to 2.8	18 to 20
M10	49 to 55	5.0 to 5.7	37 to 41
M12	78 to 90	7.9 to 9.2	58 to 66

4. Checking, disassembling, and servicing

4.1 Checking and adjusting

4.1.1 Engine body

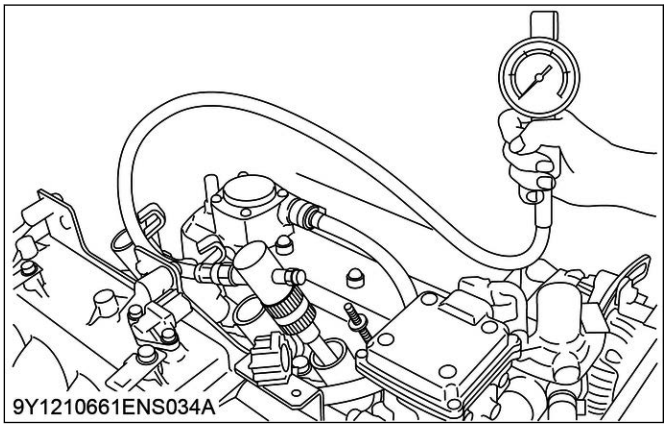
4.1.1.1 Checking compression pressure

NOTE
- **Check the compression pressure with the specified valve clearance.**
- **Always use a fully charged battery for performing this test.**
- **Variances in cylinder compression values should be under 10 %.**
- **Replace the catalytic muffler/converter gasket with a new one**

Tools required
- Compression tester

1. Run the engine until it is warmed up.
2. Stop the engine.
3. Remove all spark plugs.
4. Set a compression tester with the adapter to the spark plug hole.
5. Run the engine with the starter for 5 to 10 seconds and read the maximum compression pressure.

Compression pressure	Service specification	1.27 MPa 13.0 kgf/cm^2 184 psi
	Service limit	0.88 MPa 9.0 kgf/cm^2 130 psi

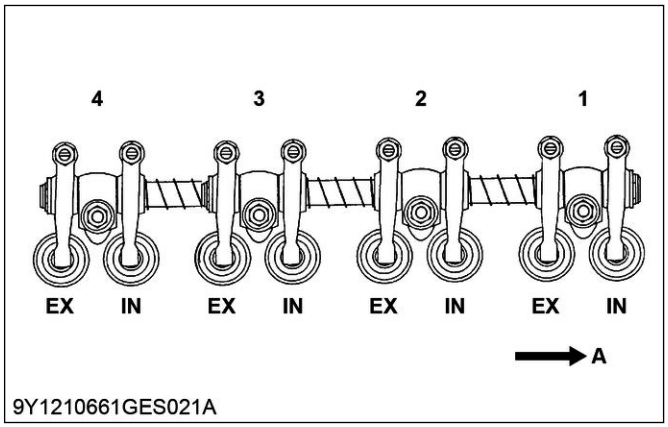


6. Do the same steps for each cylinder.
7. If the measurement is below the service limit, apply a small amount of oil to the cylinder wall through the spark plug hole and measure the compression pressure again.
   - If the compression pressure is still less than the service limit, check the top clearance, valve clearance and cylinder head.
   - If the compression pressure increases after applying oil, check the cylinder wall and piston rings.

4.1.1.2 Adjusting valve clearance

IMPORTANT
- **The clearance must be checked and adjusted when engine is cold.**

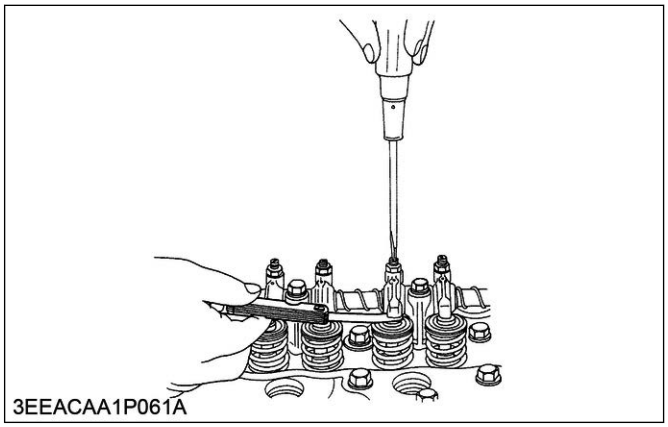
NOTE
- **The sequence of cylinder numbers is given as No. 1, No. 2, No. 3 and No. 4 starting from the gear case side.**



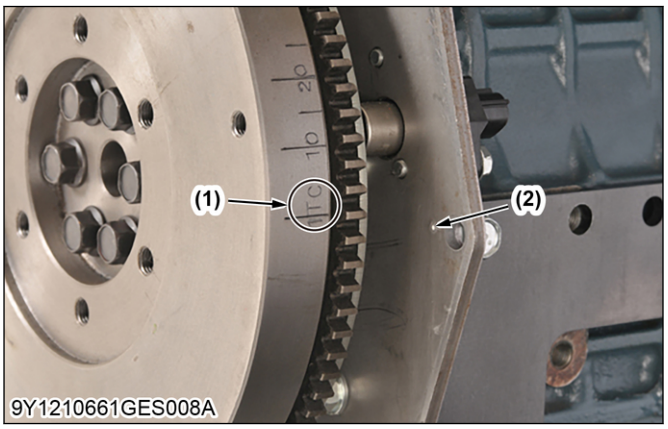
(A) Gear case side

- **After adjusting the valve clearance, secure the adjusting screw with the lock nut.**

1. Remove the cylinder head cover and the spark plugs.



2. Align the "1TC" mark (1) on the flywheel and alignment mark (2) on the rear end plate so that the No. 1 piston comes to the compression top dead center.



(1) "1TC" mark (2) Alignment mark

3. Check the following valve clearance marked with "☆" using a feeler gauge.

Adjustable cylinder location of piston		Intake valve	Exhaust valve
When No. 1 piston is at compression top dead center	1st	☆	☆
	2nd	☆	
	3rd		☆
	4th		
When No. 1 piston is at overlap position	1st		
	2nd		☆
	3rd	☆	
	4th	☆	☆

4. If the clearance is not within the service specifications, adjust with the adjusting screw.
5. Then turn the flywheel 6.28 rad (360 °), and align the "1TC" mark (1) on the flywheel and alignment mark (2) on the rear end plate so that the No. 1 piston comes to the overlap position.
6. Check the following valve clearance marked with "☆" using a feeler gauge.
7. If the clearance is not within the service specifications, adjust with the adjusting screw.

Intake and exhaust valve clearance (cold)	Service specification	0.145 to 0.185 mm 0.00571 to 0.00728 in.

4.1.2 Lubricating system

4.1.2.1 Checking engine oil pressure

■ NOTE

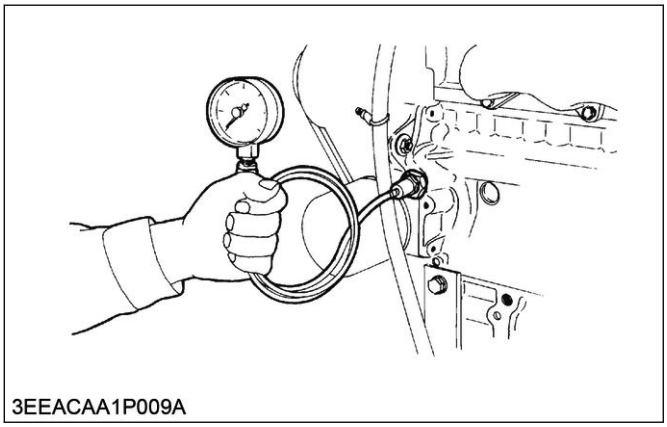
- **After checking the engine oil pressure, tighten the engine oil pressure switch to the specified torque.**

1. Remove the engine oil pressure switch, and set an oil pressure tester.
   - Tighten to the specified tightening torque.

Tightening torque	Oil pressure switch	14.7 to 19.6 N·m 1.50 to 1.99 kgf·m 10.9 to 14.4 lbf·ft

2. Start the engine. After warming up, measure the oil pressure of both idling and rated speeds.

Engine oil pressure	At idle speed	Service specification	49 kPa 0.50 kgf/cm^2 7.1 psi
	At rated speed	Service specification	196 to 441 kPa 2.00 to 4.49 kgf/cm^2 28.5 to 63.9 psi
		Service limit	147 kPa 1.50 kgf/cm^2 21.3 psi



3. If the oil pressure is less than the service limit, check the following.
   - Engine oil insufficient
   - Oil pump damaged
   - Oil strainer clogged
   - Oil filter cartridge clogged
   - Oil gallery clogged
   - Excessive oil clearance
   - Foreign matter in the relief valve

4.1.3 Cooling system

4.1.3.1 Checking fan belt tension

Tools required

- Sonic belt tension meter

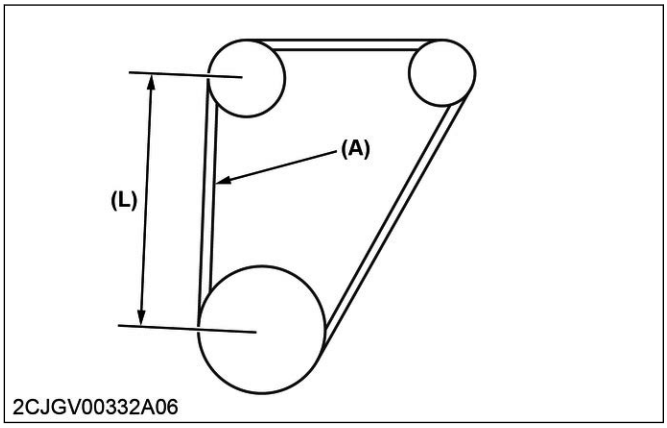
1. Check the tension of fan belt at the position (A) between the fan drive pulley and alternator pulley with sonic belt tension meter.

■ NOTE

- **If the measurement is out of the service specifications, loosen the alternator mounting screws and adjust its position.**

Sonic belt tension meter setting value	
Mass (Mass per 1 rib 1 m of belt)	75 g/rib/m
Width (Number of ribs)	1
Span L	Measure at location (A) in the figure with (L) as the distance between the fan drive pulley and alternator pulley.

Belt tension	Service specification	200 to 300 N 20.4 to 30.5 kgf 45.0 to 67.4 lbf



(A) Fan belt halfway

(Reference)

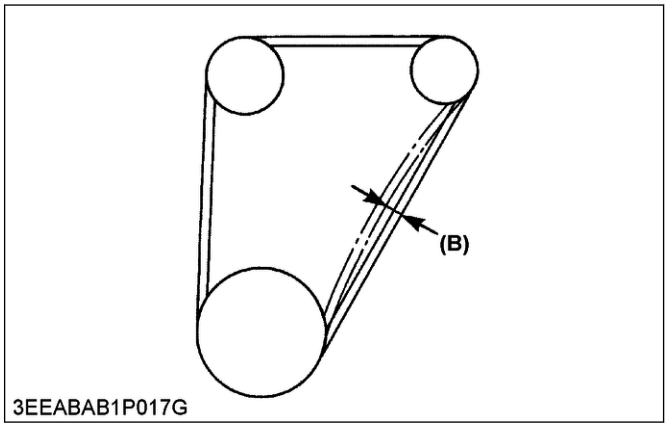
- If you can not prepare the sonic belt tension meter, check the fan belt tension by next procedure.

a. Push the belt halfway between the fan drive pulley and alternator pulley at a specified force to measure the deflection (1).

■ NOTE

- **If the measurement is out of the service specifications, loosen the alternator mounting screws and adjust its position.**

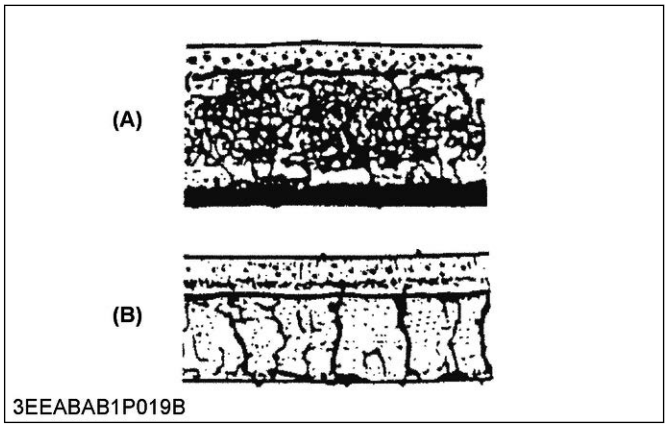
Deflection (B)	Service specification	10.0 mm 0.39 in. (Under load of 98 N (10 kgf, 22 lbf))



(B) Deflection

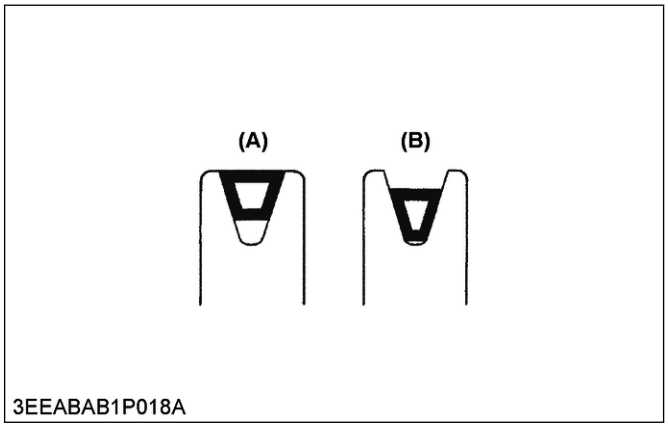
4.1.3.2 Checking fan belt damage and wear

1. Check the fan belt for damage.



(A) Good (B) Bad

2. If the fan belt is damaged, replace it.
3. Check if the fan belt is worn and sunk in the pulley groove.

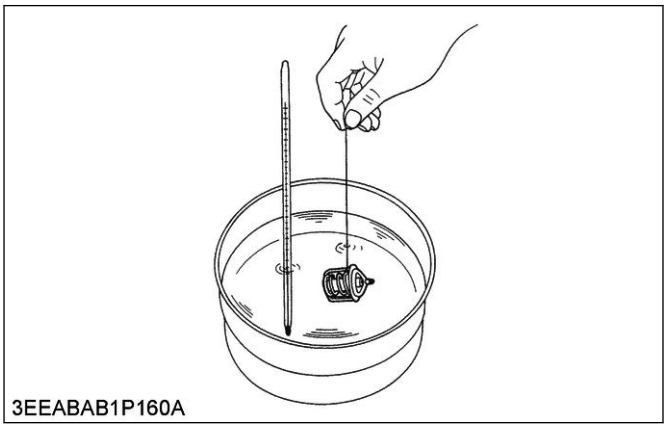


(A) Good (B) Bad

4. If the fan belt is nearly worn out and deeply sunk in the pulley groove, replace it.

4.1.3.3 Checking thermostat valve opening temperature

1. Suspend the thermostat in the water by a string with its end inserted between the valve and seat.


3EEABAB1P160A

2. Heating the water gradually, read the temperature when the valve opens and leaves the string.

Thermostat's valve opening temperature	Service specification	69.5 to 72.5 ℃ 157.1 to 162.5 ℉
Temperature at which thermostat completely opens	Service specification	85 ℃ 185 ℉

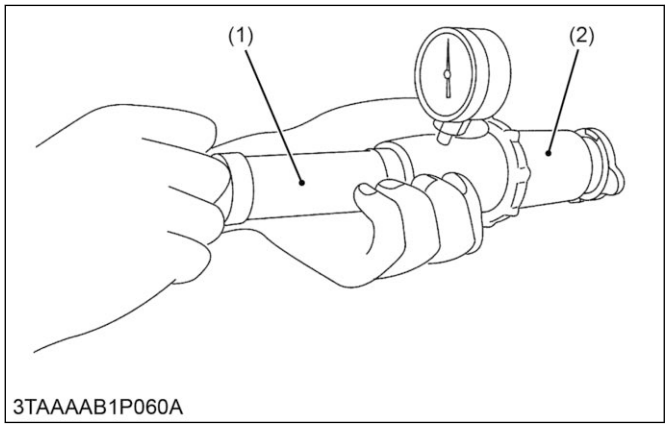
3. Continue heating and read the temperature when the valve opens approx. 8 mm (0.3 in.).
4. If the measurement is not within the service specifications, replace the thermostat.

4.1.3.4 Checking radiator cap air leakage

⚠ CAUTION
- **When removing the radiator cap, wait at least ten minutes after the engine has stopped and cooled down. Otherwise, hot water may gush out, scalding nearby people.**

Tools required
- Radiator tester

1. Set a radiator tester (1) and an adapter (2) on the radiator cap.



3TAAAAB1P060A

(A) Radiator tester (B) Adapter

2. Apply the specified pressure (90 kPa, 0.92 kgf/cm^2, 13 psi), and measure the time for the pressure to fall to 60 kPa (0.61 kgf/cm^2, 8.7 psi).

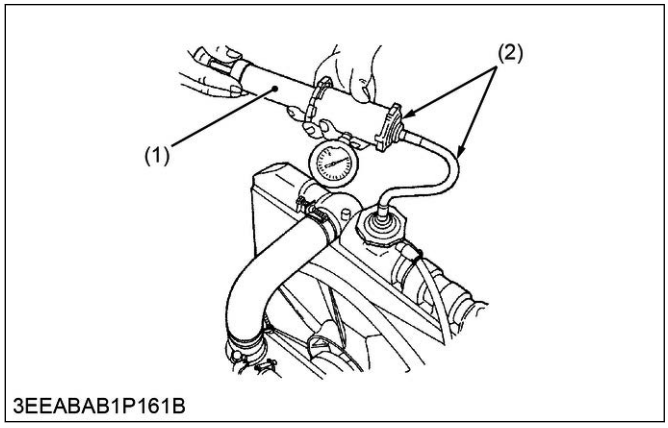
Pressure falling time	Service specification	10 seconds or more 88 → 59 kPa 0.89 → 0.61 kgf/cm^2 12 → 8.6 psi

3. If the measurement is less than the service specification, replace the radiator cap.

4.1.3.5 Checking radiator water leakage

■ NOTE
- **The pressure of the leak test is different from each radiator specification.**
  Thus, do the leak test, refer to the test pressure of each radiator specification.

1. Pour a specified amount of water into the radiator.
2. Set a radiator tester (1) and an adaptor (2) and raise the water pressure to the specified pressure (210 kPa, 2.14 kgf/cm^2, 30.5 psi).



3EEABAB1P161B

(A) Radiator tester (B) Adaptor

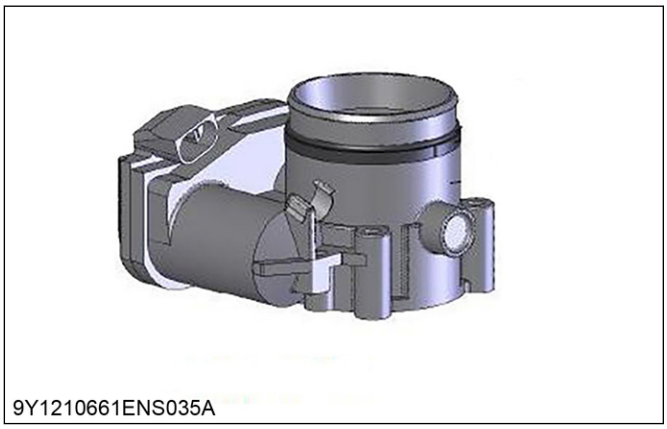
Radiator water leakage test pressure	Service specification	No leak at specified pressure

3. Check the radiator for water leaks.
4. For water leak from the pinhole, repair with the radiator cement. When water leak is excessive, replace the radiator.

4.1.4 Fuel system

4.1.4.1 Checking resistance of throttle body

1. Disconnect the connector.

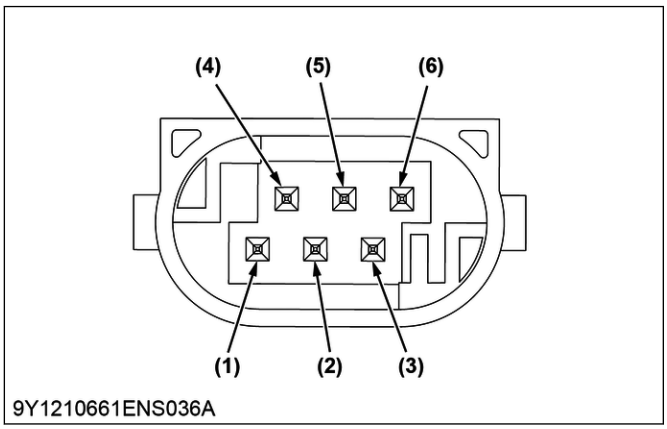

9Y1210661ENS035A

2. Measure the resistance between terminal 1 and terminal 4 with resistance range of circuit tester.

Resistance	Service specification	Terminal 1 – Terminal 4	Continuity

3. If the resistance is 0 Ω or infinity, replace it.
4. Measure the resistance between terminal 2 and terminal 3 with resistance range of circuit tester.

Resistance	Service specification	Terminal 2 – Terminal 3	0.625 to 3.000 kΩ at 20 ℃ (68 ℉)



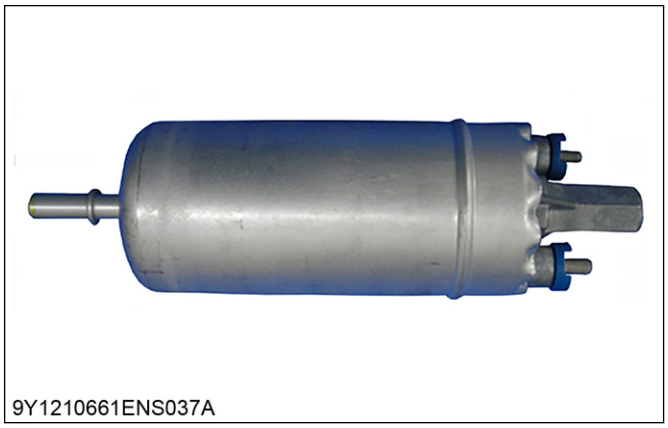
9Y1210661ENS036A

(1) Terminal 1
(2) Terminal 2
(3) Terminal 3
(4) Terminal 4
(5) Terminal 5
(6) Terminal 6

5. If the resistance is not with in the service specifications, replace it.

4.1.4.2 Checking fuel pump

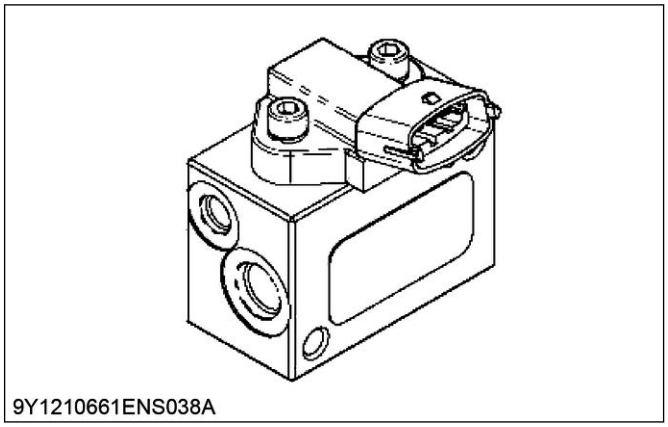
1. Disconnect the wiring.


9Y1210661ENS037A

2. Measure the resistance between terminals with resistance range of circular tester.
3. If the resistance is 0 Ω or infinity, replace it.

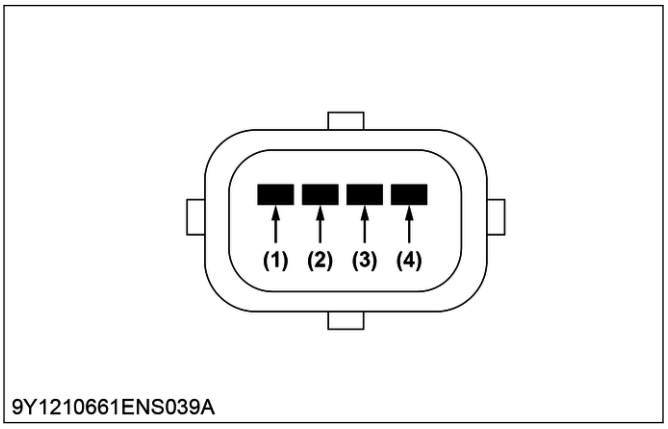
4.1.4.3 Checking resistance of fuel pressure manifold (FPM)

1. Disconnect the connector.


9Y1210661ENS038A

2. Measure the resistance between terminal 1 and terminal 2 with resistance range of circuit tester.

Resistance	Service specification	Terminal 1 – Terminal 2	2.35 to 2.65 kΩ at 20 ℃ (68 ℉)

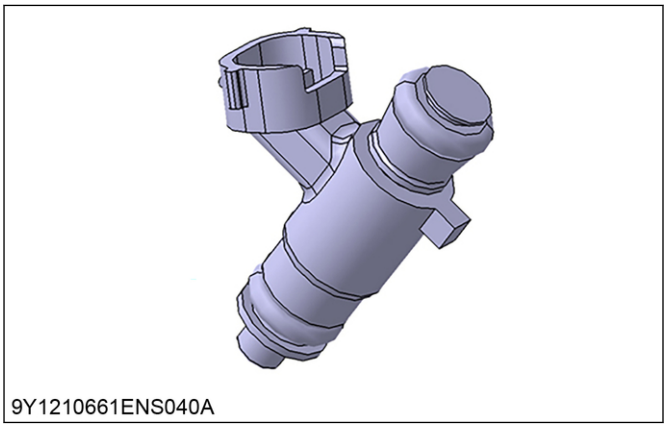


(1) Terminal 1
(2) Terminal 2
(3) Terminal 3
(4) Terminal 4

3. If the resistance is not with in the service specifications, replace it.

4.1.4.4 Checking injector

1. Disconnect the connector.



2. Measure the resistance between terminals with resistance range of circuit tester.

Resistance	Service specification	11.7 to 12.3 Ω at 20 ℃ (68 ℉)

3. If the resistance is not with in the service specifications, replace it.

4.1.4.5 Checking vaporizer hose

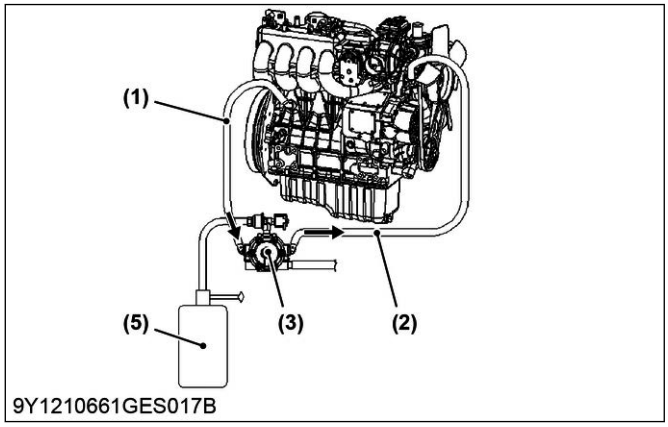
CAUTION

- **All fuel connections added to this engine must be installed by qualified personnel and utilizing recognized procedures and standards.**
- **These non-KUBOTA installed parts, such as hoses, fittings, piping, should be approved for LPG / natural gas use and conform to UL, CSA, NFPA, and all other recognized standards.**
- **An approved, lock off valve must be directly connected to the KUBOTA vaporizer.**

NOTE

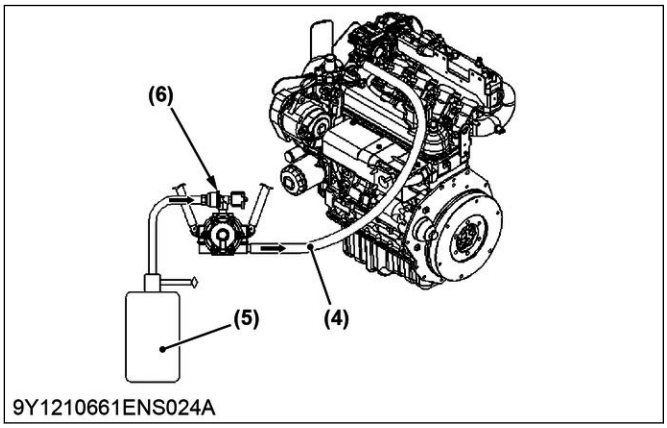
- **The LPG / natural gas in joint (fitting) to the vaporizer / regulator is not provided in the KIT by KUBOTA, due to the many different connection requirements by the OEM.**
- **Vapor hose length must not exceed 700 mm (27.6 in), shorter is generally considered better.**
- **Each hose must be tightened with a hose clamp.**

1. Connect the coolant hose (1) and (2) through the vaporizer.



(1) Coolant hose (ϕ16 mm (5/8 in.) hose fitting)
(2) Coolant hose (ϕ16 mm (5/8 in.) hose fitting)
(3) Vaporizer
(5) LPG / natural gas tank

2. Connect the vapor hose (4).



(4) Vapor hose
(5) LPG / natural gas tank
(6) Lock off valve

- Tighten to the specified tightening torque.

Tightening torque	LPG / natural gas in	19.6 to 39.2 N·m 2.00 to 3.99 kgf·m 14.5 to 28.9 lbf·ft

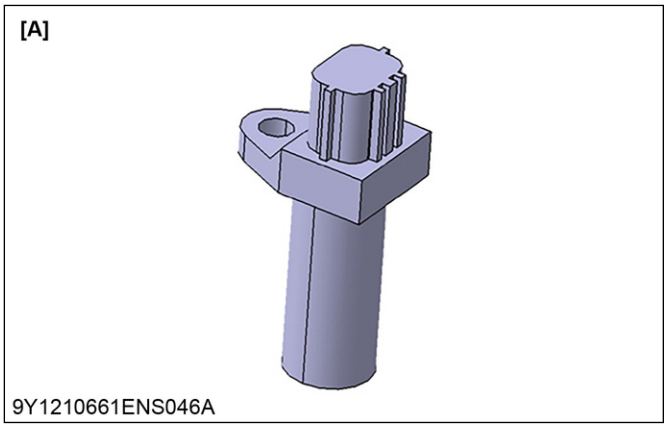
4.1.5 Ignition system

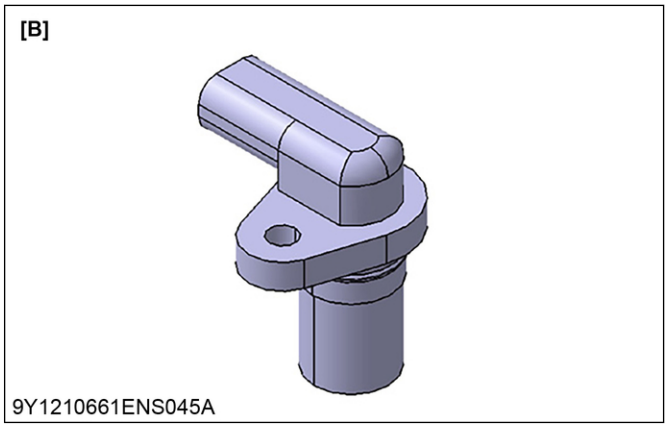
4.1.5.1 Checking resistance of crank sensor/cam sensor

NOTE

- **This table shows the results of the test conducted by using the Sanwa-made testers "SP-10/SP-150" (analog meter).**
- **Use of other testers than those figure may show different measured results.**

1. Disconnect the connector.





[A] Crank sensor
[B] Cam sensor

2. Measure the resistance with resistance range of circuit tester.

Resistance [A]	Service specification	1.85 to 2.45 kΩ at 20 ℃ (68 ℉)
Resistance [B]	Service specification	470 to 530 Ω at 20 ℃ (68 ℉)

3. If the resistance is not with in the service specifications, replace it.

(When reassembling)

- Make sure to be connected firmly.

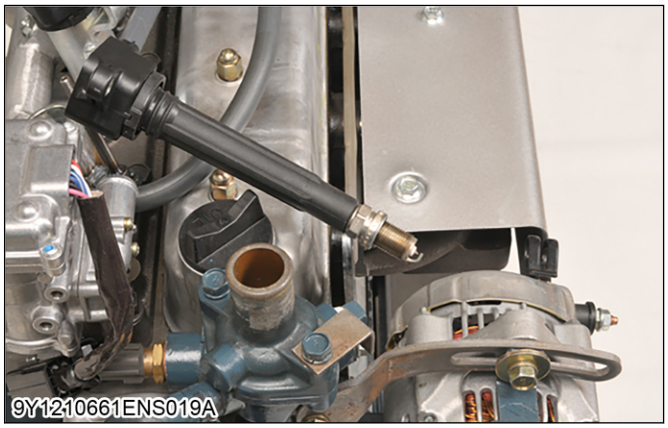
4.1.5.2 Checking spark

CAUTION

- **This test is hazardous of electric shocks. Never use hand or screwdriver to press the plug to ground it to the engine body.**
- **Keep inflammable away from the engine.**

(For gasoline)

1. Disconnect all injector connector.
2. Remove the spark plug, put it inside the ignition coil firmly, and then ground the threaded section to the engine body (not to painted or resin parts).



3. Rotate the starter with the key switch and check that the plug sparks.

4. If test is OK, tighten the spark plug with a plug wrench.

(For LPG, natural gas)

1. Close the LPG/natural gas tank valve.
2. Disconnect the lock off valve connector.
3. Remove the spark plug, put it inside the ignition coil firmly, and then ground the threaded section to the engine body (not to painted or resin parts).
4. Disconnect other ignition coil connector.
5. Rotate the starter with the key switch and check that the plug sparks.
6. If test is OK, tighten the spark plug with a plug wrench.

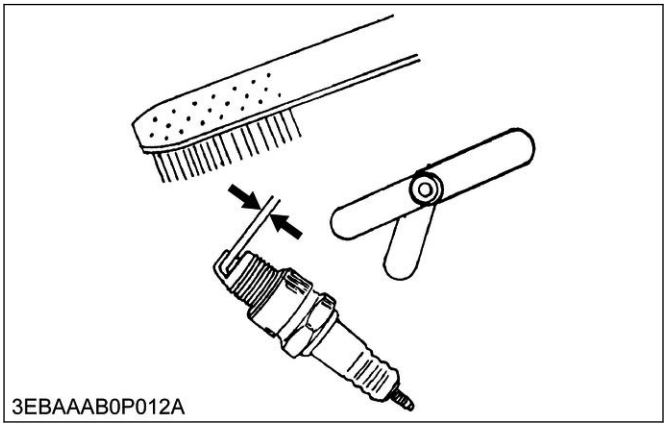
(When reassembling)

■ IMPORTANT

- **Put the ignition coil inside the spark plug terminal firmly.**
- **Make sure that the wiring and the ignition coil are correctly connected.**
- **Make sure that the removed connectors are correctly connected.**
  Open the LPG or natural gas tank valve (for LPG, natural gas).

4.1.5.3 Checking spark plug gap

1. Remove the spark plug, and remove carbon from the electrode with a wire brush or other tools.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2. Measure the spark plug gap with a feeler gauge, and repair or replace the plug if the measured gap differs from the service specification.

Spark plug gap	Service specification	0.70 to 0.80 mm 0.028 to 0.031 in.

Spark plug	NGK: IFR6F8DN

3. Replace the plug if the electrode or the insulator is deformed or cracked.
4. Tighten the plug with a plug wrench.

(When reassembling)

■ IMPORTANT

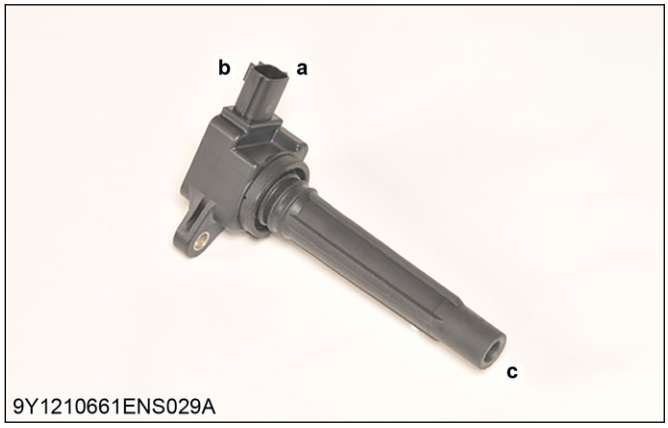
- **Put the ignition coil inside the spark plug terminal firmly.**
- **Make sure that the wiring and the ignition coil are correctly connected.**
- **Fix the ignition coil by screw / nut.**

Tightening torque	Spark plug	24.5 to 29.4 N·m 2.50 to 2.99 kgf·m 18.1 to 21.6 lbf·ft
	Ignition coil mounting screw / nut	9.81 to 11.3 N·m 1.00 to 1.15 kgf·m 7.24 to 8.33 lbf·ft

4.1.5.4 Checking resistance of ignition coil

1. Disconnect the ignition coil.
2. Measure the resistance with resistance range of circuit tester.

Resistance	Service specification	a – b	0.63 to 0.77 Ω at 25 ℃ (77 ℉)



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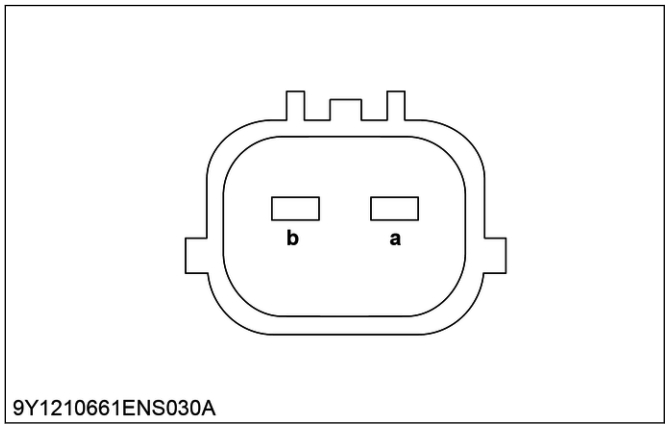


9Y1210661ENS030A

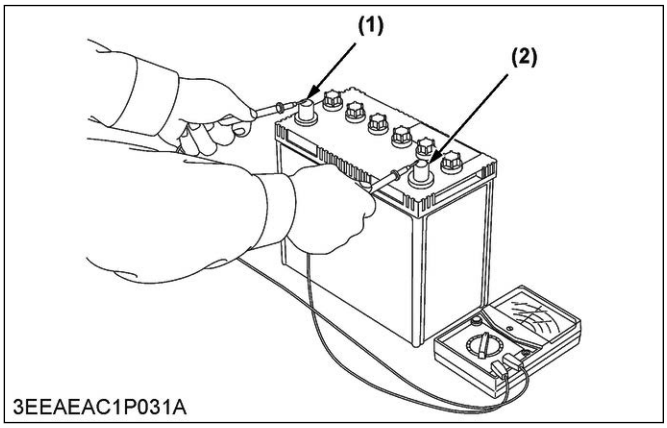
3. If the resistance is not with in the service specifications, replace it.

4.1.6 Electrical system

4.1.6.1 Checking battery voltage

1. Stop the engine.
2. Measure the voltage with a circuit tester between the battery terminals.

Battery voltage	Service specification	More than 12 V



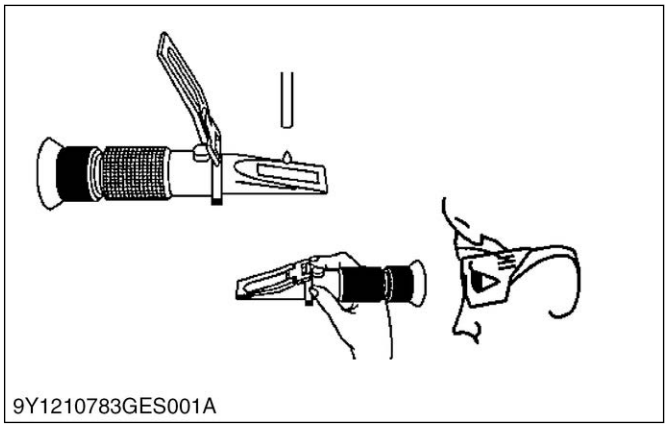
(1) Positive terminal (2) Negative terminal

3. If the battery voltage is less than the service specification, check the battery specific gravity and recharge the battery.

4.1.6.2 Checking battery specific gravity

⚠ CAUTION

- **If battery acid (dilute sulfuric acid) gets on you it could cause blindness or burns, or could cause corrosion of machinery and tools so please be careful when handling.**
- **Wear safety glasses and rubber gloves when performing battery maintenance and inspection (measuring specific gravity, replenishing water, or charging).**
- **If the gas that is generated is ignited by an ignition source, it may explode so be very careful with sparks and fire.**
- **Keep your body and face as far away from the battery as you can when performing maintenance and inspection.**
- **Do not allow people who do not know how to handle a battery or who do not sufficiently understand the danger perform inspection or maintenance.**



(Measurement items)

Zero adjustment

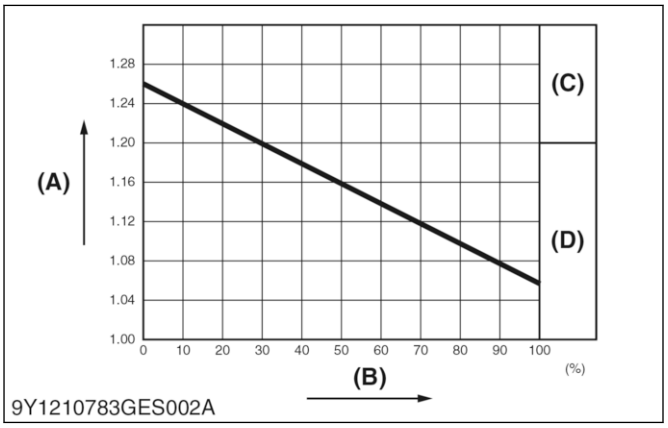
1. Open the cover and drip water on the prism surface using the included rod.
2. Close the cover.
3. Aim in a direction that is bright, look into the lens, and adjust the focus until the gradations can be seen clearly.
4. If the boundary line is not on the gradation baseline (0 position), turn the adjustment screw until it matches.
5. When zero adjustment is complete, wipe the prism and cover surface with a soft cloth or tissue paper.

Measurement of test fluid

1. Open the cover and drip test fluid on the prism surface using the included rod.
2. Close the cover.
3. Aim in a direction that is bright, look into the lens, and adjust the focus until the gradations can be seen clearly.
4. Aim in a direction that is bright, look into the lens and read the gradation of the blue boundary line.
5. When the measurement is complete, wipe the prism and cover surface with a soft cloth or tissue paper.

(Reference)

Electrolyte specific gravity and amount of discharge. Use the following table as a reference.



(A) Electrolyte specific gravity
(B) Discharge
(C) Good
(D) Charging is necessary.

Temperature conversion of electrolyte specific gravity

■ NOTE

- **Battery electrolyte specific gravity changes based on temperature.**
- **Insert the value identified on a specific gravity meter into the following conversion equation for temperature correction to learn an accurate specific gravity value.**
  (Standard temperature assumed to be 20 ℃ (68 ℉))
  D_{20} = Dt + 0.0007 (t - 20)
  D_{20} = specific gravity value converted to standard temperature of 20 ℃ (68 ℉)
  D_t = measured specific gravity value at the electrolyte temperature t ℃

4.1.6.3 Checking motor

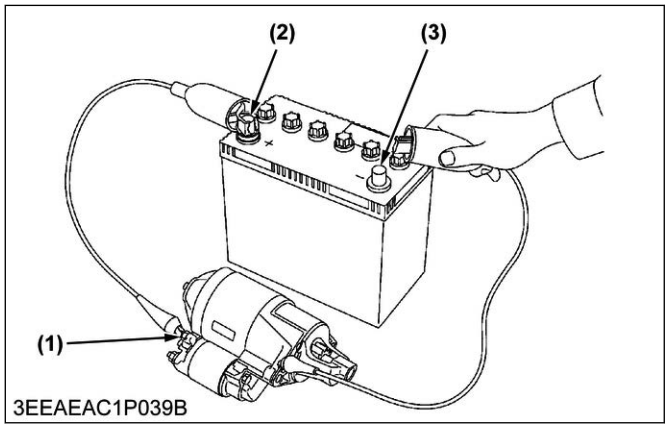
⚠ CAUTION

- **Secure the starter to prevent it from jumping up and down while testing the motor.**

■ NOTE

- **B terminal: It is the terminal which connects the cable from the battery to the starter.**
- **C terminal: It is the terminal which connects the cable from the motor to the magnet switch.**

1. Disconnect the battery negative cable from the battery.
2. Disconnect the battery positive cable from the battery.
3. Disconnect the leads from the starter B terminal.
4. Remove the starter from the engine.
5. Connect a jumper lead from the starter C terminal (1) to the battery positive terminal (2).
6. Connect a jumper lead momentarily between the starter's body and the battery negative terminal (3).



(1) C terminal
(2) Positive terminal
(3) Negative terminal

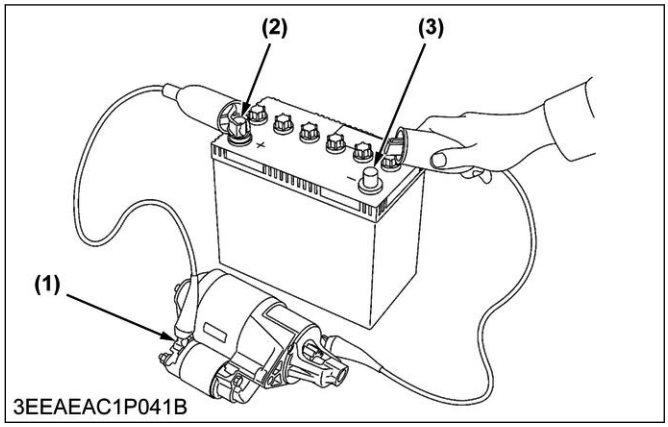
7. If the motor does not run, starter is failure. Repair or replace the starter.

4.1.6.4 Checking magnetic switch

■ NOTE

- **B terminal: It is the terminal which connects the cable from the battery to the starter.**
- **S terminal: It is the terminal which connects the cable from the starter switch to the magnet switch.**

1. Disconnect the battery negative cable from the battery.
2. Disconnect the battery positive cable from the battery.
3. Disconnect the leads from the starter B terminal.
4. Remove the starter from the engine.
5. Connect a jumper lead from the starter S terminal (1) to the battery positive terminal (2).
6. Connect a jumper lead momentarily between the starter's body and the battery negative terminal (3).

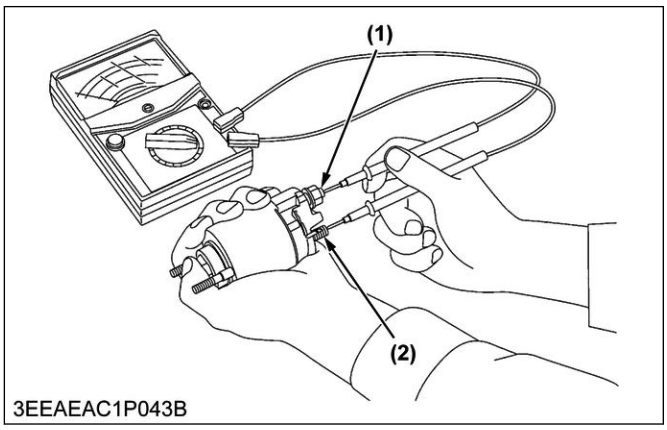


(1) S terminal
(2) Positive terminal
(3) Negative terminal

7. If the pinion gear does not pop out, the magnetic switch is failure. Repair or replace the starter.

4.1.6.5 Checking magnet switch continuity

1. Check the continuity across the C terminal (1) and the B terminal (2) with a circuit tester, pushing in the plunger.



(1) C terminal (2) B terminal

2. If not continuous or if a certain value is indicated, replace the magnet switch.

4.1.6.6 Checking alternator on unit

NOTE

- **Be careful not to touch the rotating engine parts while engine is running.**
  Keep safety distance from the engine rotating parts.

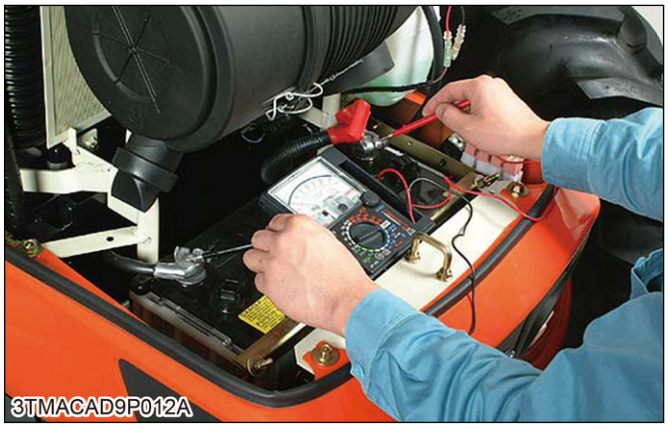
(Before testing)

- Before alternator on unit test, check the battery terminal connections, circuit connection, fan belt tension, charging indicator lamp, fuses on the circuit, and abnormal noise from the alternator.
- Prepare full charged battery for the test.

1. Start the engine.
2. When the engine is operating measure the voltage between two battery terminals. If the voltage is between 14.2 V and 14.8 V, the alternator is operating normally.

Regulating voltage at no load	Service specification	14.2 to 14.8 V at 5000 min^{-1} (rpm), 25 ℃ (77 ℉)

3. If the results of alternator on unit test are not within the specifications, disassemble the alternator and check the each component part for finding out the failure.

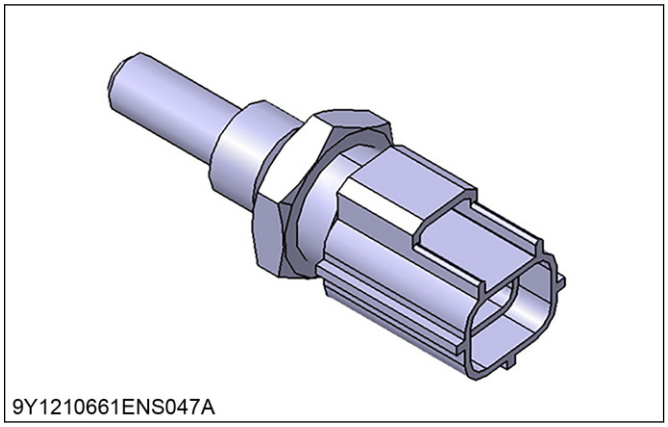


RELATED PAGE

4.2.9 Removing alternator on page 3-62
4.3.8 Alternator on page 3-83

4.1.6.7 Checking resistance of water temperature sensor

1. Disconnect the connector.



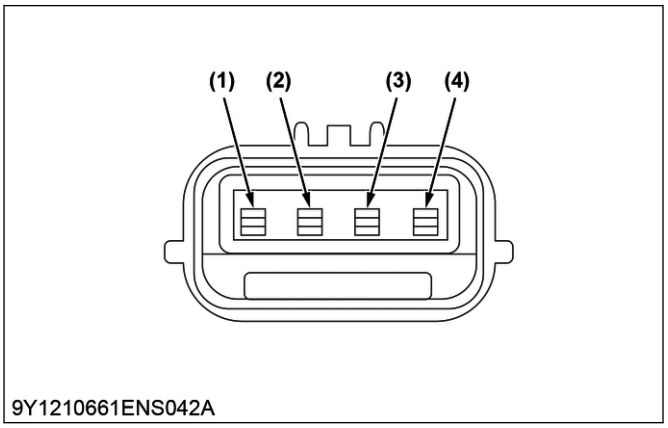
2. Measure the resistance with resistance range of circuit tester.

Resistance	Service specification	2.32 to 2.59 kΩ at 20 ℃ (68 ℉)

3. If the resistance is not with in the service specifications, replace it.

4.1.6.8 Checking resistance of temperature and manifold absolute pressure (TMAP) sensor

1. Measure the resistance between the terminal 1 and terminal 3 of the sensor.



(1) Terminal 1
(2) Terminal 2
(3) Terminal 3
(4) Terminal 4

Resistance of pressure sensor	Service specification	Terminal 1 – Terminal 3	2.174 to 2.942 kΩ at 20 ℃ (68 ℉)

2. If the measurement is not in the service specification, the sensor is damaged. Then replace it with a new one.
3. If the measurement is in the service specification, the sensor is correct electrically.

4.2 Disassembling and assembling

■ IMPORTANT

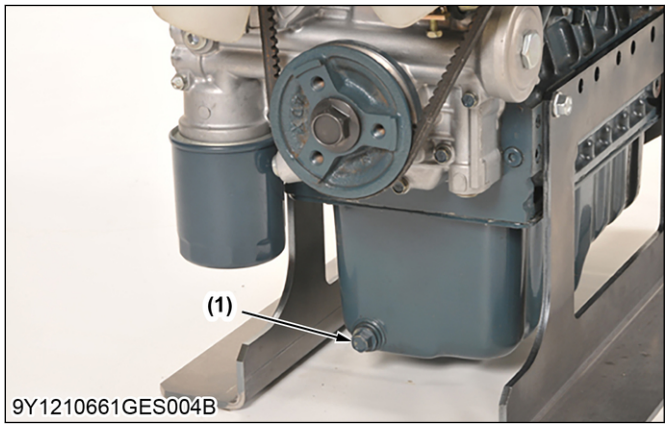
- **When reassembling, replace all of the O-rings and gaskets by new ones.**
- **When disassembling the LPG / natural gas engine after completely consuming the fuel in piping.**
- **In order to reduce the fuel pressure, do not remove the fuel hose at least 3 minutes after stopping the engine.**

4.2.1 Draining coolant and engine oil

4.2.1.1 Draining engine oil

1. Start and warm up the engine for approx. 5 minutes.
2. Place an oil pan underneath the engine.
3. Remove the drain plug (1) to drain oil.
4. After draining, screw in the drain plug (1).
   - Tighten to the specified tightening torque.

Tightening torque	Drain plug	32.4 to 37.3 N·m 3.31 to 3.80 kgf·m 23.9 to 27.5 lbf·ft



(1) Drain plug

(When refilling)

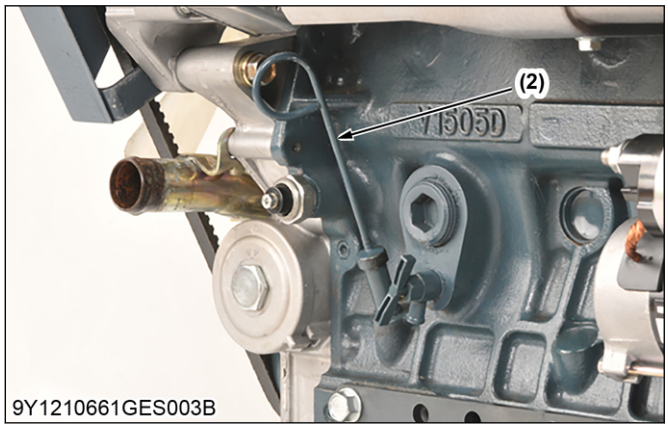
■ IMPORTANT

- **When using an oil of different maker or viscosity from the previous one, remove all of the old oil.**
- **Never mix two different types of oil.**
- **Engine oil should have properties of API classification SH.**
- **Use the proper SAE engine oil according to ambient temperature.**

Above 25 ℃ (77 ℉)	SAE30 or SAE10W-30 or SAE15W-40
0 ℃ to 25 ℃ (32 ℉ to 77 ℉)	SAE20 or SAE10W-30
0 ℃ to −20 ℃ (32 ℉ to −4 ℉)	SAE10W or SAE10W-30

- Fill the engine oil up to the upper line on the dipstick (2).

Engine oil capacity	6.0 L 1.6 U.S. gals



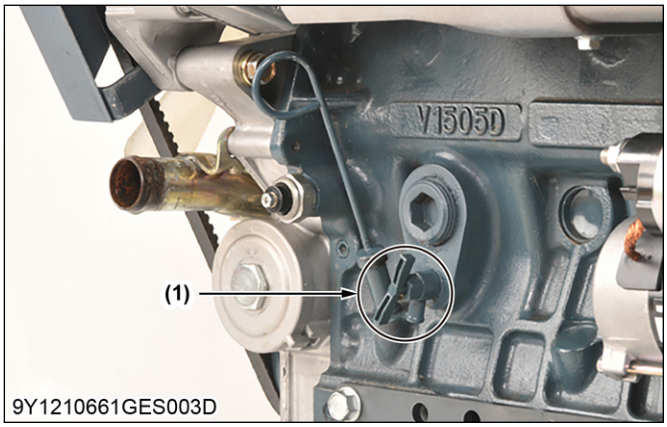
(2) Dipstick

4.2.1.2 Draining coolant

CAUTION

- **Never remove radiator cap while operating or immediately after stopping. Otherwise, hot water will spout out from the radiator. Wait for more than ten minutes to cool the radiator, before opening the cap.**

1. Prepare a bucket. Open the coolant drain valve.

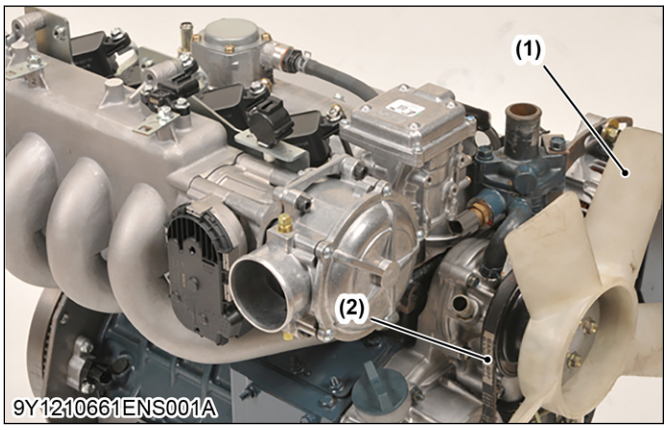


(1) Coolant drain valve

4.2.2 External components

4.2.2.1 Removing alternator, starter and others

1. Remove the air cleaner, catalytic muffler/converter and exhaust manifold.
2. Remove the cooling fan (1), fan pulley and fan belt (2).



(1) Cooling fan (2) Fan belt

3. Remove the alternator.
4. Remove the starter.

(When reassembling)

IMPORTANT

- **After reassembling the fan belt (2), be sure to adjust the fan belt tension.**
- **Do not confuse the direction of the cooling fan (1).**
- **To trace of the catalytic muffler/converter, put down the catalyst identification and engine identification when new service catalytic muffler/converter is installed.**

- Check to see that there are no cracks on the belt surface.
- Replace the exhaust system gasket with a new one.
- Tighten to the specified tightening torque.

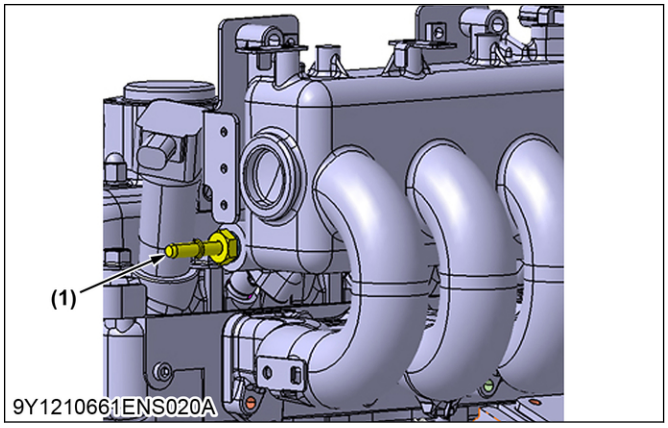
Tightening torque	Exhaust manifold mounting nut	15.7 to 18.6 N·m 1.60 to 1.89 kgf·m 11.6 to 13.7 lbf·ft
	Outlet of exhaust manifold nut	29.4 to 34.3 N·m 3.00 to 3.49 kgf·m 21.7 to 25.2 lbf·ft
	Inlet of catalytic muffler/converter mounting screw/nut	48.1 to 55.9 N·m 4.91 to 5.70 kgf·m 35.5 to 41.2 lbf·ft
	Outlet of catalytic muffler/converter mounting screw/nut	77.5 to 90.2 N·m 7.91 to 9.19 kgf·m 57.2 to 66.5 lbf·ft

4.2.2.2 Removing fuel line (WG1605-G-E3, WG1605-GL-E3, WG1605-GLN-E3)

CAUTION

- **In order to reduce the fuel pressure, do not remove the fuel hose at least 3 minutes after stopping the engine.**
- **Remove the hose after covering the hose with a waste to prevent scatter of fuel.**

1. Disconnect the gasoline hose from the connector (1).



(1) Gasoline hose connector

4.2.2.3 Removing vapor hose and coolant hose (WG1605-N-E3, WG1605-GL-E3, WG1605-LN-E3, WG1605-GLN-E3)

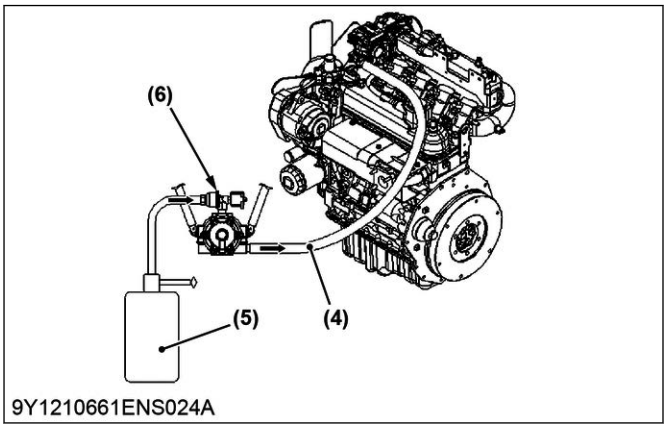
⚠ CAUTION

- **Close the LPG/natural gas tank valve.**
- **In order to reduce the fuel pressure, do not remove the fuel hose at least 3 minutes after stopping the engine.**
- **Vent the air of the water passage of vaporizer (3) after removing the coolant hose (1), (2).**

■ IMPORTANT

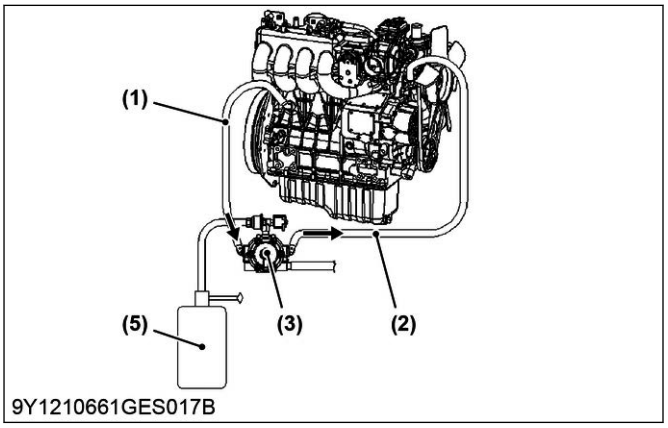
- **When disassembling the fuel system, make sure that the LPG/natural gas tank valve is closed.**

1. Disconnect the vapor hose (4).



(4) Vapor hose
(5) LPG/natural gas tank
(6) Lock off valve

2. After drain the coolant, disconnect the coolant hose (1), (2).
3. Remove the vaporizer (3) (if necessary).



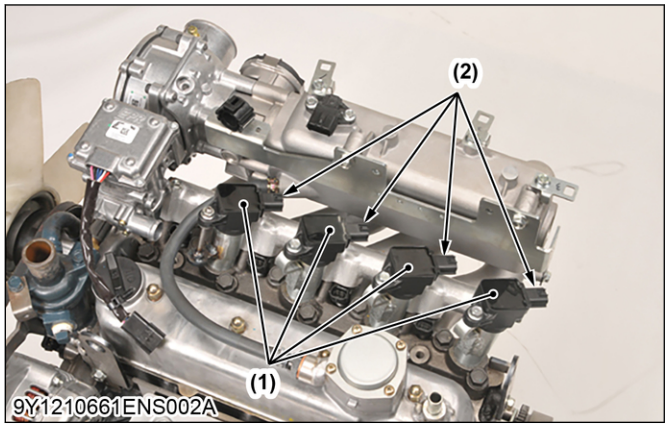
(1) Coolant hose
(2) Coolant hose
(3) Vaporizer
(5) LPG/natural gas tank

(When reassembling)

- Bleed the vaporizer after supplying coolant.

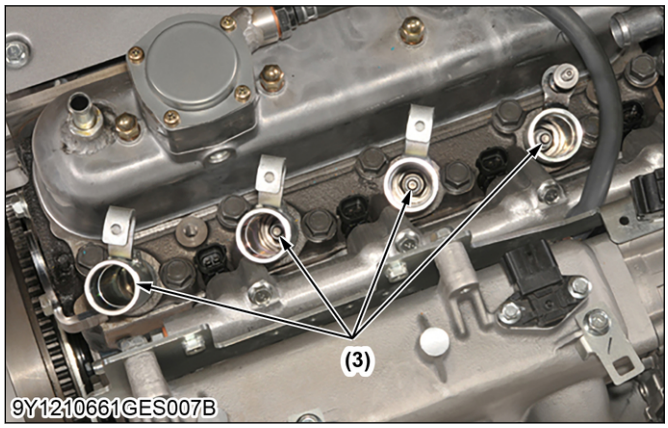
4.2.2.4 Removing ignition coil and spark plug

1. Disconnect the ignition coil connector (2).
2. Remove the ignition coil (1).



(1) Ignition coil
(2) Ignition coil connector

3. Remove the spark plug (3).



(3) Spark plug

(When reassembling)

■ NOTE

- **Put the ignition coil inside the spark plug terminal firmly.**
- **Make sure that the wiring and the ignition coil are correctly connected.**
- **Make sure that the removed connectors are correctly connected.**
- **Fix the ignition coil by screw / nut.**

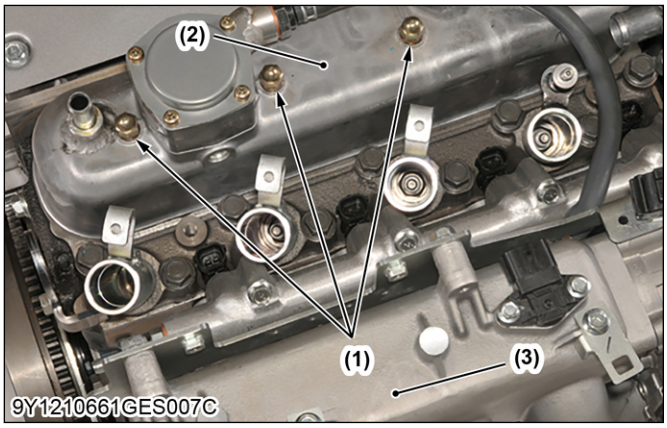
- Tighten the spark plug with a plug wrench.
- Tighten to the specified tightening torque.

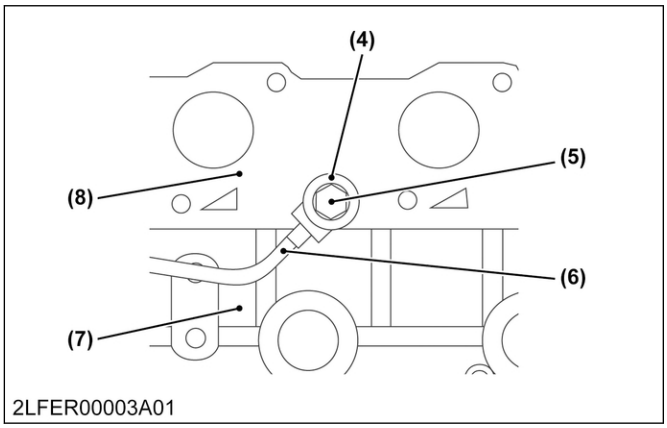
Tightening torque	Spark plug	24.5 to 29.4 N·m 2.50 to 2.99 kgf·m 18.1 to 21.5 lbf·ft
	Ignition coil mounting screw / nut	9.81 to 11.3 N·m 1.00 to 1.15 kgf·m 7.24 to 8.33 lbf·ft

4.2.3 Cylinder head, valves and oil pan

4.2.3.1 Removing cylinder head cover

1. Remove the cylinder head cover cap nut (1).
2. Remove the cylinder head cover (2).
3. Remove the intake manifold (3) and the knock sensor (4).





(1) Cylinder head cover cap nut
(2) Cylinder head cover
(3) Intake manifold
(4) Knock sensor
(5) Knock sensor mounting screw
(6) Knock sensor harness
(7) Crankcase
(8) Cylinder head

(When reassembling)

- Check to see if the cylinder head cover gasket is not damaged.
- Tighten to the specified tightening torque.

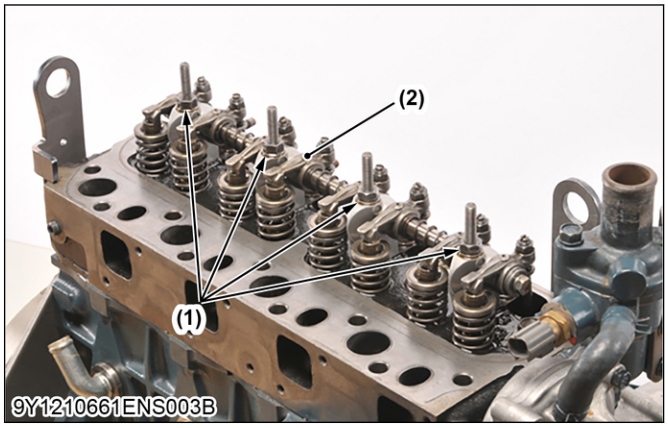
Tightening torque	Cylinder head cover cap nut	6.9 to 8.8 N·m 0.71 to 0.89 kgf·m 5.1 to 6.4 lbf·ft
	Knock sensor mounting screw	15.0 to 25.0 N·m 1.53 to 2.54 kgf·m 11.1 to 18.4 lbf·ft

■ NOTE

- **Use special screw for the knock sensor.**
- **Install the knock sensor in the direction approximately as shown in the illustration so that no force is applied to the harness.**
- **Bundle the harness with clamps so that it does not come into contact with other parts.**

4.2.3.2 Removing rocker arm and push rod

1. Remove the rocker arm bracket nuts (1).



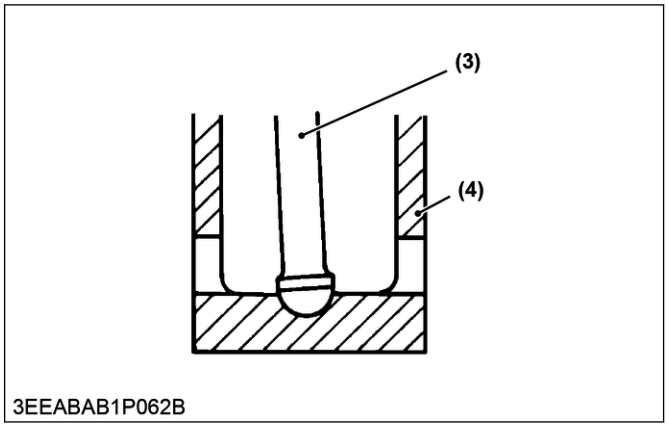
(1) Rocker arm bracket nut

2. Remove the rocker arm assembly (2).
3. Remove the push rods (3).

(When reassembling)

■ IMPORTANT

- **After installing the rocker arm, be sure to adjust the valve clearance.**
- When putting the push rods (3) onto the tappets (4), check to see if their ends are properly engaged with the dimples.



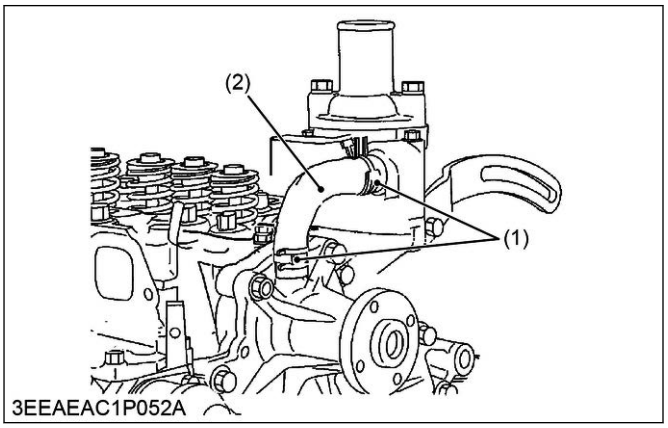
(3) Push rod
(4) Tappet

- Tighten to the specified tightening torque.

Tightening torque	Rocket arm bracket nut	21.6 to 26.5 N·m 2.21 to 2.70 kgf·m 16.0 to 19.5 lbf·ft

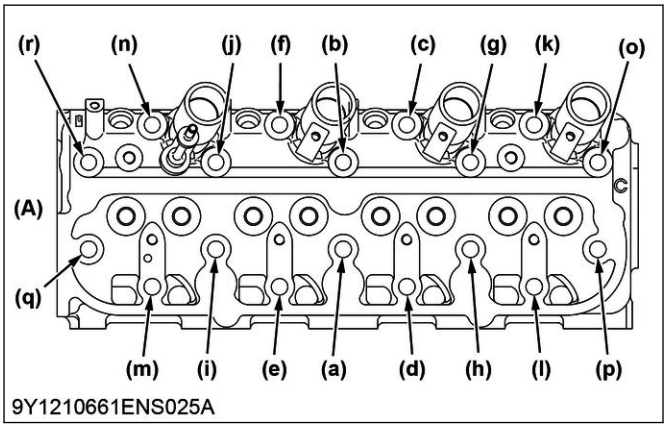
4.2.3.3 Removing cylinder head

1. Loosen the hose clamps (2), and remove the water return hose (1).



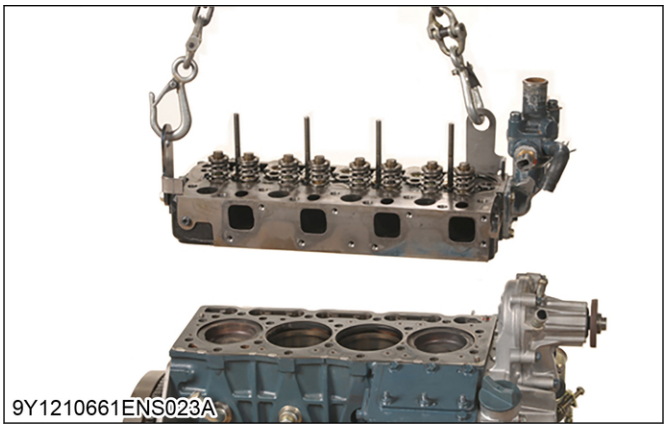
(1) Water return hose (2) Hose clamp

2. Remove the cylinder head screw in the order of (r) to (a).



(A) Gear case side

3. Remove the spark plug.
4. Remove the injector flange (WG1605-G-E3, WG1605-GL-E3)/ignition coil flange (WG1605-L-E3).
5. Lift up the cylinder head to remove.



6. Remove the cylinder head gasket.

(When reassembling)

■ NOTE

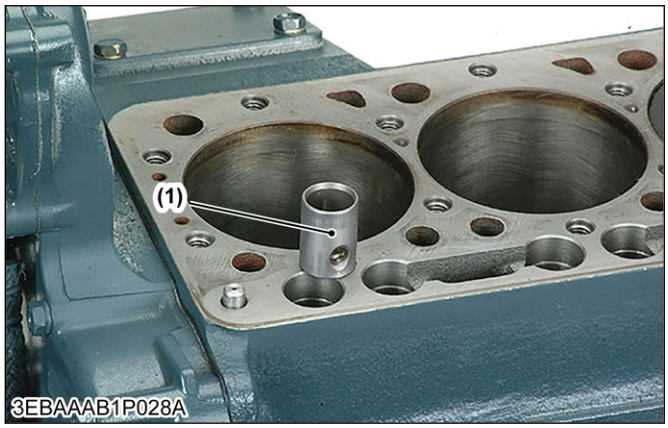
- **Injector flange (WG1605-G-E3, WG1605-GL-E3), ignition coil flange (WG1605-L-E3) mounting screw: length = 105 mm (4.13 in.)**
- **Others: length = 80.5 mm (3.17 in.)**

- Replace the cylinder head gasket with a new one.
- Tighten the cylinder head screws after applying sufficient oil.
- Tighten the cylinder head screws in order of (a) to (r).
  Tighten them uniformly, or the head may deform in the long run.
- Tighten to the specified tightening torque.

Tightening torque	Cylinder head screw	63.7 to 68.6 N·m 6.50 to 6.99 kgf·m 47.0 to 50.5 lbf·ft
	Spark plug	24.5 to 29.4 N·m 2.50 to 2.99 kgf·m 18.1 to 21.6 lbf·ft

4.2.3.4 Removing tappets

1. Remove the tappets (1) from the crankcase.



(1) Tappet

(When reassembling)

■ IMPORTANT

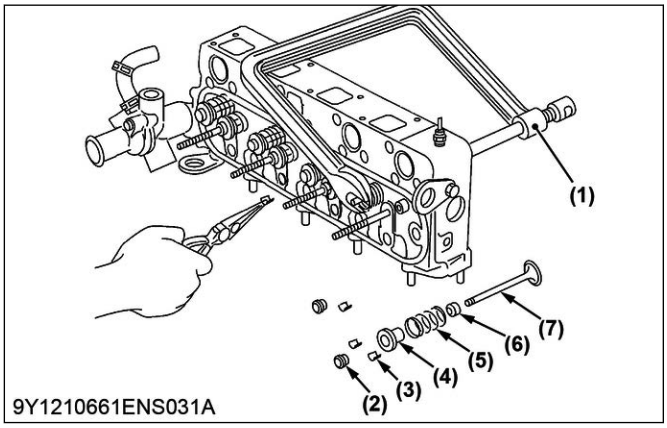
- **Do not change the combination of tappet and tappet guide.**

- Visually check the contact between tappets and cams for proper rotation. If defect is found, replace tappets.
- Before installing the tappets, apply engine oil thinly around them.

4.2.3.5 Removing valves

1. Remove the valve caps (2).

2. Remove the valve spring collet (3), pushing the valve spring retainer (4) with valve spring replacer (1).
3. Remove the valve spring retainer (4), valve spring (5) and valve stem seal (6).
4. Remove the valve (7).



(1) Valve spring replacer
(2) Valve cap
(3) Valve spring collet
(4) Valve spring retainer
(5) Valve spring
(6) Valve stem seal
(7) Valve

(When reassembling)

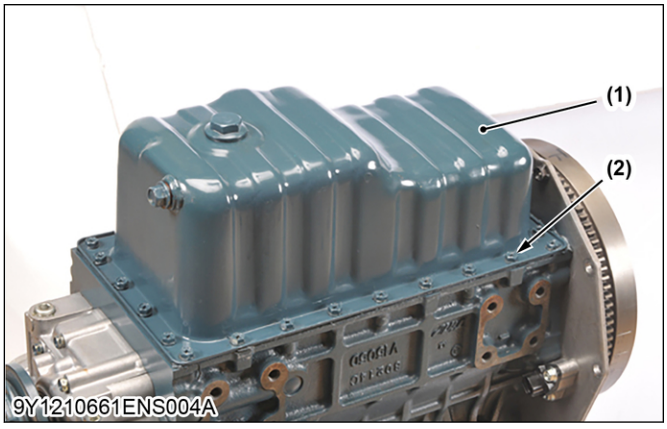
■ IMPORTANT

- **Do not change the combination of valve and valve guide.**

- Wash the valve stem and valve guide hole, and apply engine oil sufficiently.
- After installing the valve spring collets, lightly tap the stem to assure proper fit with a plastic hammer.

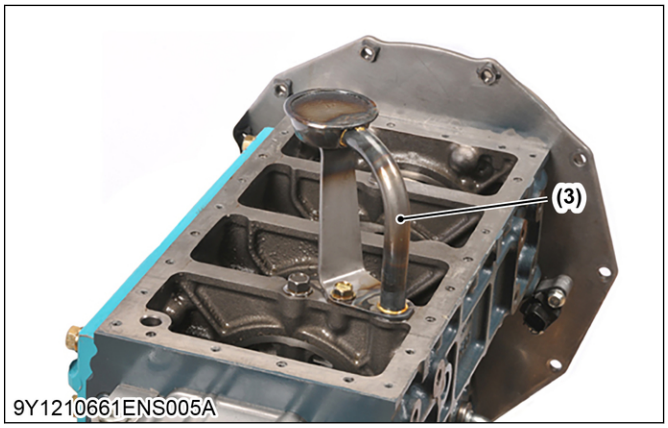
4.2.3.6 Removing oil pan and oil strainer

1. Remove the oil pan mounting screws (2).
2. Remove the oil pan (1) by lightly tapping the rim of the pan with a wooden hammer.



(1) Oil pan
(2) Oil pan mounting screw

3. Remove the oil strainer (3).

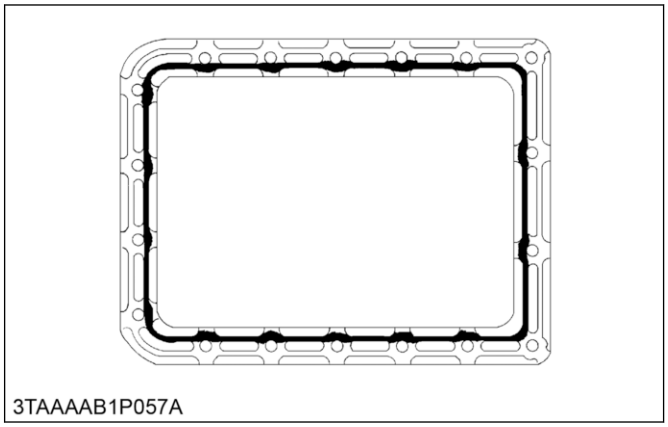


(3) Oil strainer

(When reassembling)

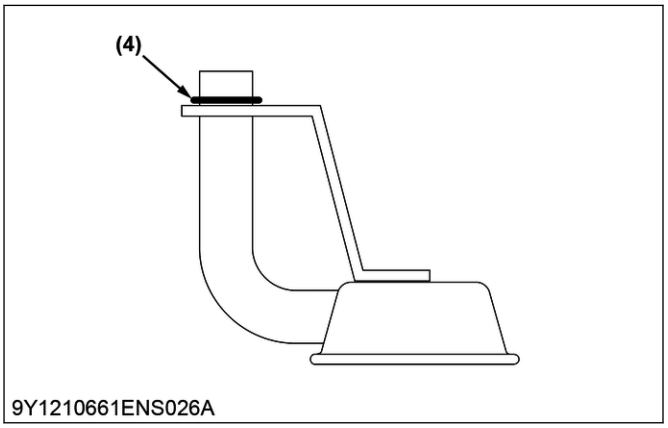
■ IMPORTANT

- **Scrape off the old adhesive completely. Wipe the sealing surface clean. Now apply new adhesive 3.0 to 5.0 mm (0.12 to 0.19 in.) thick all over the contact surface. Apply the adhesive also on the center of the flange as well as on the inner wall of each bolt hole.**



- **Cut the nozzle of the "liquid gasket" (Three Bond 1207D or equivalent) container at its second notch. Apply "liquid gasket" about 5.0 mm (0.19 in.) thick.**
  Within 20 minutes after the application of fluid sealant, reassemble the components. Wait then for about 30 minutes, and pour oil in the crankcase.

- After cleaning the oil strainer, check to see that the filter mesh in clean, and install it.
- Visually check the O-ring (4), apply engine oil, and install it.



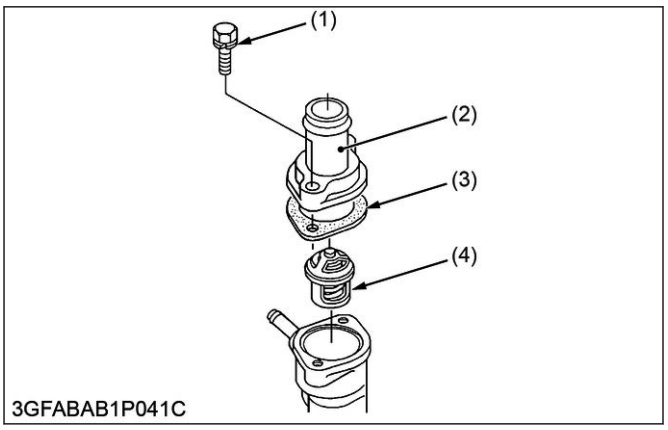
(4) O-ring

- Securely fit the O-ring to the oil strainer.
- To avoid uneven tightening, tighten oil pan mounting screws in diagonal order form the center.

4.2.4 Thermostat

4.2.4.1 Removing thermostat assembly

1. Remove the thermostat cover mounting screws (1), and remove the thermostat cover (2).
2. Remove the thermostat assembly (4).



(1) Thermostat cover mounting screw
(2) Thermostat cover
(3) Thermostat cover gasket
(4) Thermostat assembly

(When reassembling)

- Apply a liquid gasket (Three Bond 1215 or equivalent) only at the thermostat cover side of the gasket (3).

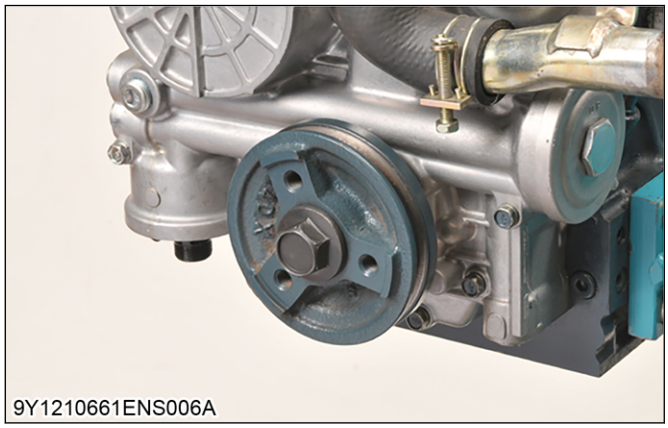
4.2.5 Timing gear, camshaft, gear shaft and PTO shaft

4.2.5.1 Removing fan drive pulley

1. Secure the flywheel to keep it from turning.
2. Remove the fan drive pulley screw.
3. Draw out the fan drive pulley with a puller.

(When reassembling)

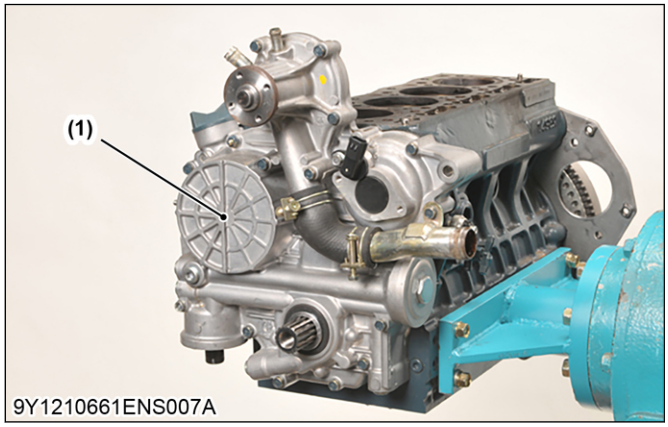
- Apply engine oil to the fan drive pulley retaining screws. And tighten it.
- Tighten to the specified tightening torque.



Tightening torque	Fan drive pulley screw	235 to 245 N·m 24.0 to 24.9 kgf·m 174 to 180 lbf·ft

4.2.5.2 Removing gear case

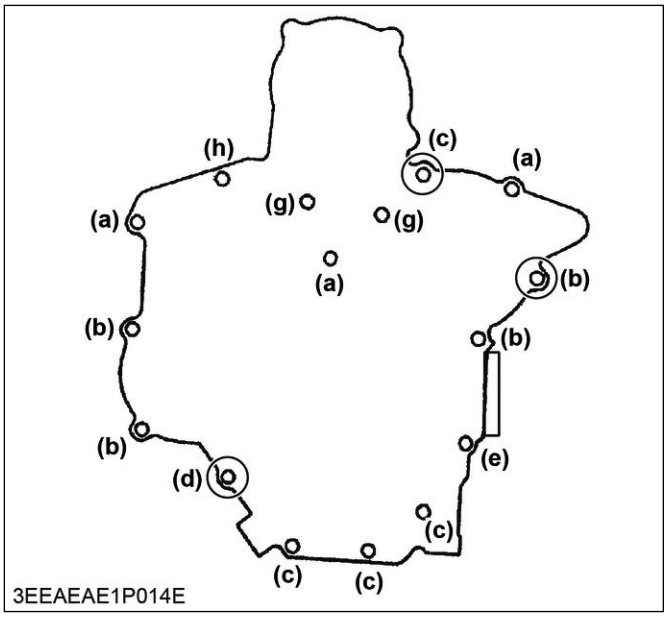
1. Remove the gear case (1).



(1) Gear case

(When reassembling)

- Apply a liquid gasket (Three bond 1215 or equivalent) to both sides of the gear case gasket.

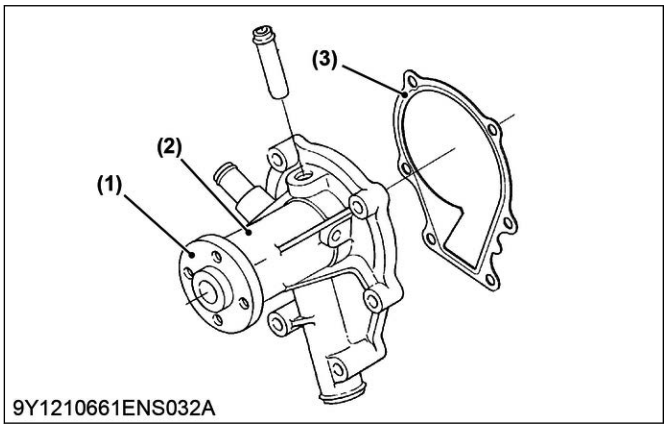


(a) Bolt length = 45 mm (1.8 in.)
(b) Bolt length = 50 mm (2.0 in.)
(c) Bolt length = 55 mm (2.2 in.)
(d) Bolt length = 65 mm (2.6 in.)
(e) Bolt length = 68 mm (2.7 in.)
(g) Bolt length = 85 mm (3.3 in.)
(h) Nut

4.2.5.3 Removing water pump assembly

1. Remove the water pump assembly (2) from the gear case cover.

(When reassembling)
- Apply a liquid gasket (Three Bond 1215 or equivalent) to both sides of water pump gasket (3).

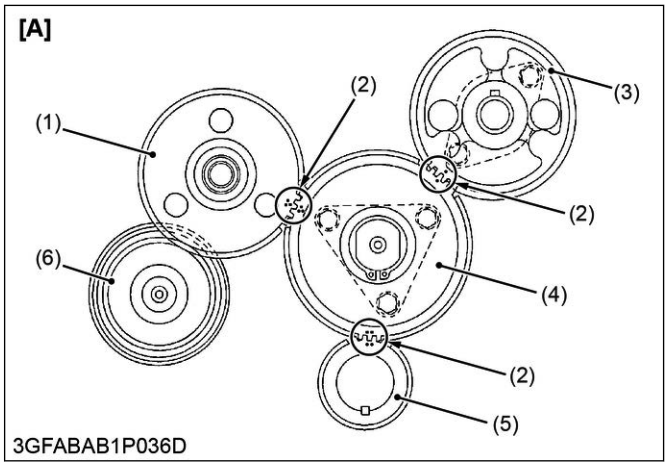


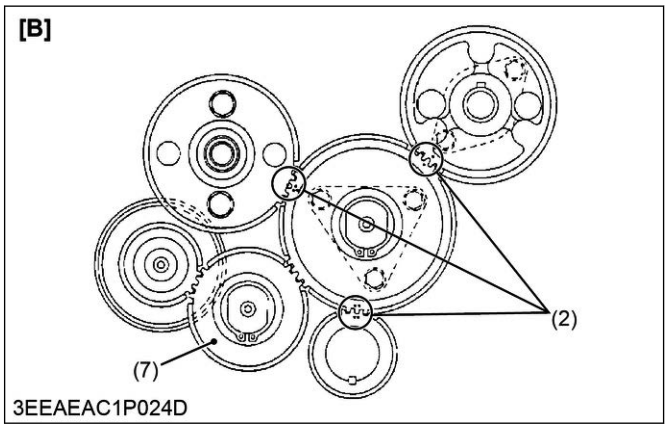
(1) Water pump flange
(2) Water pump assembly
(3) Water pump gasket

4.2.5.4 Removing cam gear, idle gear 1, 2 and governor gear

Tools required
- Adhesive (Three Bond 1324B or equivalent)

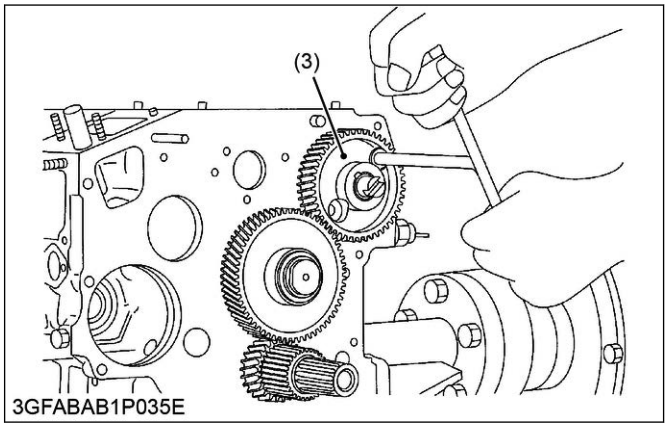
1. Remove the idle gear 2 (7)/idle gear 1 (4).





(1) Injection pump gear
(2) Alignment mark
(3) Cam gear
(4) Idle gear 1
(5) Crank gear
(6) Governor gear
(7) Idle gear 2
[A] One idle gear type
[B] Two idle gear type

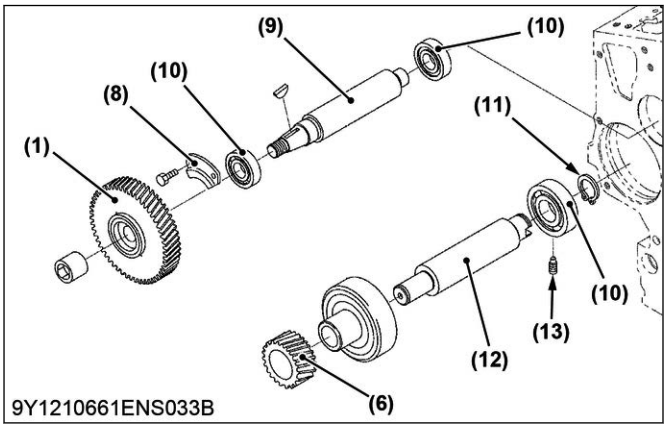
2. Remove the fuel camshaft stopper (8).
3. Draw out the injection pump gear (1) with fuel gear shaft (9).
4. Remove the camshaft stopper bolt.
5. Remove the cam gear (3) with camshaft.

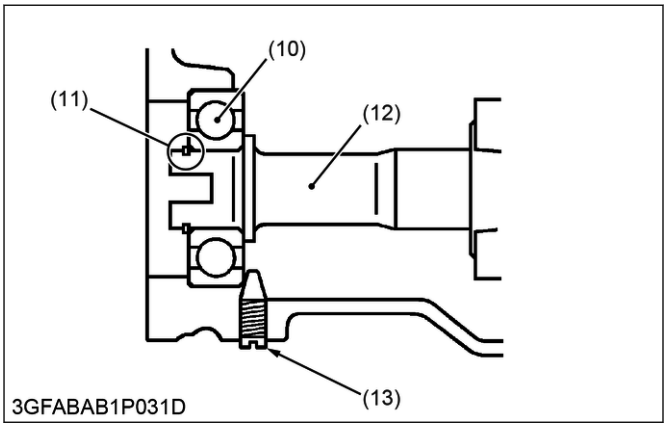


(3) Cam gear

6. Remove the external circlip (11) from the PTO shaft (12).

7. Remove the governor gear (6) with PTO shaft (12).





(1) Injection pump gear
(6) Governor gear
(8) Fuel camshaft stopper
(9) Gear shaft
(10) Ball bearing
(11) External circlip
(12) PTO shaft
(13) Set screw

(When reassembling)

IMPORTANT

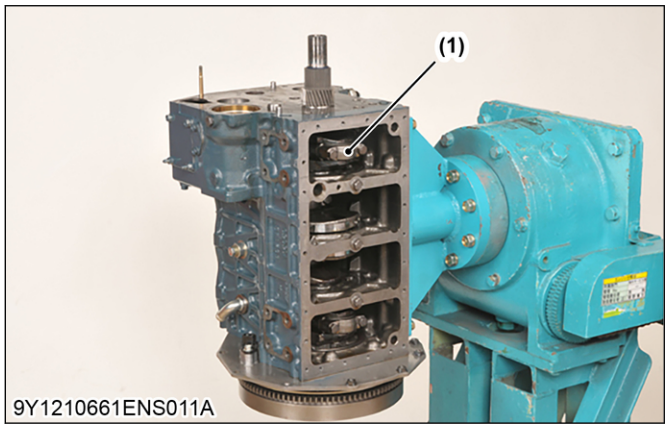
- **There is a model of idle gear 1 (4) and idle gear 2 (7) by the difference of the method of transmission the power to the governor gear (6).**
- **When replacing the ball bearing of governor shaft, securely fit the ball bearing (10) to the crankcase, apply an adhesive (Three Bond 1324B or equivalent) to the set screw (13), and fasten the screw until its tapered part contacts the circumferential end of the ball bearing.**
- **When installing the idle gear, be sure to align the alignment marks on each gears.**

- Apply engine oil thinly to the fuel camshaft before installation.
- Make sure to assemble the external circlip of the governor shaft.
- Check the governor shaft for smooth rotation.

4.2.6 Piston and connecting rod

4.2.6.1 Removing connecting rod cap

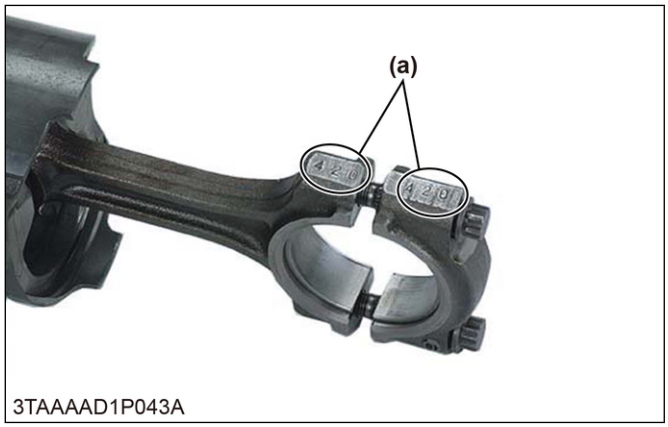
1. Remove the connecting rod caps (1) using a hexagonal 8 mm socket.



(1) Connecting rod cap

(When reassembling)

- Align the marks (a) with each other. (Face the marks toward the intake manifold.)



(a) Mark

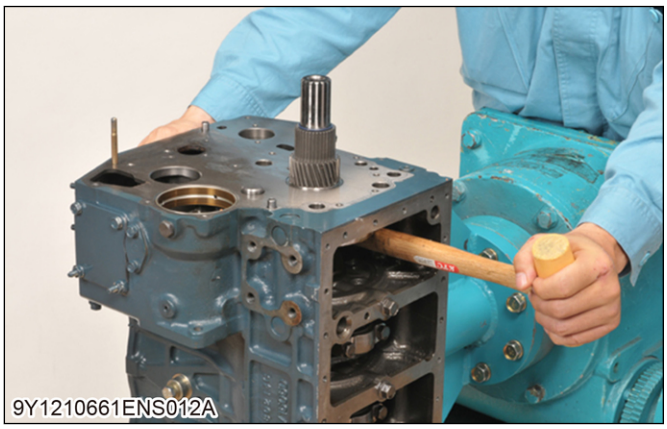
- Apply engine oil to the connecting rod screws and lightly screw it in by hand, then tighten it to the specified torque.
  If the connecting rod screw won't be screwed in smoothly, clean the threads.
  If the connecting rod screw is still hard to screw in, replace it.
- Tighten to the specified tightening torque.

Tightening torque	Connecting rod screw	41.2 to 46.1 N·m 4.21 to 4.70 kgf·m 30.4 to 34.0 lbf·ft

4.2.6.2 Removing piston

1. Turn the flywheel and bring the piston to top dead center.

2. Draw out the piston upward by lightly tapping it from the bottom of the crankcase with the grip of a hammer.

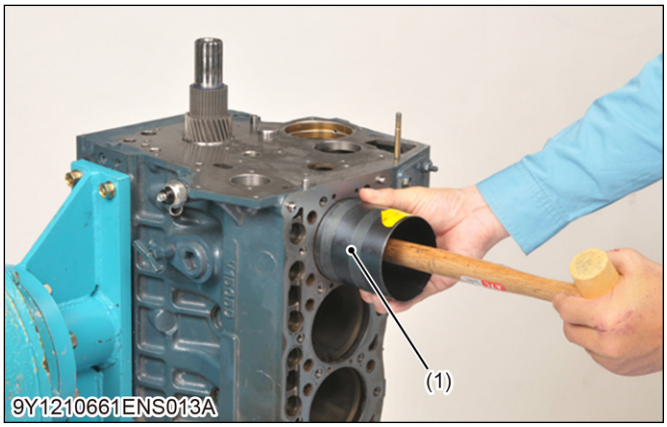


3. Draw out the other pistons after the same method as above.

(When reassembling)

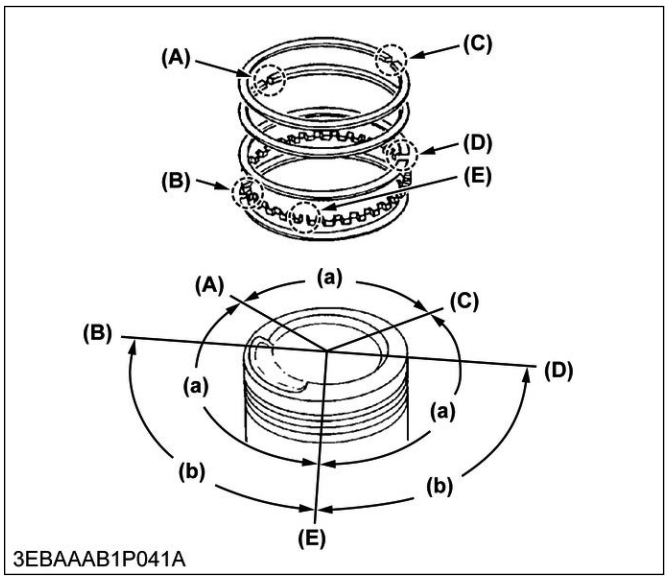
IMPORTANT

- **Do not change the combination of cylinder and piston. Make sure of the position of each piston by marking. For example, mark "1" on the No. 1 piston.**
- **When installing the piston into the cylinder, place the gaps of all of the piston rings as shown in the figure.**
- **Carefully insert the piston using a piston ring compressor (1). Otherwise, their chrome-plated section may be scratched, causing trouble inside the cylinder.**



(1) Piston ring compressor

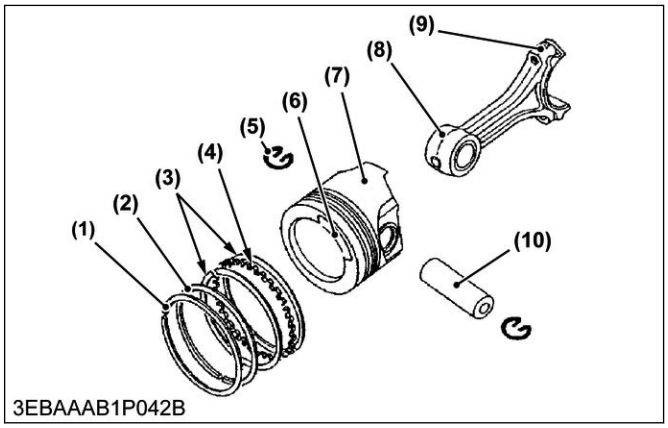
- Before inserting the piston into the cylinder, apply enough engine oil to the piston.
- When inserting the piston into the cylinder, face the mark on the connecting rod to the fuel camshaft.
- When inserting the piston into the cylinder, place the gap "C" of the top compression ring on the opposite side of the slant portion, and stagger the gaps "A", "E" of the second compression ring and spacer making 2.09 rad (120 °) from the gap of the top compression ring. Further, stagger the gaps "D", "B" of the upper and lower side rail making 1.6 rad (90 °) from the gap of the spacer.



(A) Second compression ring gap
(B) Side rail gap
(C) Top compression ring gap
(D) Side rail gap
(E) Spacer gap
(a) 2.09 rad (120 °)
(b) 1.6 rad (90 °)

4.2.6.3 Removing piston ring and connecting rod

1. Remove the piston rings using a piston ring tool.
2. Remove the piston pin (10), and separate the connecting rod (8) from the piston (7).



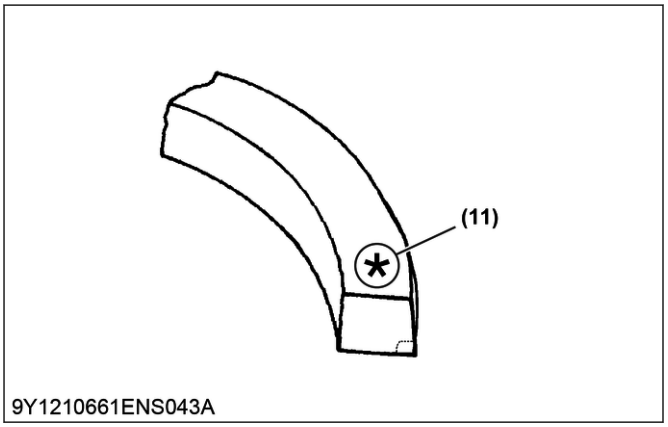
(1) Top ring
(2) Second ring
(3) Side rail
(4) Spacer
(5) Piston pin snap ring
(6) Plug recess
(7) Piston
(8) Connecting rod
(9) Mark
(10) Piston pin

(When reassembling)

IMPORTANT

- **Mark the same number on the connecting rod and the piston so as not to change the combination.**

- When installing the second ring (2), assemble the rings so that the manufacturer's mark (11) near the gap faces the top of the piston.



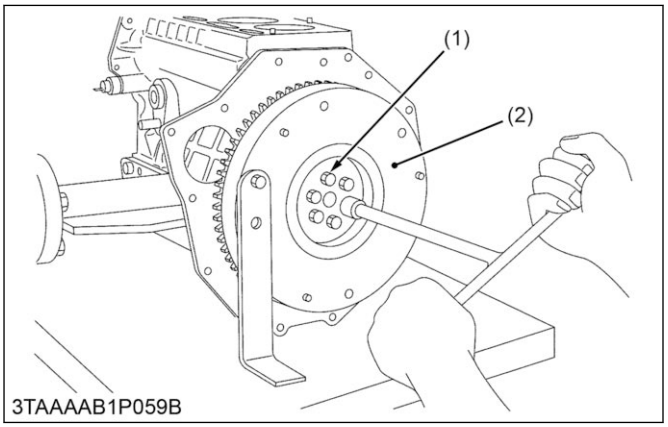
(11) Manufacturer's mark, top ring: 1N, second ring: 2N, oil ring: none

- Apply engine oil to the piston pin.
- When installing the connecting rod to the piston, immerse the piston in 80 ℃ (176 ℉) oil for 10 to 15 minutes and insert the piston pin to the piston.
- When installing the connecting rod to the piston, align the mark (9) on the connecting rod to the plug recess (6).

4.2.7 Crankshaft

4.2.7.1 Removing flywheel

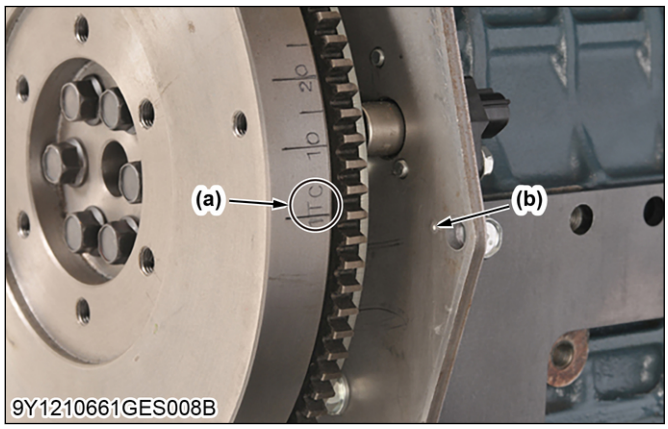
1. Secure the flywheel to keep it from turning using a flywheel stopper.
2. Remove all flywheel screws (1) and then remove the flywheel (2).



(1) Flywheel screw (2) Flywheel

(When reassembling)

- Align the "1TC" mark (a) on the outer surface of the flywheel horizontally with the alignment mark (b) on the rear end plate. Now fit the flywheel in position.



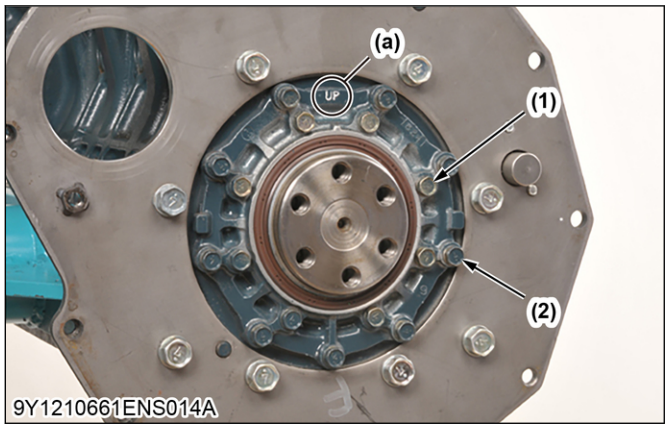
(a) 1TC mark (b) Alignment mark

- Apply engine oil to the threads and the undercut surface of the flywheel screw and fit the screw.
- Tighten to the specified tightening torque.

Tightening torque	Flywheel screw	53.9 to 58.8 N·m 5.50 to 5.99 kgf·m 39.8 to 43.3 lbf·ft

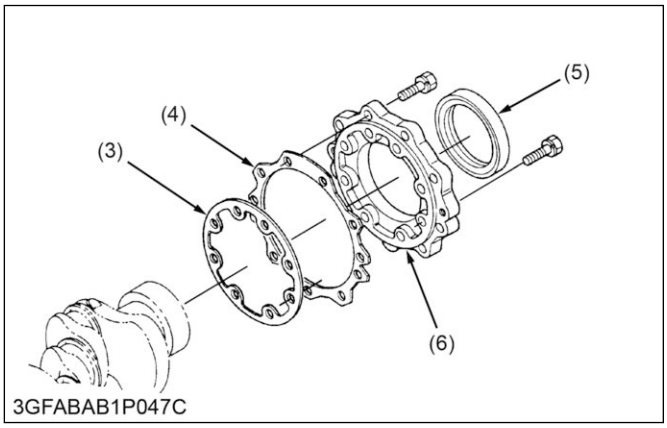
4.2.7.2 Removing bearing case cover

1. Remove the bearing case cover mounting screws. First, remove inside screws (1) and then outside screws (2).



(1) Bearing case cover mounting screw (Inside)
(2) Bearing case cover mounting screw (Outside)
(a) Top mark "UP"

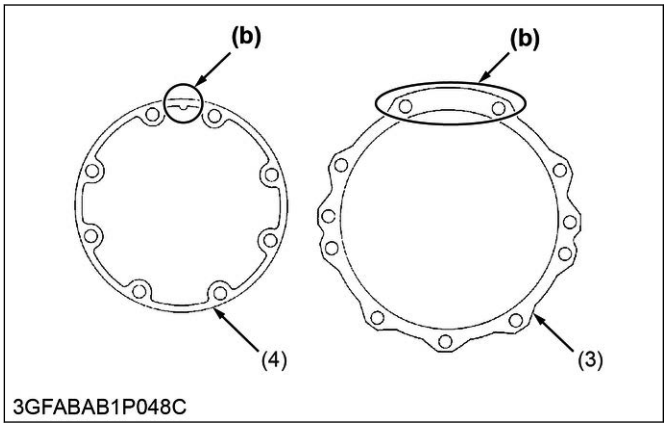
2. Remove the bearing case cover (6).



(3) Bearing case gasket
(4) Bearing case cover gasket
(5) Oil seal
(6) Bearing case cover

(When reassembling)

- Fit the bearing case gasket (3) and the bearing case cover gasket (4) with correct directions.



(3) Bearing case gasket
(4) Bearing case cover gasket
(b) Upside

- Install the bearing case cover (6) to position the casting mark "UP" (a) on it upward.
- Apply engine oil to the oil seal (5) lip and be careful that it is not rolled when installing.
- Tighten the bearing case cover mounting screws with even force on the diagonal line.
- Tighten to the specified tightening torque.

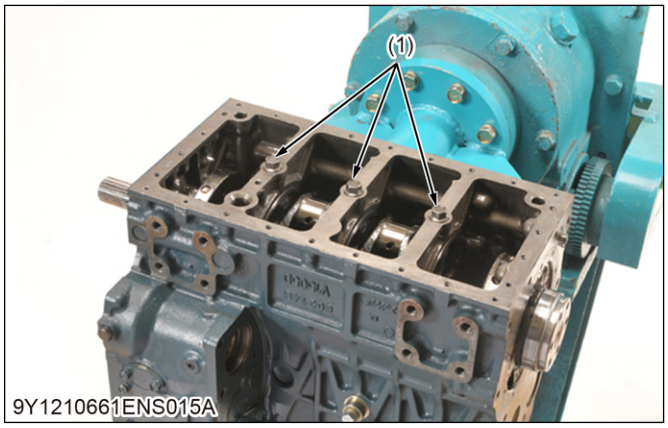
Tightening torque	Bearing case cover mounting screw	9.81 to 11.3 N·m 1.00 to 1.15 kgf·m 7.24 to 8.33 lbf·ft

4.2.7.3 Removing crankshaft assembly

IMPORTANT

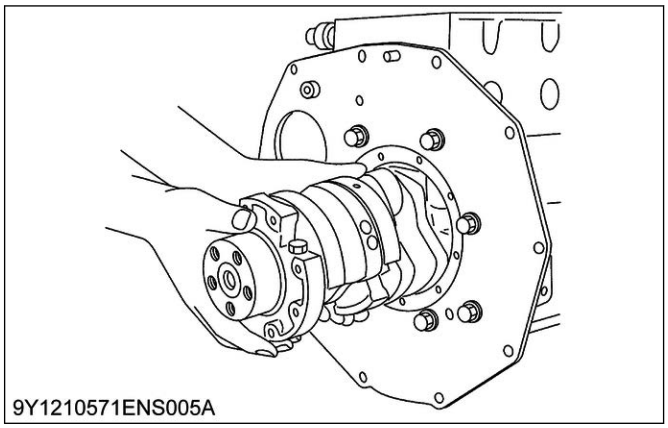
- **Be careful to protect crankshaft bearing 1 from scratches, caused by the crank shaft, etc.**

1. Remove the main bearing case screw 2 (1).



(1) Main bearing case screw 2

2. Pull out the crankshaft assembly.



(When reassembling)

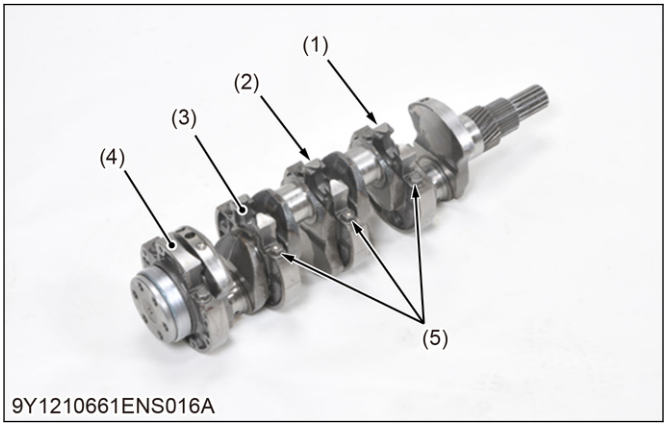
- Clean the oil passage of the crankshaft with compressed air.
- Apply oil to the main bearing case screw 2 (1).
- Install the crankshaft assembly, aligning the screw hole of main bearing case with the screw hole of crankcase.
- Clean the oil passage of the crankshaft with compressed air.
- Tighten to the specified tightening torque.

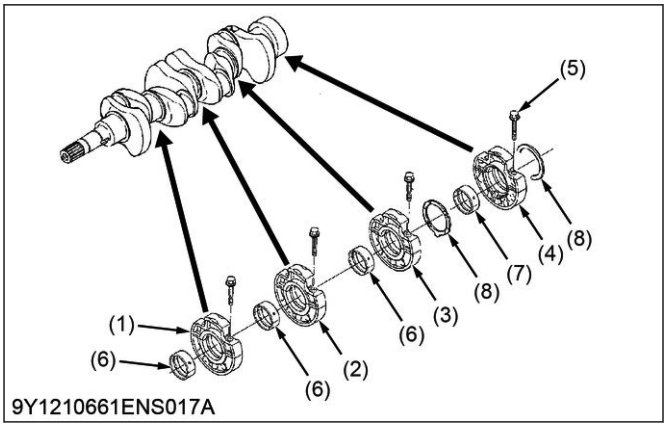
Tightening torque	Main bearing case screw 2	49.0 to 53.9 N·m 5.00 to 5.49 kgf·m 36.2 to 39.7 lbf·ft

4.2.7.4 Removing main bearing case assembly

1. Remove the two main bearing case screws 1 (5), and remove the main bearing case assembly 1 (1), being careful with crankshaft bearing 3 (7).

2. Remove the main bearing case assembly 2 (2), the main bearing case assembly 3 (3) and the main bearing case assembly (4) as above. Keep in mind, however, that the thrust bearing (8) is installed in the main bearing case assembly (4).

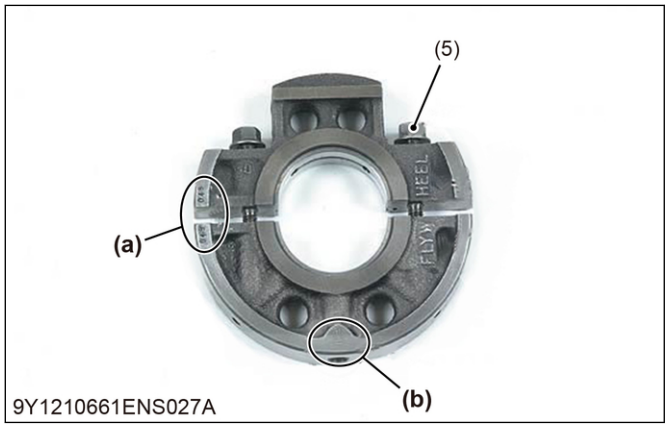




(1) Main bearing case assembly 1
(2) Main bearing case assembly 2
(3) Main bearing case assembly 3
(4) Main bearing case assembly
(5) Main bearing case screw 1
(6) Crankshaft bearing 2
(7) Crankshaft bearing 3
(8) Thrust bearing

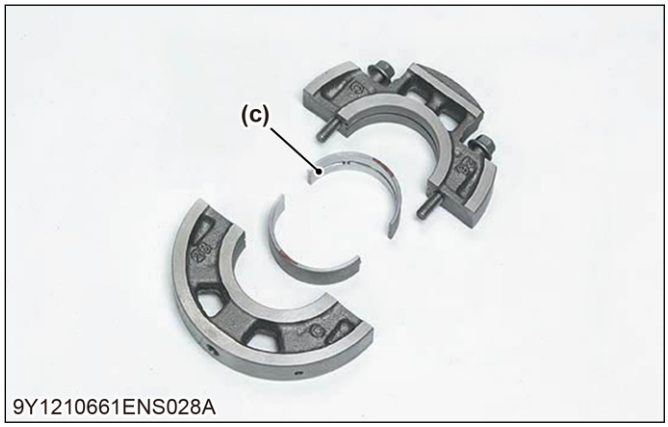
(When reassembling)

- Clean the oil passage in the main bearing cases.
- Apply clean engine oil to the bearings.
- Install the main bearing case assemblies in original positions. Since diameters of main bearing cases vary, install them in order of marking (b) from the gear case side. (Refer to the figure.)



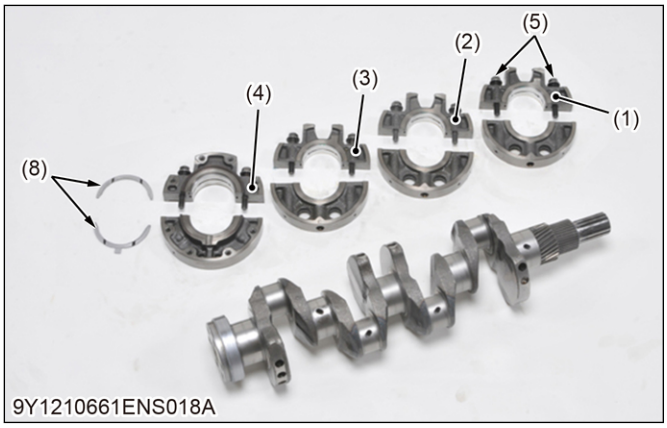
(5) Main bearing case screw 1
(b) Marking (A, B, C)
(a) Alignment number

- Be careful not to confuse the top and bottom of the crankshaft bearing 3 (7). (Install the bearing with the oil groove (c) up.).



(c) Oil groove

- Match the alignment numbers (a) on the main bearing case assembly 1.
- Do the same for the main bearing case assembly 2 (2), the main bearing case assembly 3 (3) and the main bearing case assembly (4) too.
- When installing the main bearing case 1, 2 and 3, face the mark "Flywheel" to the flywheel.
- Install the thrust bearing (8) with its oil groove facing outward.



(1) Main bearing case assembly 1
(2) Main bearing case assembly 2
(3) Main bearing case assembly 3
(4) Main bearing case assembly
(5) Main bearing case screw 1
(8) Thrust bearing

- Make sure that the main bearing case moves smoothly after tightening the main bearing case screw 1 (5) to the specified torque.
- Tighten to the specified tightening torque.

Tightening torque	Main bearing case screw 1	29.4 to 34.3 N·m 3.00 to 3.49 kgf·m 21.7 to 25.2 lbf·ft

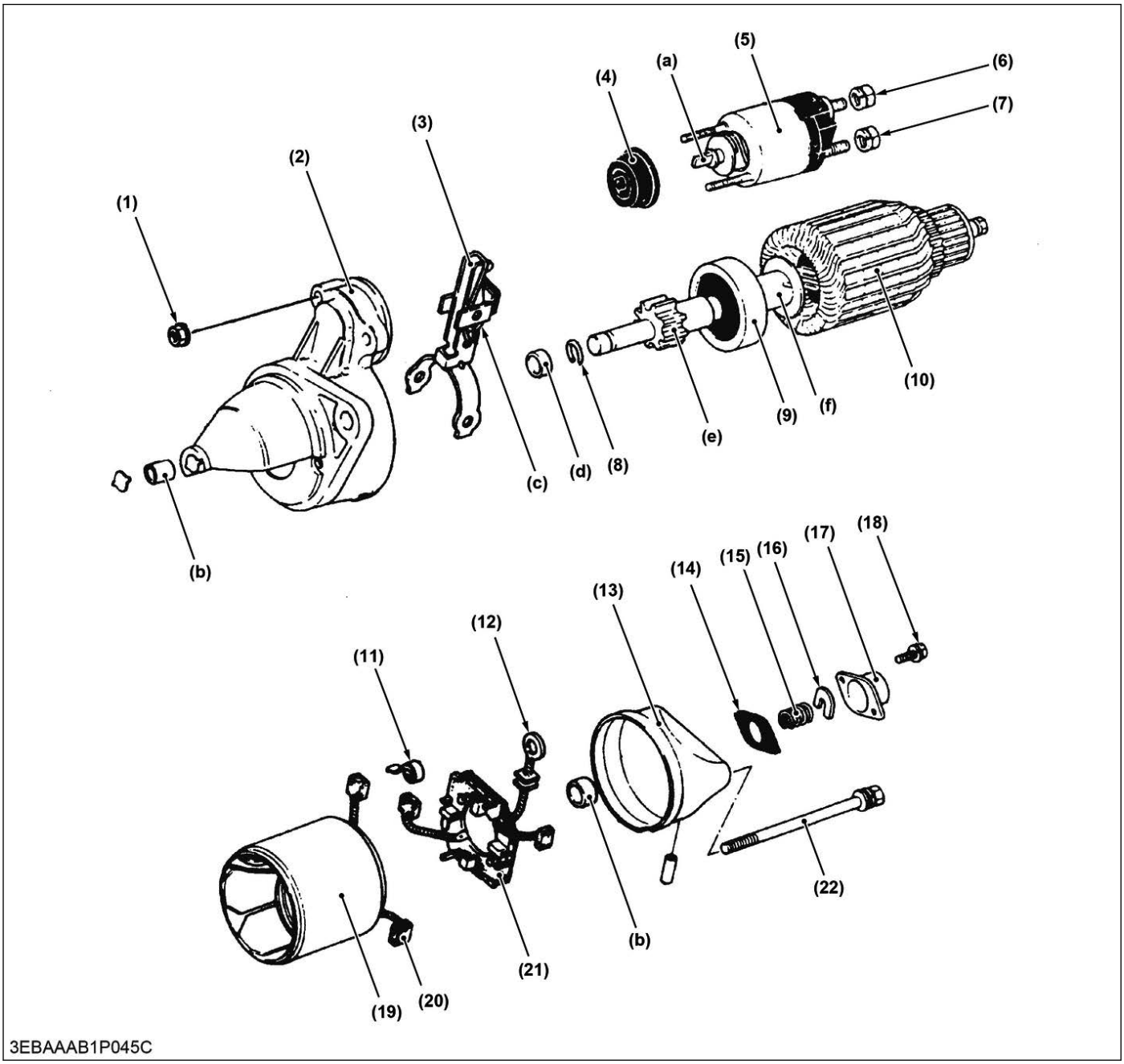
4.2.8 Removing starter

NOTE

- **Do not damage to the brush and commutator.**

1. Remove the C terminal nut (7), and disconnect the connecting lead (12).
2. Remove the solenoid switch mounting nuts (1), then the solenoid switch (5).
3. Remove the end frame cap (17).
4. Remove the brake shoe (16), brake spring (15) and gasket (14).
5. Remove the through bolts (22), then the rear end frame (13).
6. Remove the brush from the brush holder while holding the spring up.
7. Remove the brush holder (21).
8. Draw out the yoke (19) from the starter drive housing (2).

9. Draw out the armature (10) with the drive lever (3).



(1) Solenoid switch mounting nut
(2) Starter drive housing
(3) Drive lever
(4) Gasket
(5) Solenoid switch
(6) B terminal nut
(7) C terminal nut
(8) Snap ring
(9) Overrunning clutch
(10) Armature
(11) Brush spring
(12) Connecting lead
(13) Rear end frame
(14) Gasket
(15) Brake spring
(16) Brake shoe
(17) End frame cap
(18) Screw
(19) Yoke
(20) Brush
(21) Brush holder
(22) Through bolt

(When reassembling)

- Apply grease (DENSO.CO.LTD. No. 50 or equivalent) to the parts indicated in the figure.
  - Joint of solenoid switch (a)
  - Bushing (b)
  - Drive lever (c)
  - Collar (d)
  - Teeth of pinion gear (e)
  - Armature shaft (f)

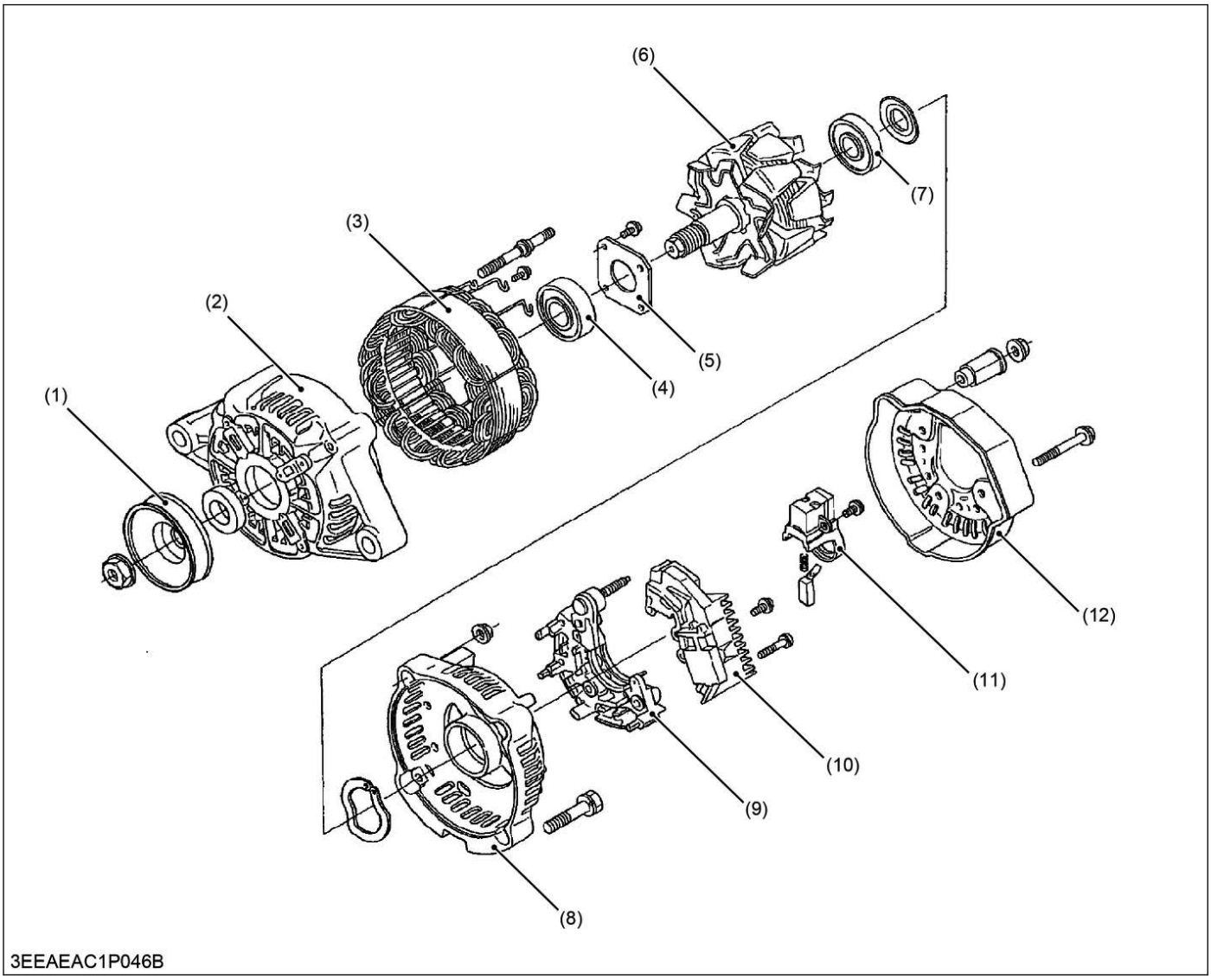
- Tighten to the specified tightening torque.

Tightening torque	Starter's terminal B mounting nut	5.88 to 11.8 N·m 0.600 to 1.20 kgf·m 4.34 to 8.70 lbf·ft

4.2.9 Removing alternator

1. Remove the pulley (1).
2. Remove the rear end cover (12).
3. Remove the brush holder (11).
4. Remove the IC regulator (10).
5. Remove the four screws holding the stator lead wires.
6. Remove the rectifier (9).
7. Remove the rear end frame (8).
8. Press out the rotor (6) from drive end frame (2).
9. Remove the retainer plate (5).
10. Press out the bearing (4) from drive end frame (2) with a press and jig.

11. Lightly secure the rotor with a vise to prevent damage, and remove the bearing (7) with a puller.



3EEAEAC1P046B

(1) Pulley
(2) Drive end frame
(3) Stator
(4) Bearing
(5) Retainer plate
(6) Rotor
(7) Bearing
(8) Rear end frame
(9) Rectifier
(10) IC regulator
(11) Brush holder
(12) Rear end cover

(When reassembling)

- Tighten to the specified tightening torque.

Tightening torque	Alternator's pulley nut	58.4 to 78.9 N·m 5.95 to 8.05 kgf·m 43.1 to 58.2 lbf·ft

4.3 Servicing

4.3.1 Cylinder head and valves

4.3.1.1 Measuring top clearance

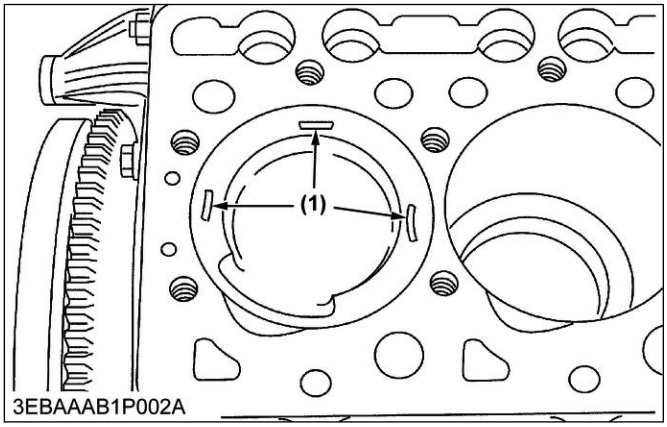
Top clearance	Service specification	1.2 to 1.5 mm 0.048 to 0.059 in.

1. Remove the cylinder head.

NOTE

- **Top clearance = Width of the crushed plastigauge (2).**

2. With the piston at TDC, use grease to affix three or four plastigauges (1) of a diameter 1.5 mm (0.059 in.) × 5.0 to 7.0 mm (0.20 to 0.27 in.) long to the crown of the piston; keep the gauges away from the intake valve and combustion chamber fittings.

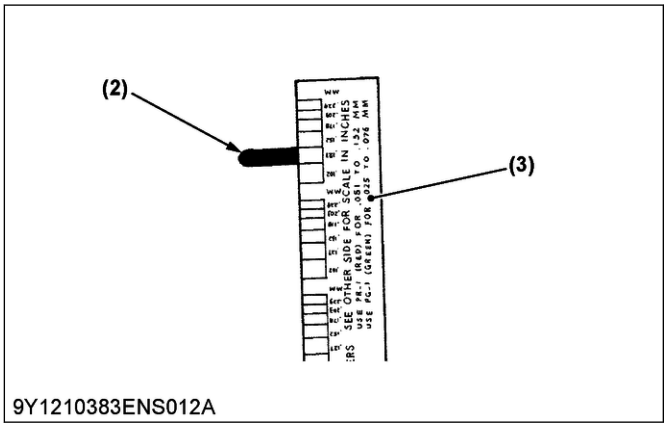


(1) Plastigauge

3. Take the piston to an intermediate position, install the cylinder head and tighten the head bolts to the specified torque.
   - Tighten to the specified tightening torque.

Tightening torque	Cylinder head screws	63.7 to 68.6 N·m 6.50 to 6.99 kgf·m 47.0 to 50.5 lbf·ft

4. Turn the crankshaft so the piston goes through TDC.
5. Remove the cylinder head and compare the width of the crushed plastigauges (2) with the scale (3).



(2) Crushed plastigauge (3) Scale

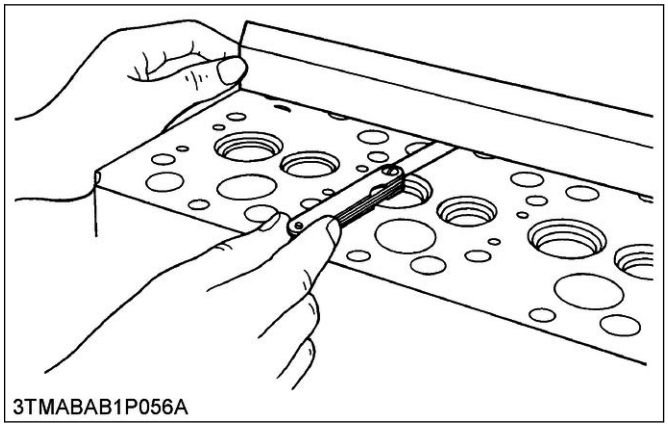
6. If they are out of spec, check the oil clearance of the crank pin, journal and piston pins.

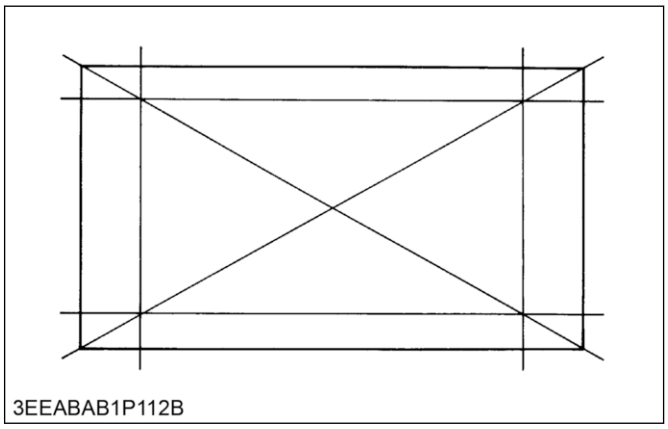
4.3.1.2 Measuring cylinder head surface flatness

IMPORTANT

- **Be sure to check the valve recessing after replacing cylinder head.**

1. Clean the cylinder head surface.
2. Place a straightedge on the cylinder head's four sides and two diagonal as shown in the figure. Measure the clearance with a feeler gauge.





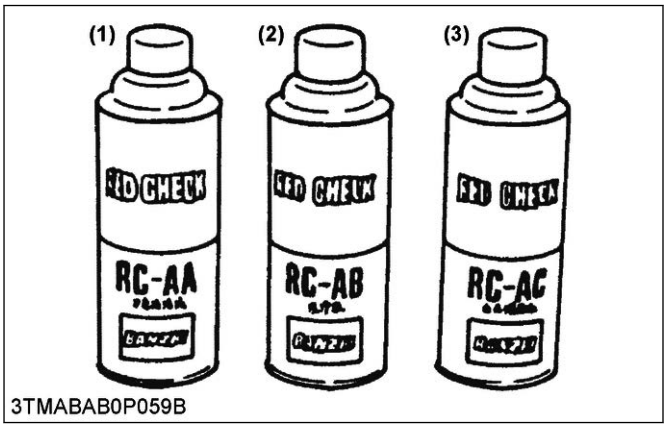
3. If the measurement exceeds the service limit, replace the cylinder head.

Cylinder head surface flatness	Service limit	0.05 mm 0.002 in.

4.3.1.3 Checking cylinder head flaw

1. Prepare an air spray red check.
2. Clean the surface of the cylinder head with the detergent (2).
3. Spray the cylinder head surface with the red permeative liquid (1). Leave it five to ten minutes after spraying.
4. Wash away the red permeative liquid on the cylinder head surface with the detergent (2).

5. Spray the cylinder head surface with the white developer (3).



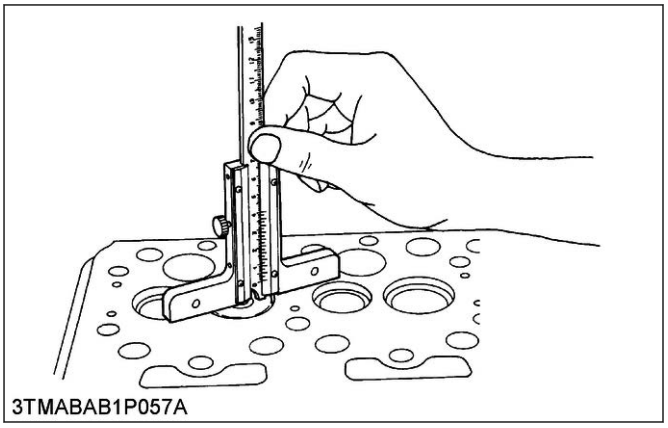
(1) Red permeative liquid
(2) Detergent
(3) White developer

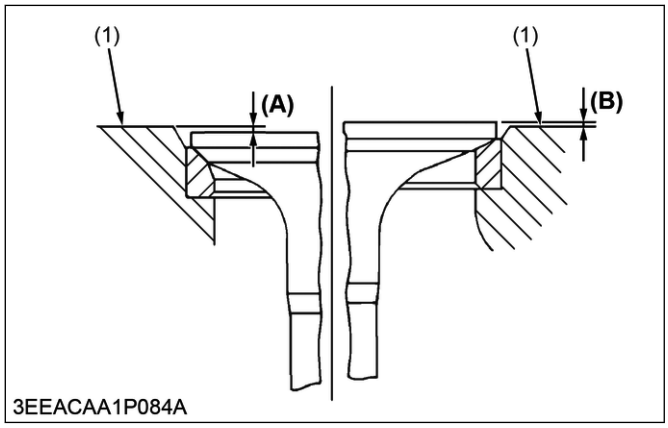
6. If flawed, it can be identified as red marks.

4.3.1.4 Measuring valve recessing

1. Clean the cylinder head, the valve face and seat.
2. Insert the valve into the valve guide.
3. Measure the valve recessing with a depth gauge.

Valve recessing (Intake and Exhaust)	Service specification	0.050 (protrusion) to 0.25 (recessing) mm 0.0020 (protrusion) to 0.0098 (recessing) in.
	Service limit	0.40 (recessing) mm 0.016 (recessing) in.



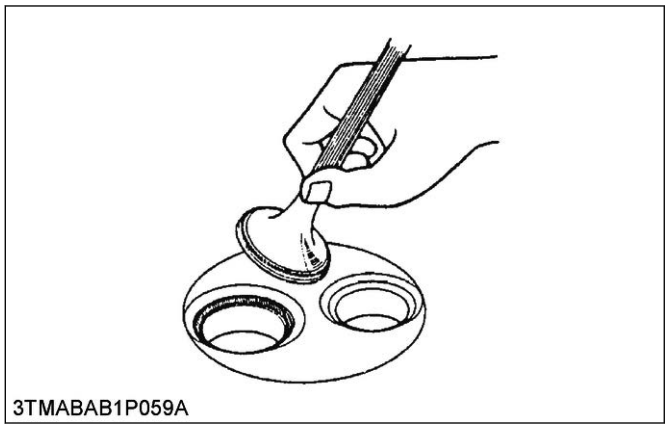


(1) Cylinder head surface
(A) Recessing
(B) Protrusion

4. If the measurement exceeds the service limit, replace the valve.
5. If it still exceeds the service limit after replacing the valve, replace the cylinder head.

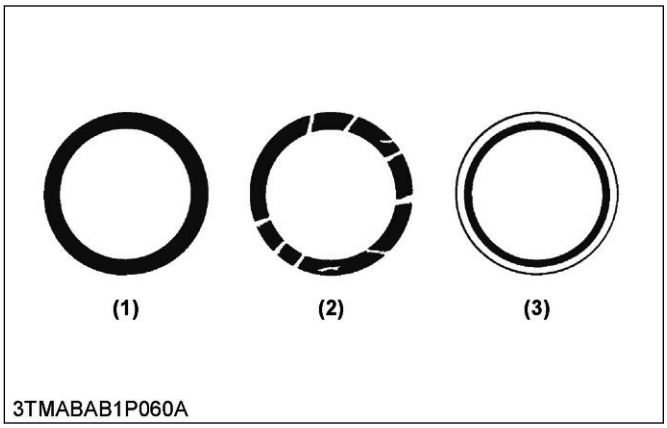
4.3.1.5 Checking valve seating

1. Coat the valve face lightly with prussian blue and put the valve on its seat to check the contact.



2. If the valve does not seat all the way around the valve seat or the valve contact is less than 70 %, correct the valve seating as follows.

Valve seat width	Service specification	2.12 mm 0.0835 in.



(1) Correct
(2) Incorrect
(3) Incorrect

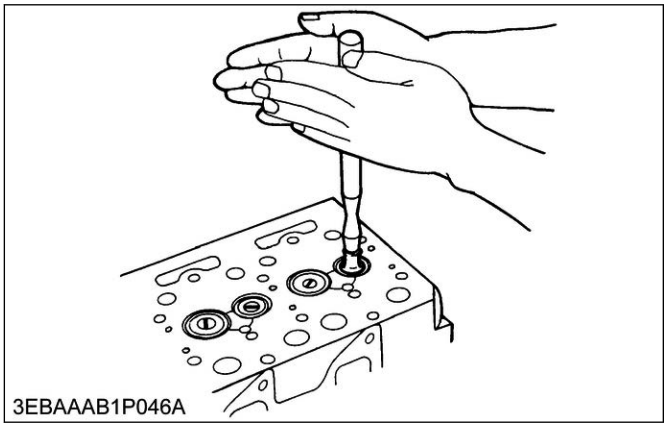
3. If the valve contact does not comply with the reference value, replace the valve or correct the contact of valve seating.

4.3.1.6 Adjusting valve lapping

IMPORTANT

- **When valve lapping is performed, be sure to check the valve recessing and adjust the valve clearance after assembling the valve.**

1. Apply compound evenly to the valve lapping surface.
2. Insert the valve into the valve guide. Lap the valve onto its seat with a valve flapper or screwdriver.



3. After lapping the valve, wash the compound away and apply oil, then repeat valve lapping with oil.
4. Apply prussian blue to the contact surface to check the seated rate. If it is less than 70 %, repeat valve lapping again.

4.3.1.7 Adjusting valve and valve seat

NOTE

- **Before correcting the valve and seat, check the valve stem and the I.D. of valve guide section, and repair them if necessary.**
- **After correcting the valve seat, be sure to check the valve recessing.**

Correcting valve

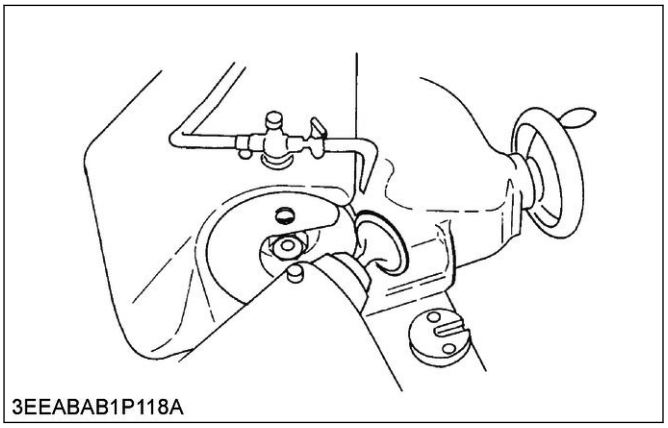
1. Correct the valve with a valve refacer.

Valve face angle	Service specification	IN.	1.0 rad 60 °
		EX.	1.0 rad 60 °

Correcting valve seat

1. Slightly correct the seat surface with a 1.0 rad (60 °) valve seat cutter.
2. Resurface the seat surface with a 0.52 rad (30 °) valve seat cutter so that the width is close to specified valve seat width (2.12 mm, 0.0835 in.).

Valve seat angle	Service specification	IN.	1.0 rad 60 °
		EX.	1.0 rad 60 °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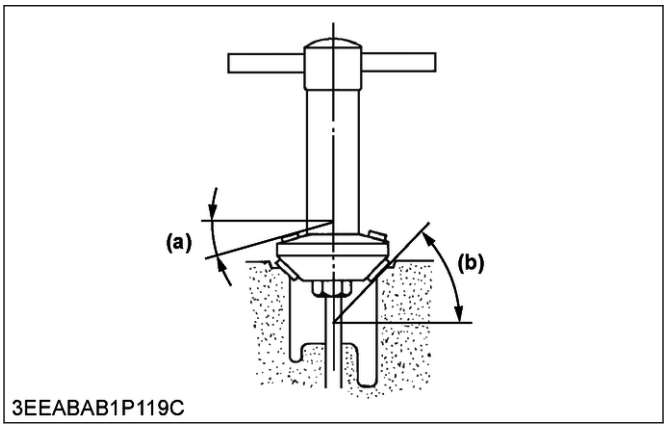

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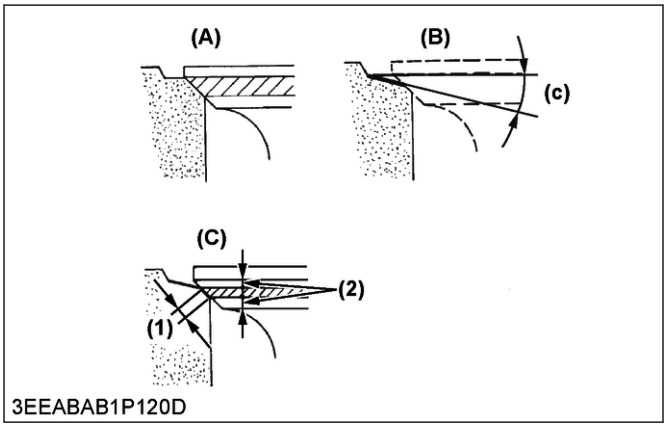

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(1) Valve seat width
(2) Identical dimensions
(A) Check contact
(B) Correct seat width
(C) Check contact
(a) 0.52 rad (30 °)
(b) 1.0 rad (60 °)
(c) 0.52 rad (30 °)

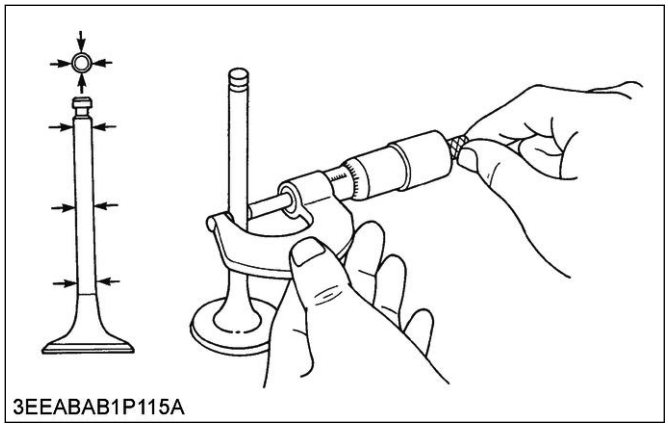
3. After resurfacing the seat, inspect for even valve seating, apply a thin film of compound between the valve face and valve seat, and fit them with valve lapping tool.
4. Check the valve seating with prussian blue. The valve seating surface should show good contact all the way around.

4.3.1.8 Measuring clearance between valve stem and valve guide

Tools required
- Outside micrometer

1. Remove carbon from the valve guide section.
2. Measure the valve stem O.D. with an outside micrometer.

Valve stem O.D.	Service specification	6.960 to 6.975 mm 0.2741 to 0.2746 in.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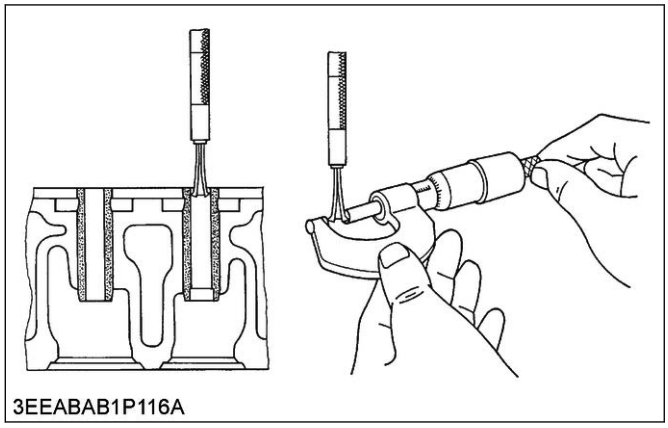
3. Measure the valve guide I.D. with a small hole gauge, and calculate the clearance.

Valve guide I.D.	Service specification	7.010 to 7.025 mm 0.2760 to 0.2765 in.

Clearance between valve stem and valve guide	Service specification	0.035 to 0.065 mm 0.0014 to 0.0025 in.
	Service limit	0.10 mm 0.0039 in.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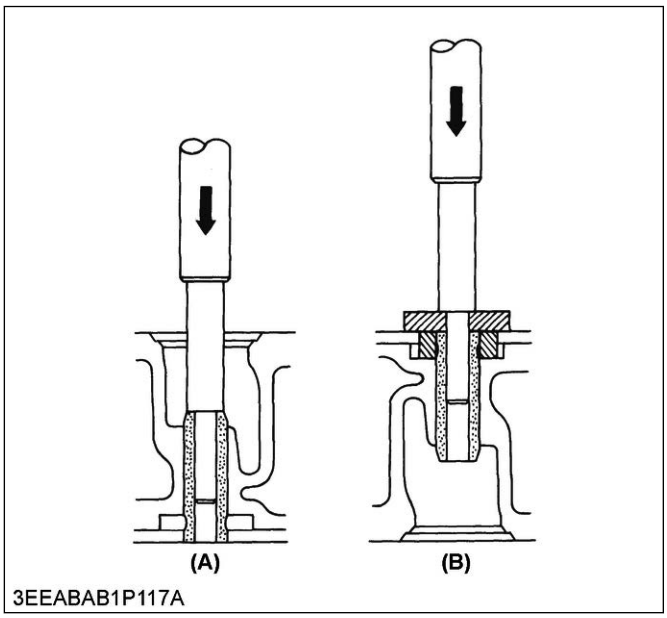
4. If the measurement exceeds the service limit, replace the valve.
5. If it still exceeds the service limit after replacing the valve, replace the valve guide.

4.3.1.9 Replacing valve guide

IMPORTANT
- **Do not hit the valve guide with a hammer during replacement.**

(When removing)

1. Press out the used valve guide using a valve guide replacing tool.



(A) When removing (B) When installing

(When installing)

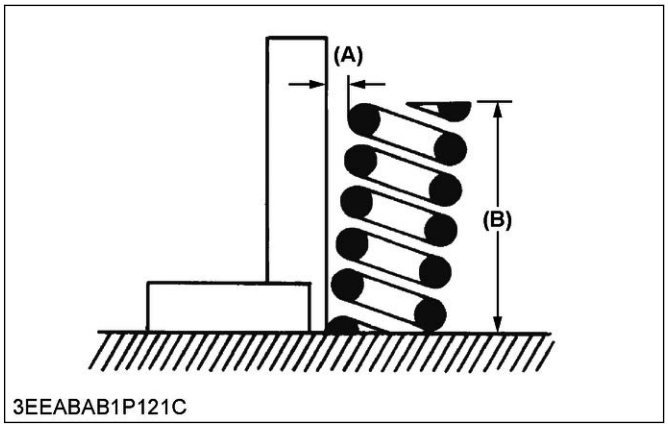
1. Clean a new valve guide and valve guide bore, and apply engine oil to them.
2. Press in a new valve guide using a valve guide replacing tool.
3. Ream precisely the I.D. of the valve guide to the specified dimension.

Valve guide I.D. (Intake and exhaust)	Service specification	7.010 to 7.025 mm 0.2760 to 0.2765 in.

4.3.1.10 Measuring free length and tilt of valve spring

1. Measure the free length (B) of valve spring with vernier calipers. If the measurement is less than the service limit, replace it.

Free length (B)	Service specification	35.1 to 35.6 mm 1.39 to 1.40 in.
	Service limit	34.8 mm 1.37 in.



(A) Tilt (B) Free length

2. Put the spring on a surface plate, place a square on the side of the spring.
3. Check to see if the entire side is in contact with the square. Rotate the valve spring and measure the maximum tilt (A). If the measurement exceeds the service limit, replace it.

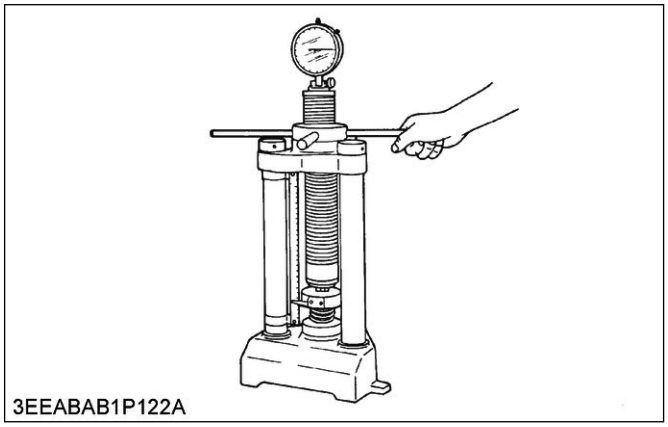
Tilt (A)	Service specification	1.0 mm 0.039 in.

4. Check the entire surface of the valve spring for scratches. If there is any defect, replace it.

4.3.1.11 Measuring valve spring setting load

1. Place the valve spring on a tester and compress it to the same length it is actually compressed in the engine.

Setting load / setting length	Service specification	74 N / 31.0 mm 7.5 kgf / 31.0 mm 17 lbf / 1.22 in.
	Service limit	63 N / 31.0 mm 6.4 kgf / 31.0 mm 14 lbf / 1.22 in.



2. Read the compression load on the gauge.
3. If the measurement is less than the service limit, replace it.

4.3.1.12 Measuring oil clearance between rocker arm and rocker arm shaft

1. Measure the rocker arm shaft O.D. with an outside micrometer.

Rocker arm shaft O.D.	Service specification	11.973 to 11.984 mm 0.47138 to 0.47181 in.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2. Measure the rocker arm I.D. with an inside micrometer, and then calculate the oil clearance.

Rocker arm I.D.	Service specification	12.000 to 12.018 mm 0.47244 to 0.47314 in.

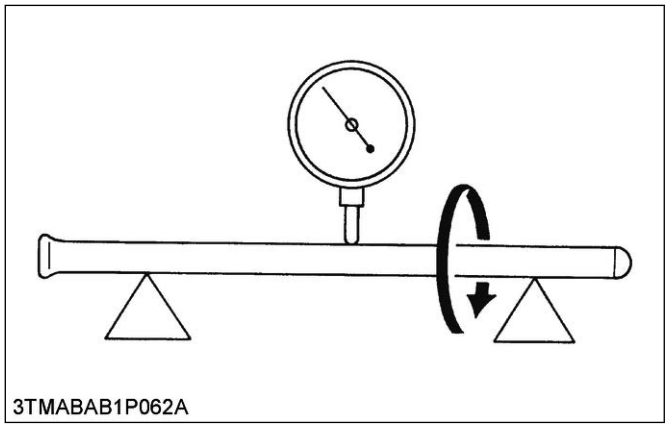
3. If the oil clearance exceeds the service limit, replace the rocker arm and measure the oil clearance again. If it still exceeds the service limit, replace also the rocker arm shaft.

Oil clearance between rocker arm and rocker arm shaft	Service specification	0.016 to 0.045 mm 0.00063 to 0.0017 in.
	Service limit	0.15 mm 0.0059 in.

4.3.1.13 Measuring push rod alignment

1. Place the push rod on V blocks.
2. Measure the push rod alignment.

Push rod alignment	Service limit	0.25 mm 0.0098 in.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3. If the measurement exceeds the service limit, replace the push rod.

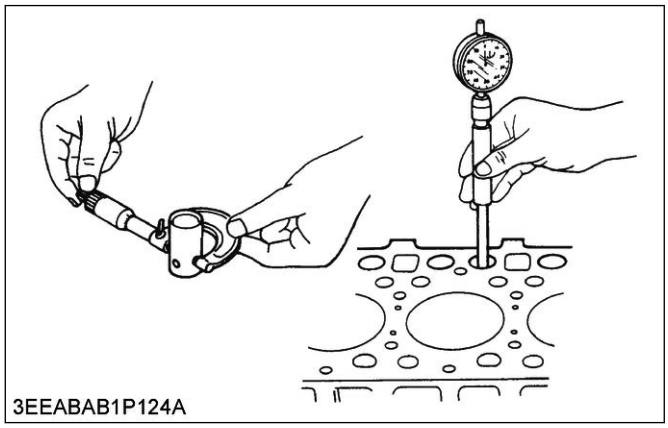
4.3.1.14 Measuring oil clearance between tappet and tappet guide bore

1. Measure the tappet O.D. with an outside micrometer.

Tappet O.D.	Service specification	19.959 to 19.980 mm 0.78579 to 0.78661 in.

2. Measure the I.D. of the tappet guide bore with a cylinder gauge, and calculate the oil clearance.

Tappet guide bore I.D.	Service specification	20.000 to 20.021 mm 0.78741 to 0.78822 in.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3. If the oil clearance exceeds the service limit or the tappet is damaged, replace the tappet.

Oil clearance between tappet and tappet guide bore	Service specification	0.020 to 0.062 mm 0.00079 to 0.0024 in.
	Service limit	0.07 mm 0.003 in.

4.3.2 Timing gear and camshaft

4.3.2.1 Measuring timing gear backlash

Tools required

- Dial indicator (lever type)

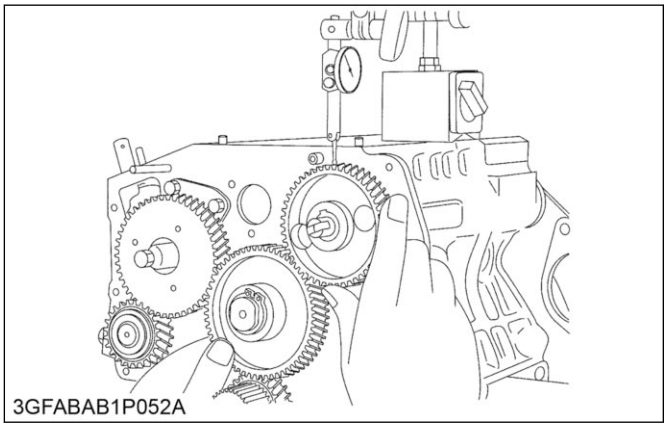
1. Set a dial indicator (lever type) with its tip on the gear tooth.
2. Move the gear to measure the backlash, holding its mating gear.

Backlash between idle gear 1 and crank gear	Service specification	0.0320 to 0.115 mm 0.00126 to 0.00452 in.
	Service limit	0.15 mm 0.0059 in.

Backlash between idle gear 1 and cam gear	Service specification	0.0360 to 0.114 mm 0.00142 to 0.00448 in.
	Service limit	0.15 mm 0.0059 in.

Backlash between idle gear 1 and injection pump gear	Service specification	0.0340 to 0.116 mm 0.00134 to 0.00456 in.
	Service limit	0.15 mm 0.0059 in.

(equipped with idle gear 2) Backlash between idle gear 1 and idle gear 2	Service specification	0.0330 to 0.117 mm 0.00130 to 0.00460 in.
	Service limit	0.15 mm 0.0059 in.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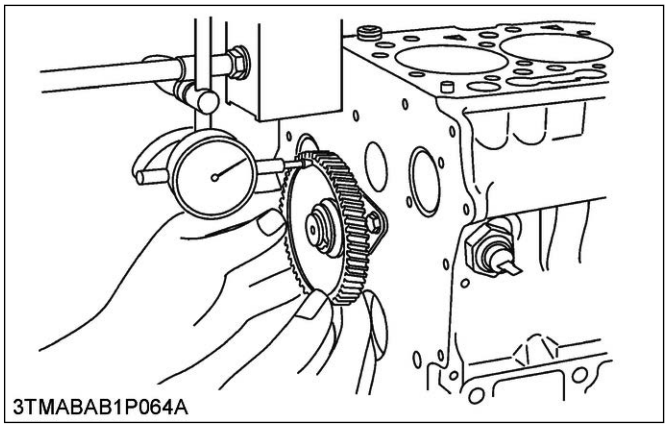
3. If the backlash exceeds the service limit, check the oil clearance of the shafts and the gear.
4. If the oil clearance is proper, replace the gear.

4.3.2.2 Measuring idle gear 1 and 2 side clearance

1. Set a dial indicator with its tip on the idle gear.
2. Measure the side clearance by moving the idle gear to the front and rear.

Idle gear 1 and 2 side clearance	Service specification	0.20 to 0.51 mm 0.0079 to 0.020 in.
	Service limit	0.80 mm 0.031 in.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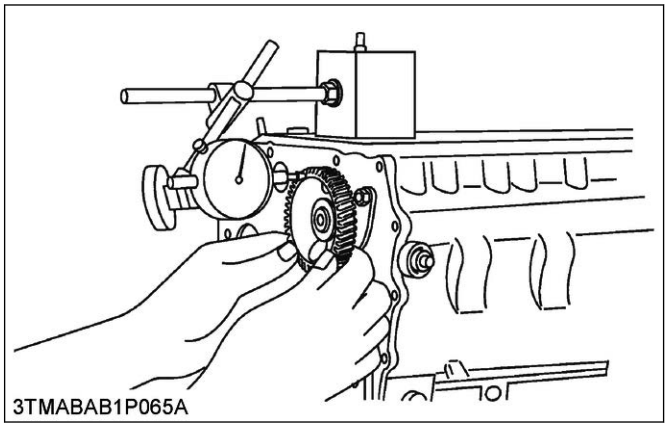
3. If the measurement exceeds the service limit, replace the idle gear collar.

4.3.2.3 Measuring camshaft side clearance

1. Set a dial indicator with its tip on the camshaft.
2. Measure the side clearance by moving the cam gear to the front and rear.

Camshaft side clearance	Service specification	0.0700 to 0.220 mm 0.00276 to 0.00866 in.
	Service limit	0.30 mm 0.012 in.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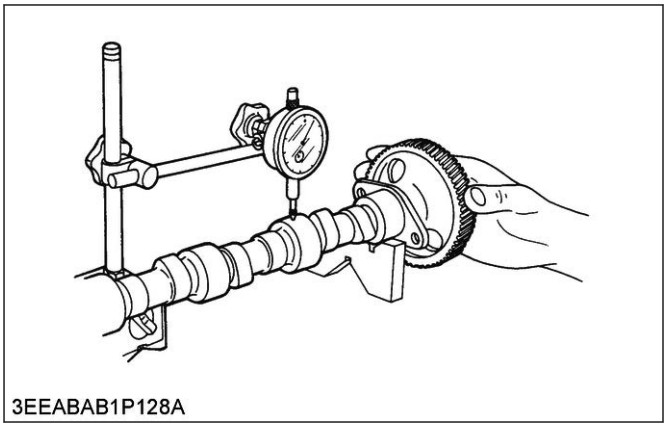
3. If the measurement exceeds the service limit, replace the camshaft stopper.

4.3.2.4 Camshaft alignment

1. Support the camshaft with V blocks on the surface plate at both end journals.
2. Set a dial indicator with its tip on the intermediate journal.

3. Measure the camshaft alignment.

Camshaft alignment	Service specification	0.01 mm 0.0004 in.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4. If the measurement exceeds the service limit, replace the camshaft.

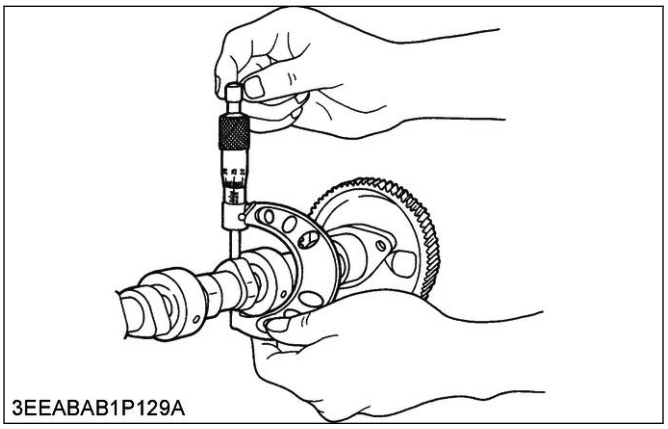
4.3.2.5 Measuring cam height

Tools required

- Outside micrometer

1. Measure the height of the cam at its highest point with an outside micrometer.

Cam height	Service specification	IN.	28.80 mm 1.134 in.
		EX.	29.00 mm 1.142 in.
	Service limit	IN.	28.75 mm 1.132 in.
		EX.	28.95 mm 1.140 in.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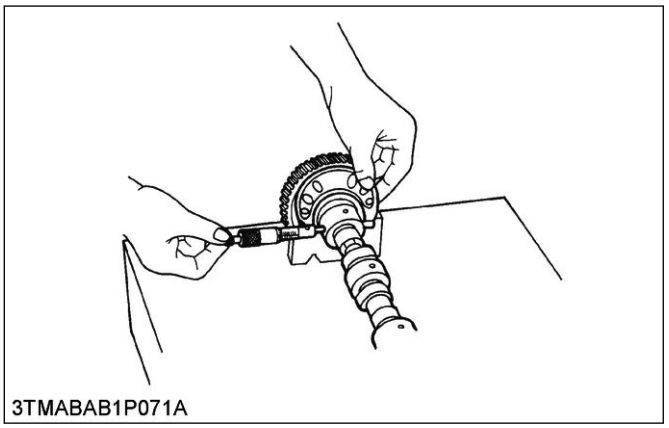
2. If the measurement is less than the service limit, replace the camshaft.

4.3.2.6 Measuring oil clearance of camshaft journal

1. Measure the camshaft journal O.D. with an outside micrometer.

Camshaft journal O.D.	Service specification	35.934 to 35.950 mm 1.4148 to 1.4153 in.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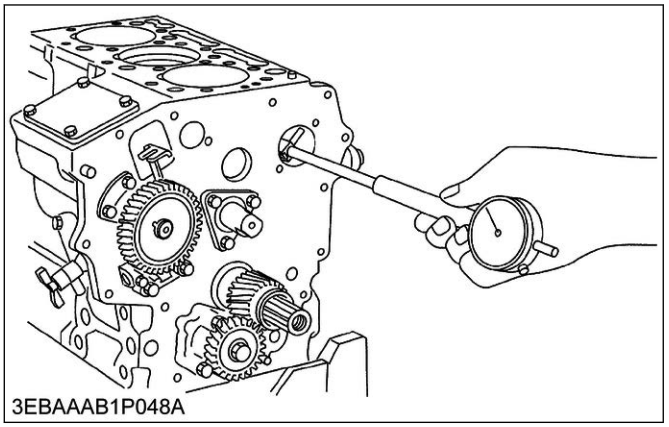
2. Measure the cylinder block bore I.D. for camshaft with a inside micrometer, and calculate the oil clearance.

Camshaft bearing I.D. (Cylinder block bore I.D.)	Service specification	36.000 to 36.025 mm 1.4174 to 1.4183 in.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3. If the clearance exceeds the service limit, replace the camshaft.

Oil clearance of camshaft journal	Service specification	0.050 to 0.091 mm 0.0020 to 0.0035 in.
	Service limit	0.15 mm 0.0059 in.

4.3.2.7 Measuring oil clearance between idle gear shaft 1 and 2 and idle gear bushing

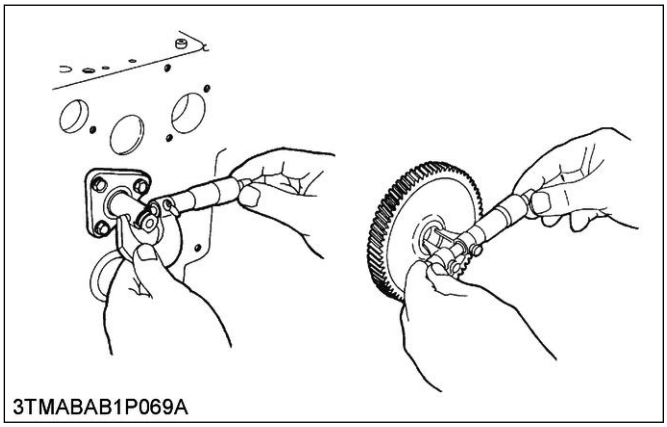
1. Measure the idle gear shaft O.D. with an outside micrometer.

Idle gear shaft 1 and 2 O.D.	Service specification	25.967 to 25.980 mm 1.0224 to 1.0228 in.

2. Measure the idle gear bushings I.D. with an inside micrometer, and calculate the oil clearance.

Idle gear bushing 1 and 2 I.D.	Service specification	26.000 to 26.021 mm 1.0237 to 1.0244 in.

Oil clearance between idle gear shaft (1 and 2) and idle gear bushing	Service specification	0.020 to 0.054 mm 0.00079 to 0.0021 in.
	Service limit	0.10 mm 0.0039 in.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3. If the oil clearance exceeds the service limit, replace the bushing.
4. If it still exceeds the service limit, replace the idle gear shaft.

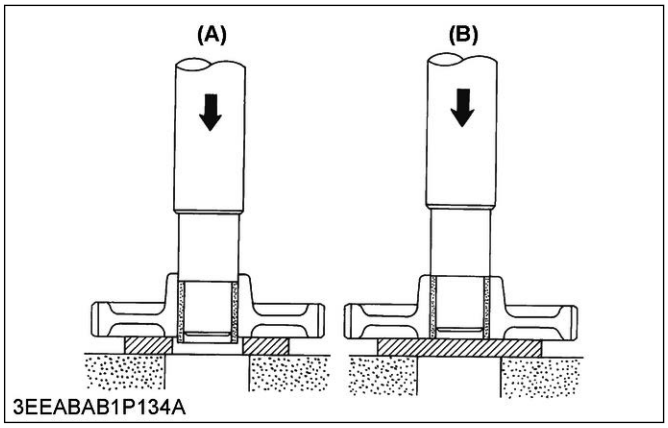
4.3.2.8 Replacing idle gear bushing

(When removing)

1. Press out the used idle gear bushing using an idle gear bushing replacing tool.

(When installing)

1. Clean a new idle gear bushing and idle gear bore, and apply engine oil to them.
2. Press in a new bushing using an idle gear bushing replacing tool, until it is flush with the end of the idle gear.



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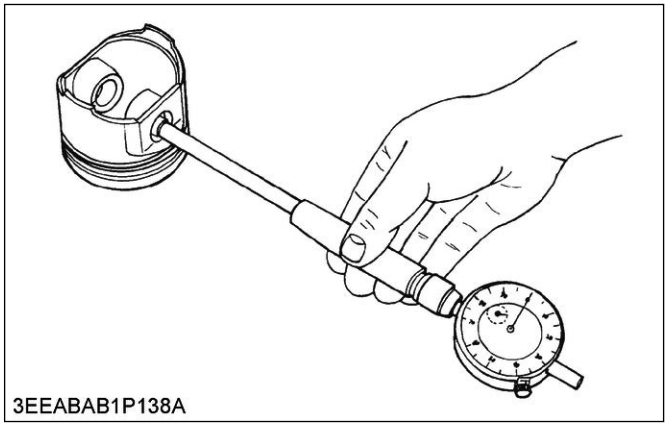
(A) When removing (B) When installing

4.3.3 Piston and connecting rod

4.3.3.1 Measuring piston pin bore I.D.

1. Measure the piston pin bore I.D. in both the horizontal and vertical directions with a cylinder gauge.

Piston pin bore I.D.	Service specification	22.000 to 22.013 mm 0.86615 to 0.86665 in.
	Service limit	22.03 mm 0.8673 in.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2. If the measurement exceeds the service limit, replace the piston.

4.3.3.2 Measuring oil clearance between piston pin and small end bushing

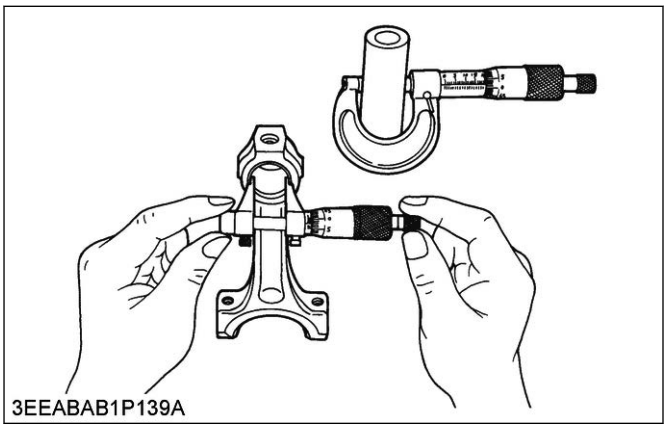
1. Measure the O.D. of the piston pin where it contacts the bushing with an outside micrometer.

Piston pin O.D.	Service specification	22.002 to 22.011 mm 0.86622 to 0.86657 in.

2. Measure the small end bushing I.D. with an inside micrometer, and calculate the oil clearance.

Small end bushing I.D.	Service specification	22.025 to 22.040 mm 0.86713 to 0.86771 in.

Oil clearance between piston pin and small end bushing	Service specification	0.014 to 0.038 mm 0.00056 to 0.0014 in.
	Service limit	0.10 mm 0.0039 in.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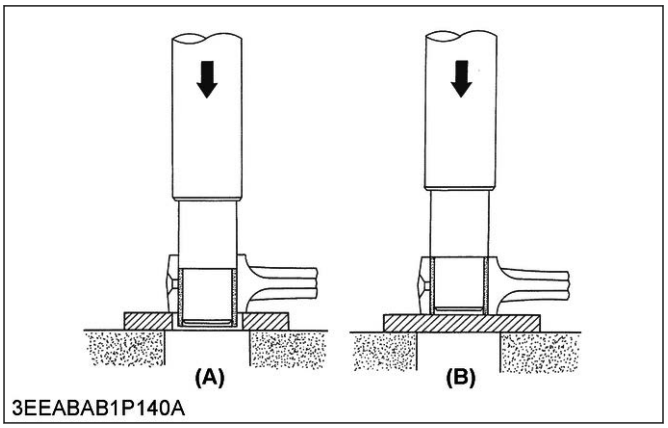
3. If the oil clearance exceeds the service limit, replace the bushing. If it still exceeds the service limit, replace the piston pin.

4.3.3.3 Replacing small end bushing

Tools required
- Small end bushing replacement tool

(When removing)
1. Press out the used bushing using a small end bushing replacing tool.

(When installing)
1. Clean a new small end bushing and bore, and apply engine oil to them.
2. Using a small end bushing replacing tool, press in a new bushing (service parts) taking due care to see that the connecting rod hole matches the bushing hole.



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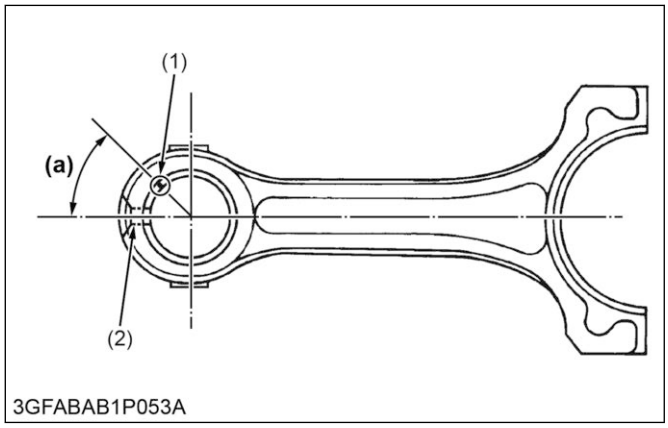

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(1) Seam
(2) Oil hole
(A) When removing
(B) When installing
(a) 0.79 rad (45°)

Servicing parts dimension

Oil clearance between piston pin and small end bushing (Spare parts)	Service specification	0.014 to 0.038 mm 0.00056 to 0.0014 in.
	Service limit	0.15 mm 0.0059 in.

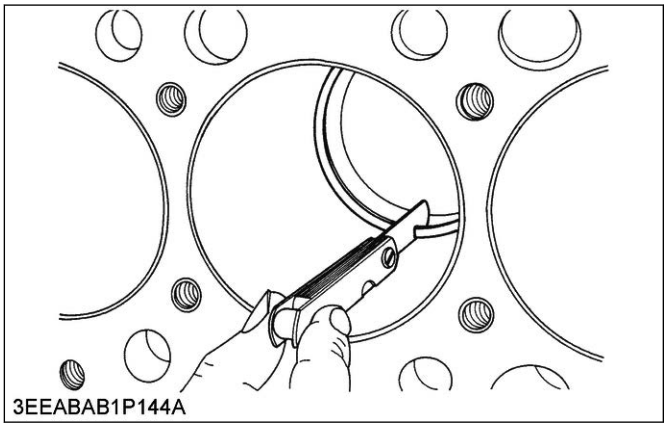
Small end bushing I.D. (Spare parts)	Service specification	22.076 to 22.146 mm 0.86914 to 0.87188 in.

4.3.3.4 Measuring piston ring gap

1. Insert the piston ring into the lower part of the cylinder (the least worn out part) with a piston ring compressor and piston.

2. Measure the ring gap with a feeler gauge.

Piston ring gap	Top ring	Service specification	0.30 to 0.45 mm 0.012 to 0.017 in.
		Service limit	1.25 mm 0.0492 in.
	Second ring	Service specification	0.30 to 0.45 mm 0.012 to 0.017 in.
		Service limit	1.25 mm 0.0492 in.
	Oil ring	Service specification	0.20 to 0.70 mm 0.0079 to 0.027 in.
		Service limit	1.25 mm 0.0492 in.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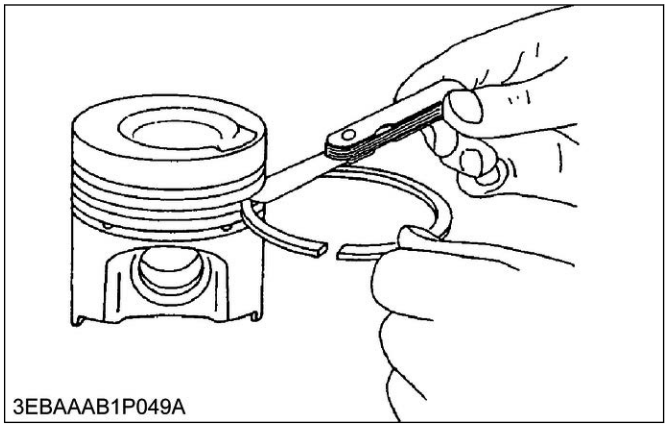
3. If the measurement exceeds the service limit, replace the piston ring.

4.3.3.5 Measuring clearance between piston ring and piston ring groove

1. Clean the rings and the ring grooves, and install each ring in its groove.
2. Measure the clearance between the ring and the groove with a thickness gauge.

Clearance between piston ring and piston ring groove	Top ring	Service specification	0.040 to 0.080 mm 0.0016 to 0.0031 in.
		Service limit	0.2 mm 0.008 in.
	Second ring	Service specification	0.030 to 0.070 mm 0.0012 to 0.0027 in.
		Service limit	0.2 mm 0.008 in.
	Oil ring	Service specification	0.020 to 0.19 mm 0.00079 to 0.0074 in.
		Service limit	0.2 mm 0.008 in.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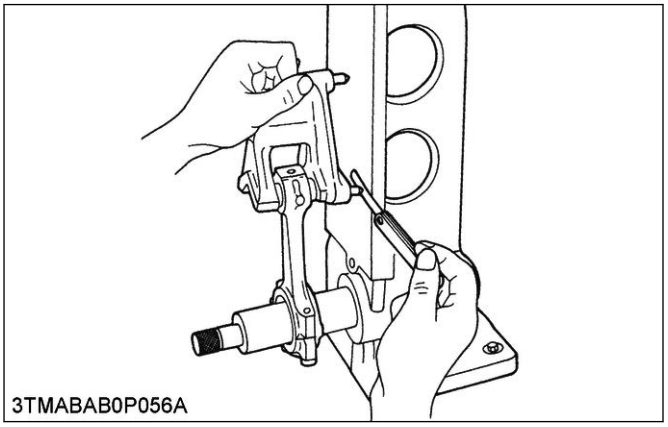
3. If the clearance exceeds the service limit, replace the piston ring.
4. If the clearance still exceeds the service limit with new ring, replace the piston.

4.3.3.6 Connecting rod alignment

1. Remove the crankpin bearing, and install the connecting rod cap.
2. Install the piston pin in the connecting rod.
3. Install the connecting rod on the connecting rod alignment tool.
4. Put a gauge over the piston pin, and move it against the face plate.

5. If the gauge does not fit squarely against the face plate, measure the space between the pin of the gauge and the face plate.

Space between gauge pin face plate	Service limit	0.05 mm 0.002 in.



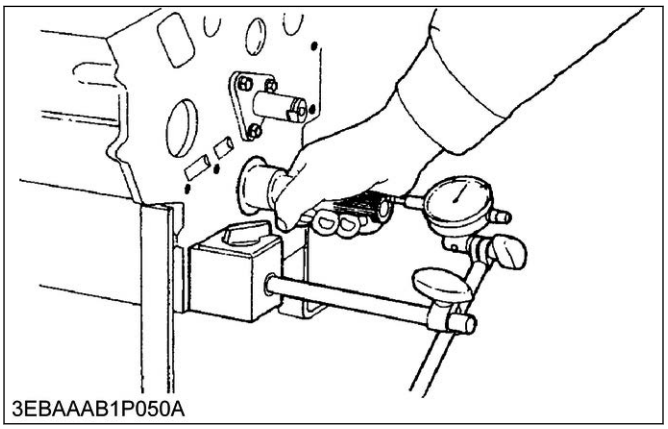
6. If the measurement exceeds the service limit, replace the connecting rod.

4.3.4 Crankshaft

4.3.4.1 Measuring crankshaft side clearance

1. Set a dial indicator with its tip on the end of the crankshaft.
2. Measure the side clearance by moving the crankshaft to the front and rear.

Crankshaft side clearance	Service specification	0.15 to 0.31 mm 0.0059 to 0.012 in.
	Service limit	0.50 mm 0.020 in.

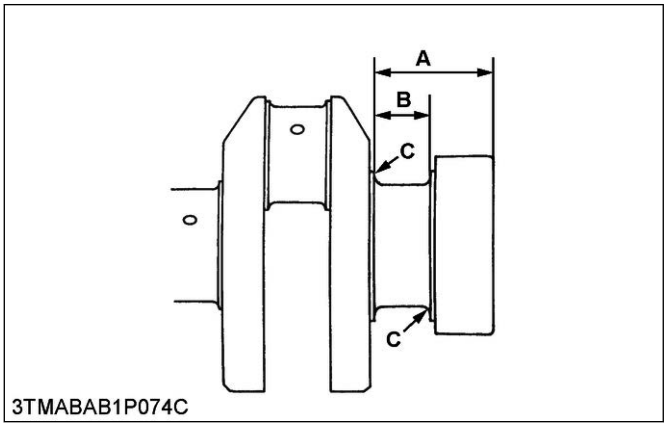


3. If the measurement exceeds the service limit, replace the thrust bearings.
4. If the same size bearing is useless because of the crankshaft journal wear, replace it with an oversize one referring to the table and figure.

(Reference)

- Oversize dimensions of crankshaft journal

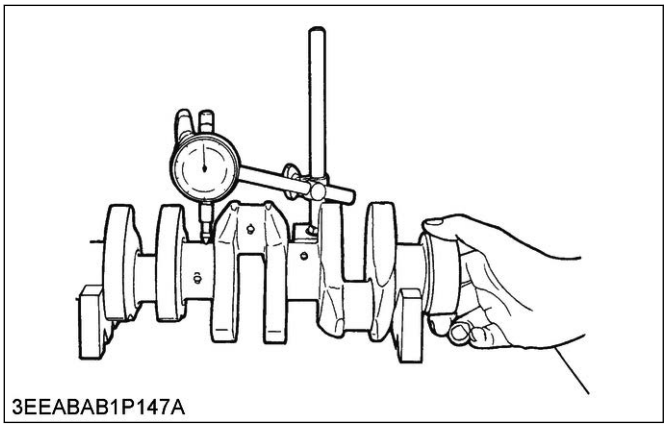
Oversize	0.2 mm 0.008 in.	0.4 mm 0.02 in.
Dimension A	51.50 to 51.70 mm 2.028 to 2.035 in.	51.60 to 51.80 mm 2.032 to 2.039 in.
Dimension B	28.20 to 28.25 mm 1.111 to 1.112 in.	28.40 to 28.45 mm 1.119 to 1.120 in.
Dimension C	2.3 to 2.7 mm radius 0.091 to 0.10 in. radius	2.3 to 2.7 mm radius 0.091 to 0.10 in. radius
The crankshaft journal must be fine-finished to higher than Rmax = 0.8 S		



4.3.4.2 Crankshaft alignment

1. Support the crankshaft with V blocks on the surface plate at both end journals.
2. Set a dial indicator with its tip on the intermediate journal.
3. Measure the crankshaft alignment.

Crankshaft alignment	Service limit	0.02 mm 0.0008 in.



4. If the measurement exceeds the service limit, replace the crankshaft.

4.3.4.3 Measuring oil clearance between crank pin and crank pin bearing

NOTE

- **Never insert the plastigauge into the crank pin oil hole.**
- **Be sure not to move the crankshaft while the connecting rod screws are tightened.**

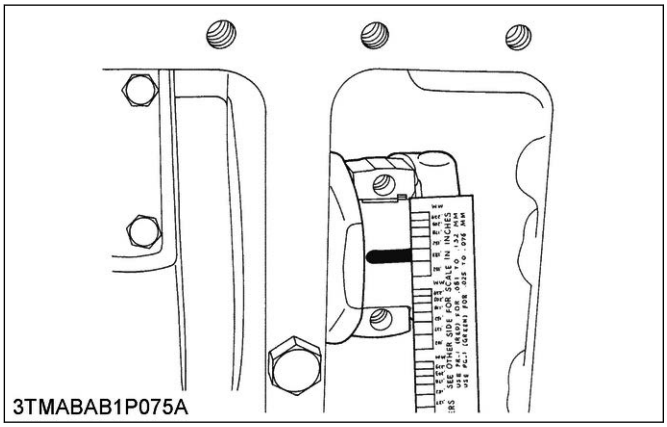
1. Clean the crank pin and crank pin bearing.
2. Put a strip of plastigauge on the center of the crank pin
3. Install the connecting rod cap and tighten the connecting rod screws to the specified torque, and remove the cap again.

Crank pin O.D.	Service specification	39.959 to 39.975 mm 1.5732 to 1.5738 in.

Crank pin bearing I.D.	Service specification	40.040 to 40.050 mm 1.5764 to 1.5767 in.

4. Measure the amount of the flattening with the scale, and get the oil clearance.

Oil clearance between crank pin and crank pin bearing	Service specification	0.065 to 0.091 mm 0.0026 to 0.0035 in.
	Service limit	0.15 mm 0.0059 in.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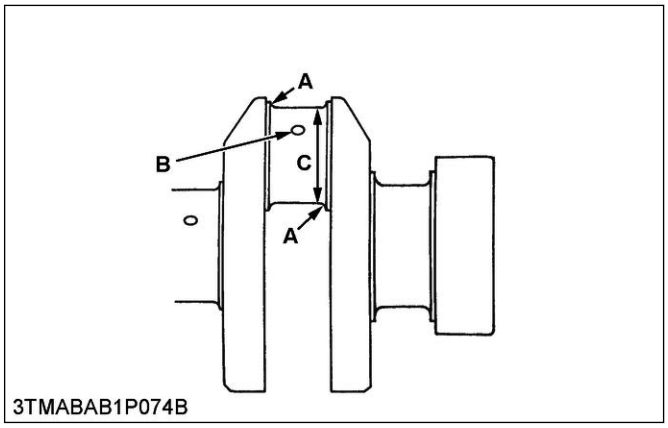
5. If the oil clearance exceeds the service limit, replace the crank pin bearing.
6. If the same size bearing is useless because of the crank pin wear, replace it with an undersize one referring to the table and figure.

(Reference)

- Undersize dimensions of crank pin

Undersize	0.2 mm 0.008 in.	0.4 mm 0.02 in.
Dimension A	2.8 to 3.2 mm radius 0.11 to 0.12 in. radius	2.8 to 3.2 mm radius 0.11 to 0.12 in. radius
*Dimension B	1.0 to 1.5 mm relief 0.040 to 0.059 in. relief	1.0 to 1.5 mm relief 0.040 to 0.059 in. relief
Dimension C	39.759 to 39.775 mm dia. 1.5654 to 1.5659 in. dia.	39.559 to 39.575 mm dia. 1.5575 to 1.5580 in. dia.
The crank pin journal must be fine-finished to higher than Rmax = 0.8 S *Holes to be de-burred and edges rounded with 1.0 to 1.5 mm (0.040 to 0.059 in.) relief.		



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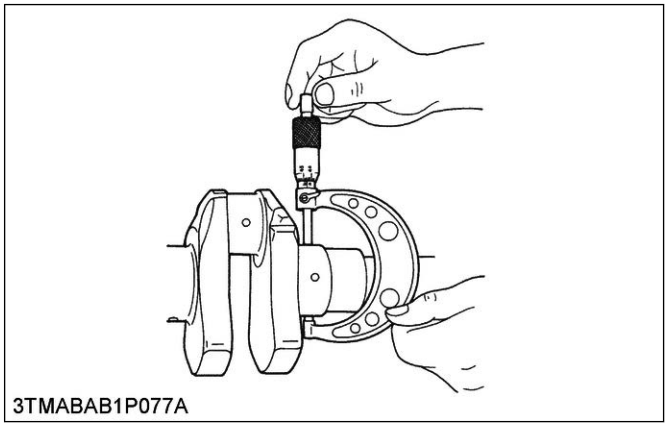
4.3.4.4 Measuring oil clearance between crankshaft journal and crankshaft bearing 1

1. Measure the O.D. of the crankshaft front journal with an outside micrometer.

Crankshaft journal O.D.	Service specification	47.934 to 47.950 mm 1.8872 to 1.8877 in.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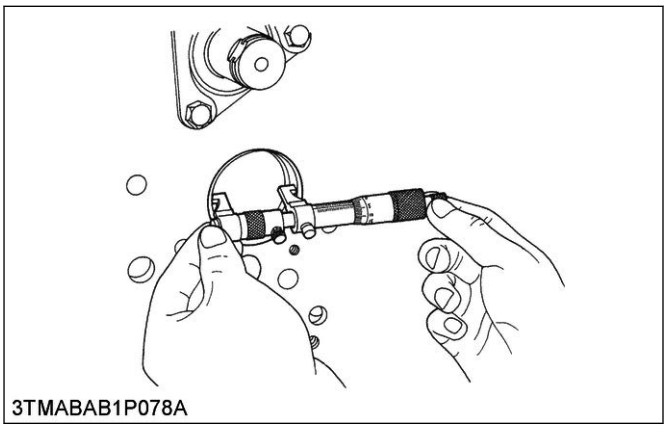
2. Measure the I.D. of the crankshaft bearing 1 with an inside micrometer, and calculate the oil clearance.

Crankshaft bearing 1 I.D.	Service specification	47.984 to 48.048 mm 1.8892 to 1.8916 in.

Oil Clearance between crankshaft journal and crankshaft bearing 1	Service specification	0.0340 to 0.114 mm 0.00134 to 0.00448 in.
	Service limit	0.20 mm 0.0079 in.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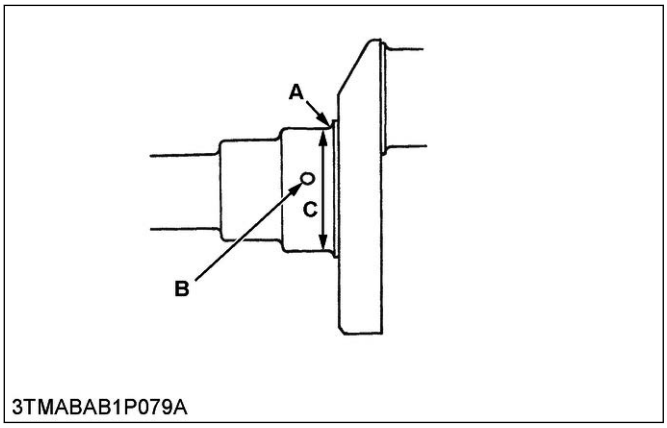
3. If the oil clearance exceeds the service limit, replace the crankshaft bearing 1.
4. If the same size bearing is useless because of the crankshaft journal wear, replace it with an undersize one referring to the table and the figure.

(Reference)

- Undersize dimensions of crankshaft journal

Undersize	0.2 mm 0.008 in.	0.4 mm 0.02 in.
Dimension A	2.3 to 2.7 mm radius 0.091 to 0.10 in. radius	2.3 to 2.7 mm radius 0.091 to 0.10 in. radius
*Dimension B	1.0 to 1.5 mm relief 0.040 to 0.059 in. relief	1.0 to 1.5 mm relief 0.040 to 0.059 in. relief
Dimension C	47.734 to 47.750 mm dia. 1.8793 to 1.8799 in. dia.	47.534 to 47.550 mm dia. 1.8715 to 1.8720 in. dia.
The crankshaft journal must be fine-finished to higher than Rmax = 0.8 S *Holes to be de-burred and edges rounded with 1.0 to 1.5 mm (0.040 to 0.059 in.) relief.		



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4.3.4.5 Replacing crankshaft bearing 1

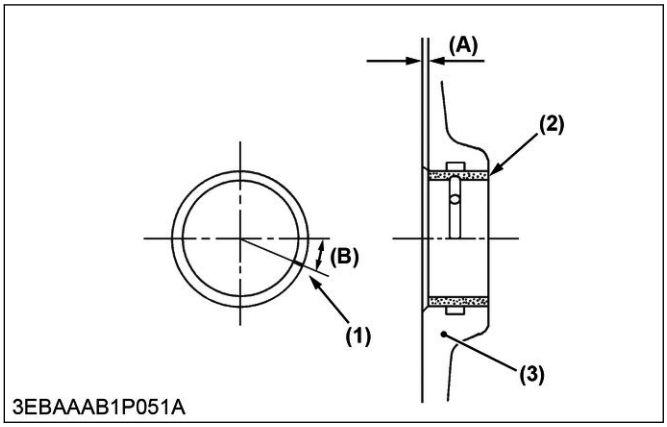
(When removing)

1. Press out the used crankshaft bearing 1 using a crankshaft bearing 1 replacing tool.

(When installing)

1. Clean a new crankshaft bearing 1 and crankshaft journal bore, and apply engine oil to them.
2. Using a crankshaft bearing 1 replacing tool, press in a new bearing 1 (2) so that its seam (1) directs toward the exhaust manifold side. (See figure.)

Dimension (A)	Service specification	0 to 0.3 mm 0 to 0.01 in.



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(1) Seam
(2) Crankshaft bearing 1
(3) Cylinder block
(A) Dimension
(B) 0.37 rad (21°)

4.3.4.6 Measuring oil clearance between crankshaft journal and crankshaft bearing 2 (Crankshaft bearing 3)

■ NOTE

- **Be sure not to move the crankshaft while the bearing case screws are tightened.**

1. Put a strip of plastigauge on the center of the journal.

2. Install the bearing case and tighten the bearing case screws 1 to the specified torque, and remove the bearing case again.

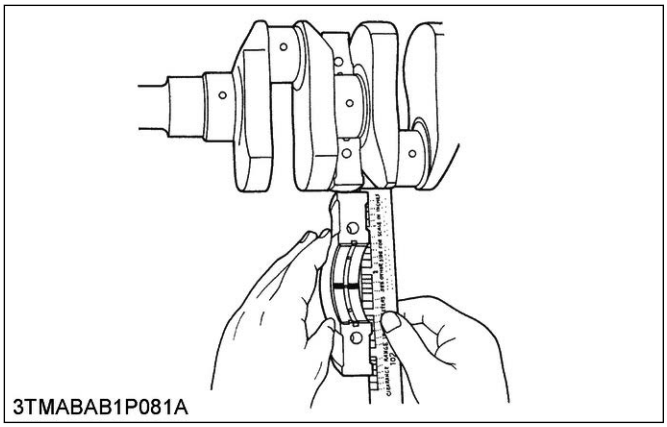
Crankshaft journal O.D. (Flywheel side)	Service specification	47.934 to 47.950 mm 1.8872 to 1.8877 in.
Crankshaft bearing 2 I.D.	Service specification	47.984 to 48.029 mm 1.8892 to 1.8909 in.

Crankshaft journal O.D. (Intermediate)	Service specification	51.921 to 51.940 mm 2.0442 to 2.0448 in.
Crankshaft bearing 3 I.D.	Service specification	51.974 to 52.024 mm 2.0463 to 2.0481 in.

3. Measure the amount of the flattening with the scale, and get the oil clearance.

Oil clearance between crankshaft journal and crankshaft bearing 2	Service specification	0.034 to 0.095 mm 0.0014 to 0.0037 in.
	Service limit	0.20 mm 0.0079 in.

Oil clearance between crankshaft journal and crankshaft bearing 3	Service specification	0.0340 to 0.103 mm 0.00134 to 0.00405 in.
	Service limit	0.20 mm 0.0079 in.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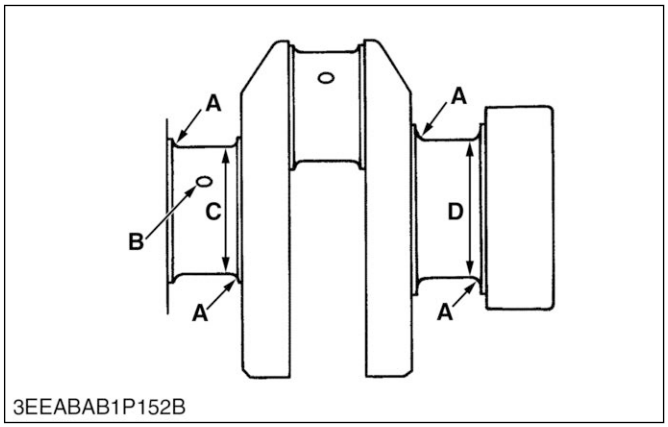
4. If the oil clearance exceeds the service limit, replace the crankshaft bearing 2 (crankshaft bearing 3).
5. If the same size bearing is useless because of the crankshaft journal wear, replace it with an undersize one referring to the table and figure.

(Reference)
- Undersize dimensions of crankshaft journal

Undersize	0.2 mm 0.008 in.	0.4 mm 0.02 in.
Dimension A	2.3 to 2.7 mm radius 0.091 to 0.10 in. radius	2.3 to 2.7 mm radius 0.091 to 0.10 in. radius
*Dimension B	1.0 to 1.5 mm relief 0.040 to 0.059 in. relief	1.0 to 1.5 mm relief 0.040 to 0.059 in. relief
Dimension C	47.734 to 47.750 mm dia. 1.8793 to 1.8799 in. dia.	47.534 to 47.550 mm dia. 1.8715 to 1.8720 in. dia.
Dimension D	51.721 to 51.740 mm dia. 2.0362 to 2.0370 in. dia.	51.521 to 51.540 mm dia. 2.0284 to 2.0291 in. dia.
The crankshaft journal must be fine-finished to higher than Rmax = 0.8 S *Holes to be de-burred and edges rounded with 1.0 to 1.5 mm (0.040 to 0.059 in.) relief.		



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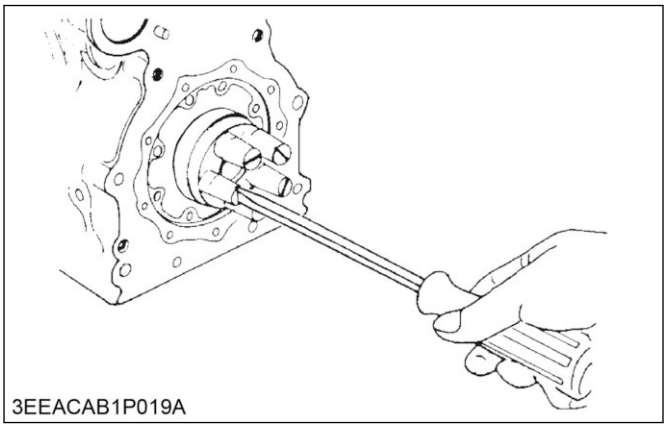
4.3.4.7 Replacing crankshaft sleeve

NOTE
- **Mount the sleeve with its largely chamfered surface facing outward.**
- **Should heating is not enough, a sleeve might stop halfway, so careful.**

1. Remove the used crankshaft sleeve.

2. Set the sleeve guide (2) to the crankshaft.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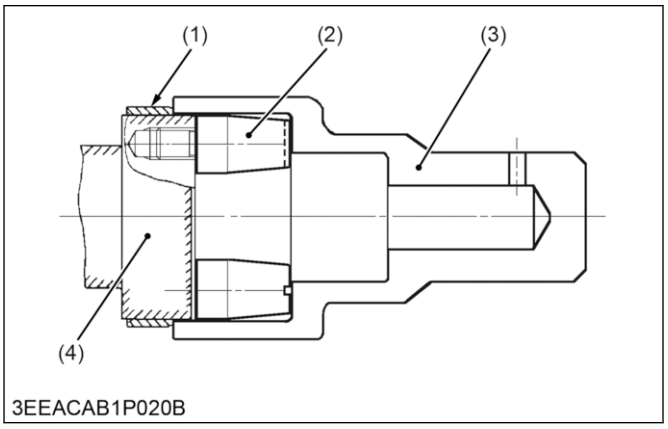
3. Heat a new sleeve to a temperature between 150 and 200 ℃ (302 and 392 ℉), and fix the sleeve to the crankshaft as shown in figure.
4. Press fit the sleeve using the auxiliary socket for pushing (3).



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(1) Crankshaft sleeve
(2) Sleeve guide
(3) Auxiliary socket for pushing
(4) Crankshaft

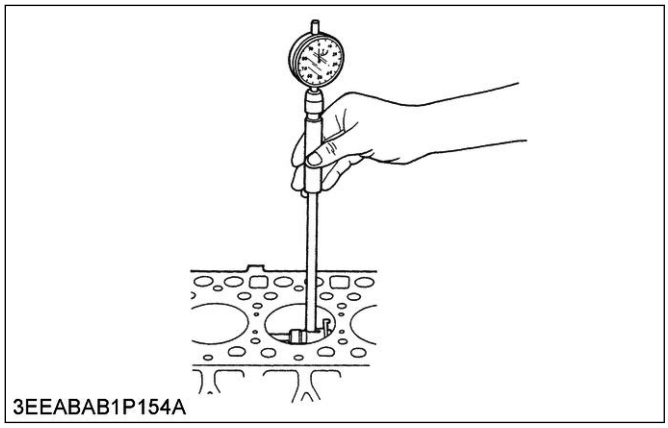
4.3.5 Cylinder

4.3.5.1 Checking cylinder wear

Tools required
- Cylinder gauge

1. Measure the I.D. of the cylinder at the 6 positions (see figure) with a cylinder gauge to find the maximum and minimum I.D.'s.

Cylinder I.D.	Service specification	79.000 to 79.019 mm 3.1103 to 3.1109 in.
	Service limit	79.15 mm 3.116 in.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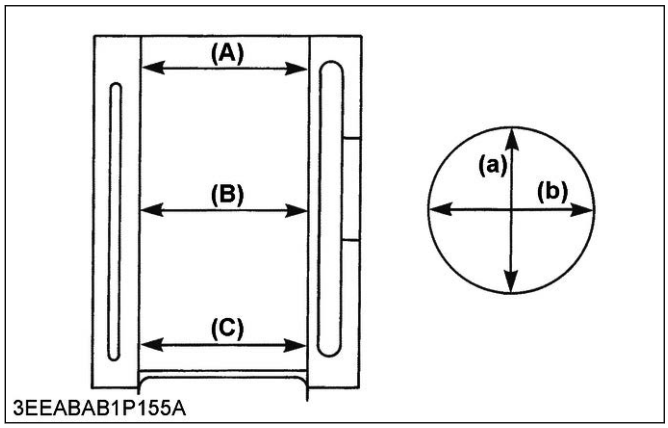

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(A) Top
(B) Middle
(C) Bottom (Skirt)
(a) Right-angled to piston pin
(b) Piston pin direction

2. Get the difference (Maximum wear) between the maximum and the minimum I.D.'s.

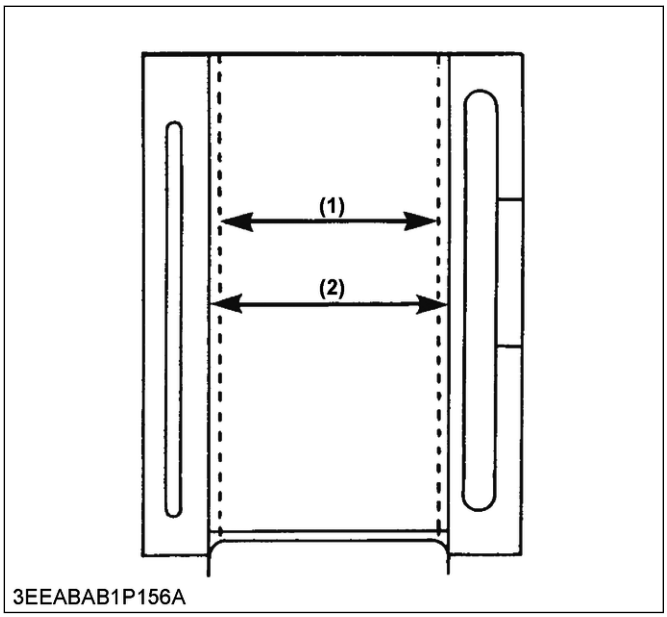
4.3.5.2 Correcting cylinder (Oversize)

NOTE
- **When the oversize cylinder is worn beyond the service limit, replace the cylinder block with a new one.**

1. When the cylinder is worn beyond the service limit, bore and hone it to the specified dimension.

Cylinder liner I.D.	Service specification	79.500 to 79.519 mm 3.1300 to 3.1306 in.
	Service limit	79.65 mm 3.136 in.

Finishing	Hone to 2.2 to 3.0 µm Rz (87 to 110 µin.Rz)



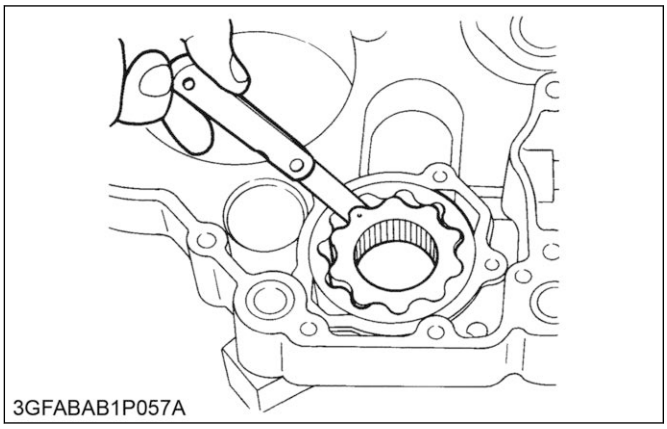
(1) Cylinder I.D. (Before correction) (2) Cylinder I.D. (Oversize)

2. Replace the piston and piston rings with oversize ones. Oversize: 0.5 mm (0.02 in.) Marking: 05

4.3.6 Oil pump

4.3.6.1 Measuring rotor lobe clearance

1. Measure the clearance between lobes of the inner rotor and the outer rotor with a feeler gauge.

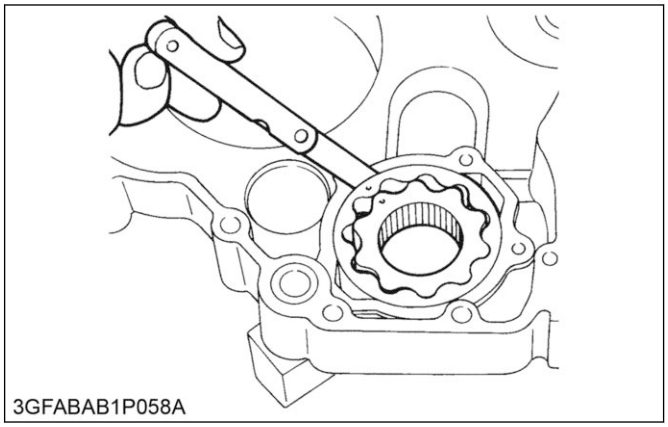


2. If the clearance exceeds the service specifications, replace the oil pump rotor assembly.

Rotor lobe clearance	Service specification	0.060 to 0.18 mm 0.0024 to 0.0071 in.

4.3.6.2 Measuring clearance between outer rotor and pump body

1. Measure the clearance between the outer rotor and the pump body with a feeler gauge.

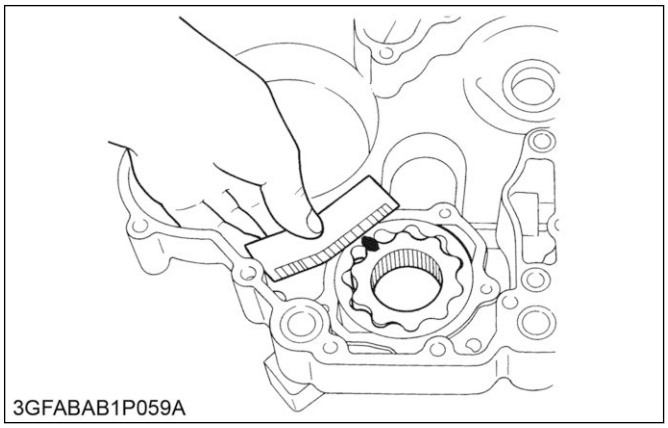


2. If the clearance exceeds the service specifications, replace the oil pump rotor assembly.

Clearance between outer rotor and pump body	Service specification	0.100 to 0.180 mm 0.00394 to 0.00708 in.

4.3.6.3 Measuring between rotor and cover

1. Put a strip of plastically onto the rotor face with grease.
2. Install the cover and tighten the screws.
3. Remove the cover carefully, and measure the amount of the flattening with the scale and get the clearance.



4. If the clearance exceeds the service specifications, replace the oil pump rotor assembly.

Clearance between rotor and cover	Service specification	0.025 to 0.075 mm 0.00099 to 0.0029 in.

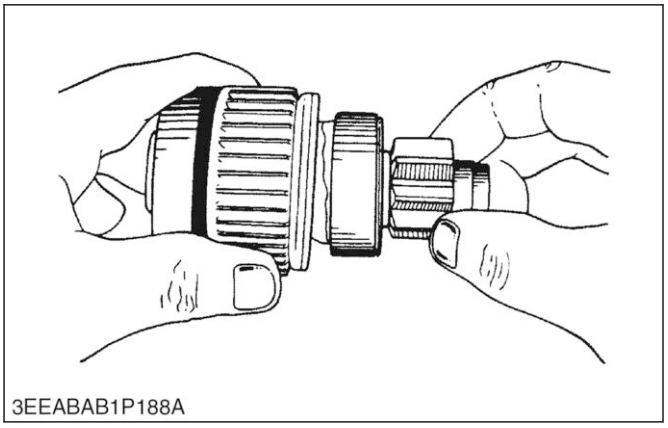
4.3.7 Starter

4.3.7.1 Checking starter overrunning clutch

NOTE

- **Do not wash off the grease in the overrunning clutch with chemicals or oils.**

1. Check the pinion and if worn or damage, replace the clutch assembly.
2. Check that the pinion turns freely and smoothly in the overrunning direction and does not slip in the cranking direction.
3. If the piston slips or does not turn in both directions, replace the overrunning clutch assembly.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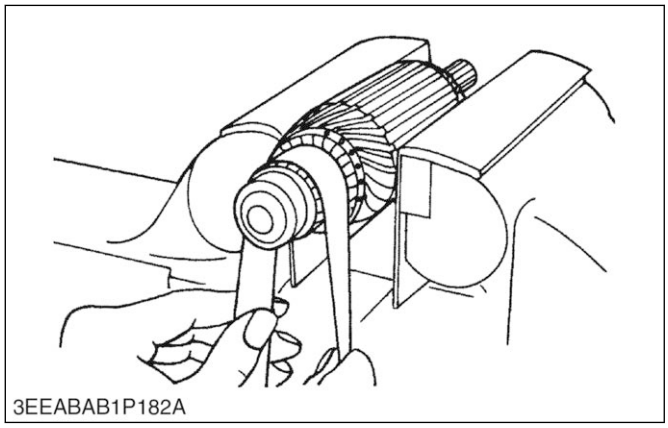
4.3.7.2 Checking starter commutator and mica

Tools required

- Outside micrometer
- Emery paper

1. Check the contact of the commutator for wear, and grind the commutator with emery paper if it is slightly worn.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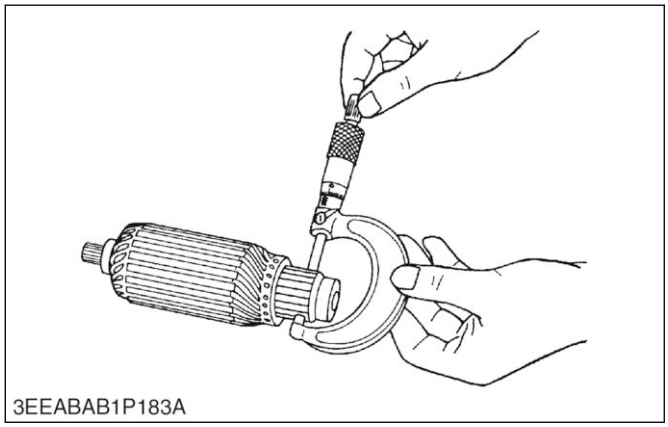
2. Measure the commutator O.D. with an outside micrometer at several points.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3. If the minimum O.D is less than the service limit, replace the armature.

Commutator O.D.	Service specification	28.0 mm 1.10 in.
	Service limit	27.0 mm 1.06 in.

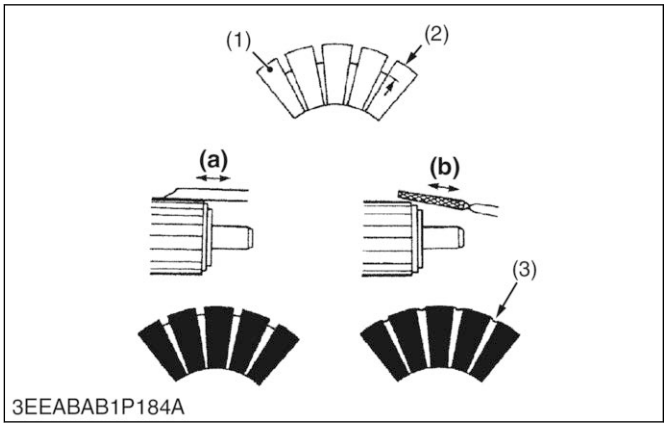
4. If the difference of the O.D.'s exceeds the service limit, correct the commutator on a lathe to the service specification.

Difference of O.D.'s	Service specification	Less than 0.05 mm 0.002 in.
	Service limit	0.4 mm 0.02 in.

5. Measure the mica undercut.

6. If the undercut is less than the service limit, correct it with a saw blade and chamfer the segment edges.

Mica undercut	Service specification	0.50 to 0.80 mm 0.020 to 0.031 in.
	Service limit	0.20 mm 0.0079 in.

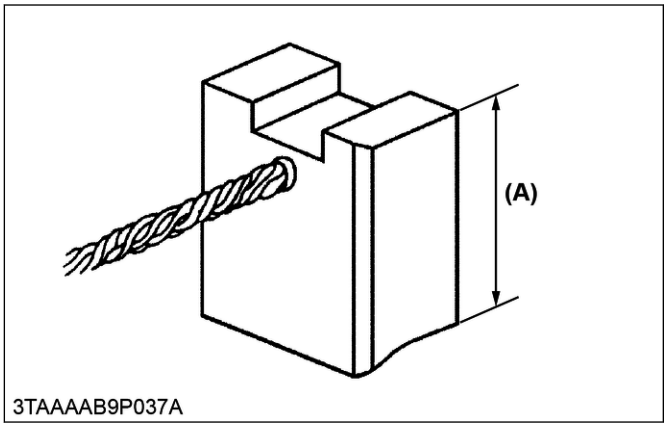


(1) Segment
(2) Undercut
(3) Mica
(a) Good
(b) Bad

4.3.7.3 Checking starter brush wear

Tools required
- Vernier caliper
- Emery paper

1. If the contact face of the brush is dirty or dusty, clean it with emery paper.
2. Measure the brush length (A) with vernier caliper.



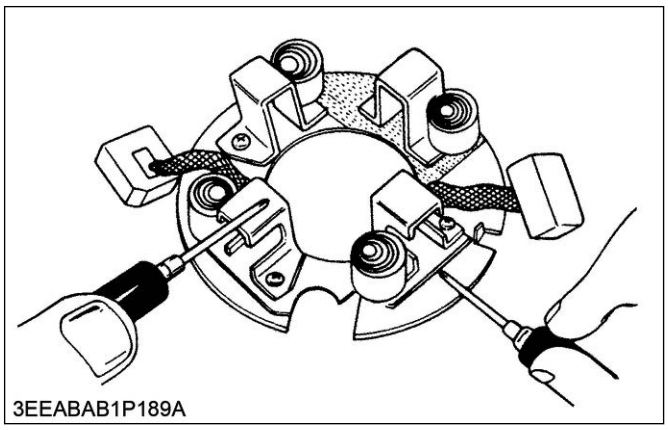
(A) Brush length

3. If the length is less than the service limit, replace the yoke assembly and brush holder.

Brush length (A)	Service specification	16.0 mm 0.630 in.
	Service limit	10.5 mm 0.413 in.

4.3.7.4 Checking brush holder

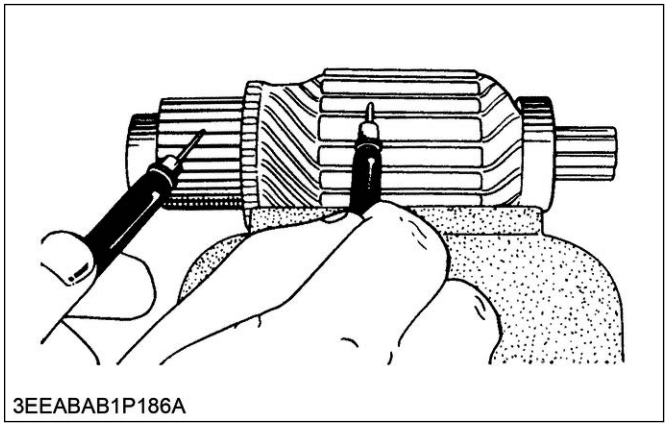
1. Check the continuity across the brush holder and the holder support with resistance range of circuit tester.



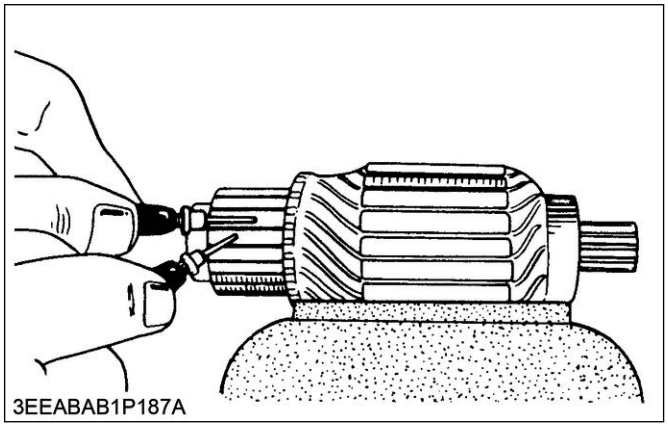
2. If it conducts, replace the brush holder.

4.3.7.5 Checking starter armature coil

1. Check the continuity across the commutator and armature coil core with resistance range of circuit tester.



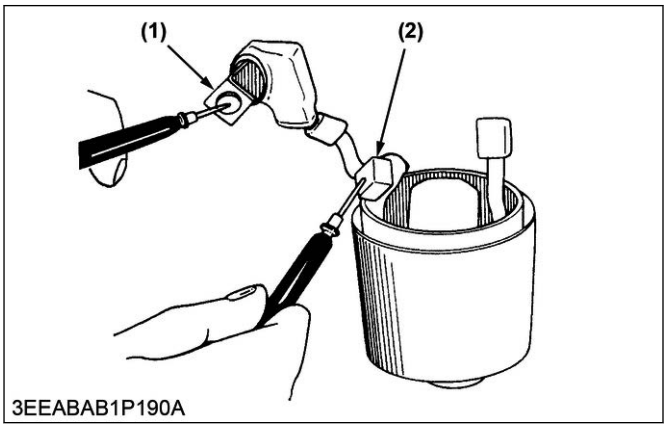
2. If it conducts, replace the armature.
3. Check the continuity across the segments of the commutator with resistance range of circuit tester.



4. If it does not conduct, replace the armature.

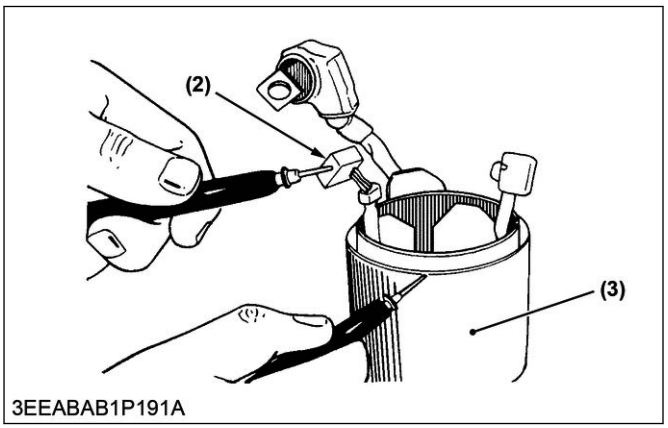
4.3.7.6 Checking field coil

1. Check the continuity across the lead (1) and brush (2) with resistance range of circuit tester.



(1) Lead (2) Brush

2. If it does not conduct, replace the yoke assembly.
3. Check the continuity across the brush (2) and yoke (3) with resistance range of circuit tester.



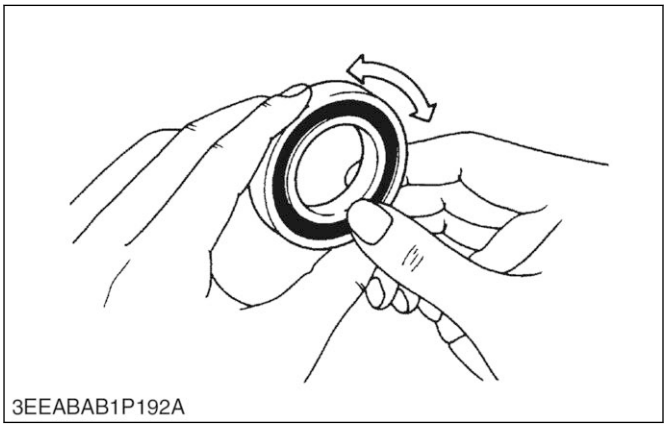
(2) Brush (3) Yoke

4. If it conducts, replace the yoke assembly.

4.3.8 Alternator

4.3.8.1 Checking alternator bearing

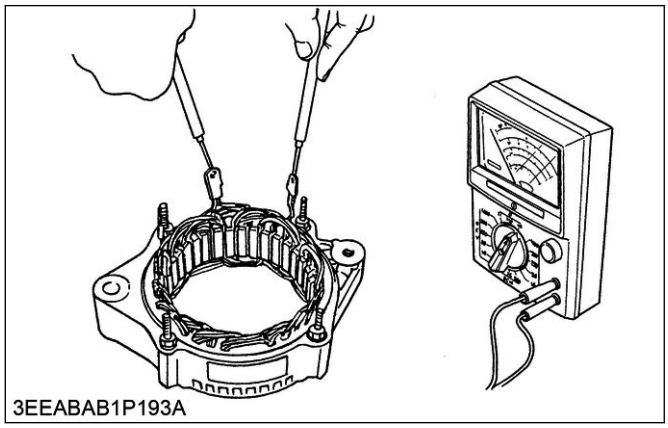
1. Check the bearing for smooth rotation.



2. If it does not rotate smoothly, replace it.

4.3.8.2 Checking alternator stator

1. Measure the resistance across each lead of the stator coil with resistance range of circuit tester.



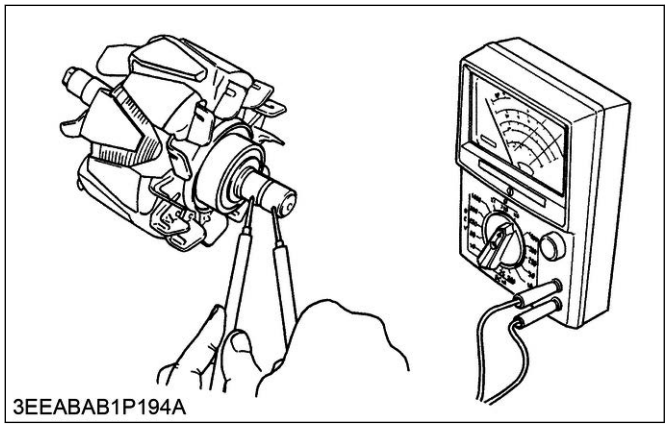
2. If the measurement is not within the service specification, replace it.
3. Check the continuity across each stator coil lead and core with resistance range of circuit tester.

Resistance	Service specification	Less than 1.0 Ω

4. If infinity is not indicated, replace it.

4.3.8.3 Checking alternator rotor

1. Measure the resistance across the slip rings.
2. If the resistance is not the service specification, replace it.
3. Check the continuity across the slip ring and core with resistance range of circuit tester.



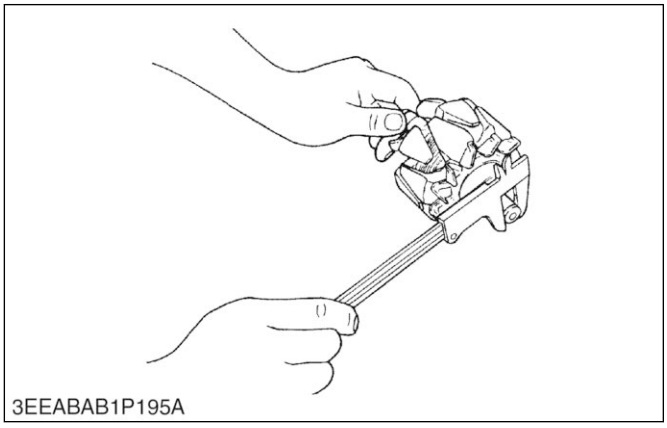
4. If infinity is not indicated, replace it.

Resistance	Service specification	2.9 Ω

4.3.8.4 Checking alternator slip ring

Tools required
- Vernier calipers
- Emery paper

1. Check the slip ring for score.
2. If scored, correct with an emery paper or on a lathe.
3. Measure the O.D. of the slip ring with vernier calipers.


3EEABAB1P195A

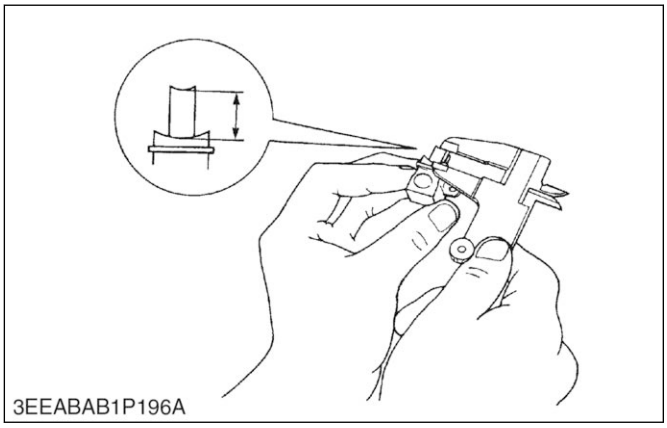
4. If the measurement is less than the service limit, replace it.

Slip ring O.D.	Service specification	14.4 mm 0.567 in.
	Service limit	14.0 mm 0.551 in.

4.3.8.5 Checking alternator brush wear

Tools required
- Vernier calipers

1. Measure the brush length with vernier calipers.


3EEABAB1P196A

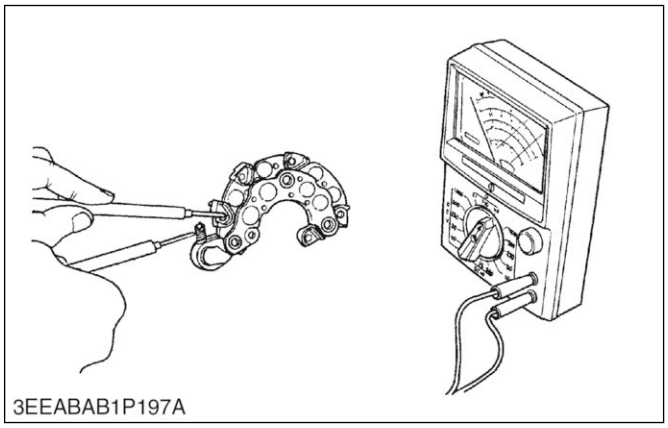
2. If the measurement is less than the service limit, replace it.

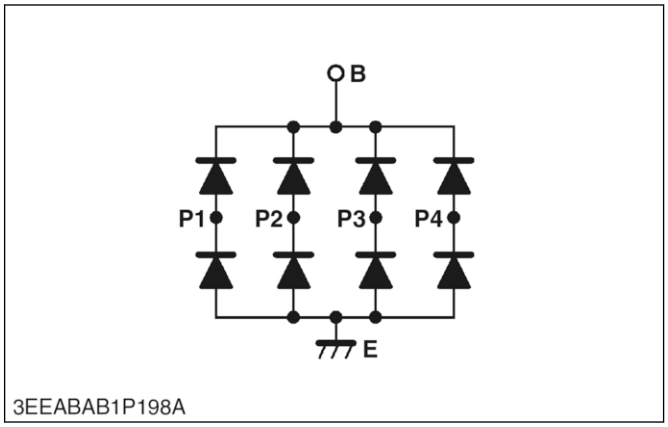
Brush length	Service specification	10.0 mm 0.394 in.
	Service limit	8.4 mm 0.33 in.

3. Make sure that the brush moves smoothly.
4. If the brush is damaged, replace it.

4.3.8.6 Checking alternator rectifier

1. Check the continuity across each diode of rectifier with resistance range of circuit tester.


3EEABAB1P197A

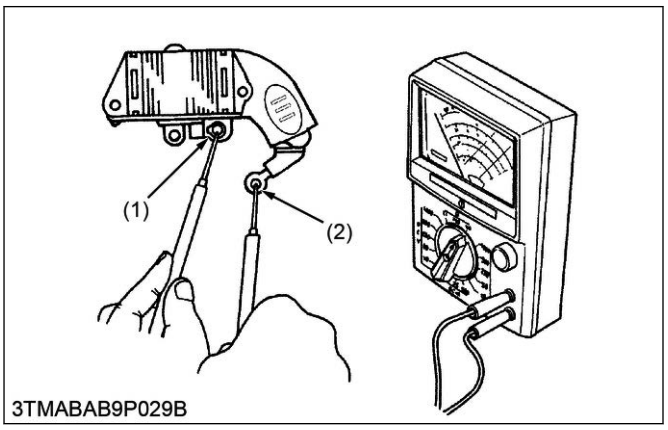


3EEABAB1P198A

2. The rectifier is normal if the diode in the rectifier conducts in one direction and does not conduct in the reverse direction.

4.3.8.7 Checking alternator IC regulator

1. Check the continuity across the B terminal (2) and the F terminal (1) of IC regulator with resistance range of circuit tester.



(1) F terminal (2) B terminal

2. The IC regulator is normal if the conducts in one direction and does not conduct in the reverse direction.

INDEX

D

E

F

G

I

K

L

M

N

T

V

W

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