WSM

WORKSHOP MANUAL
DIESEL ENGINE

68mm STROKE SERIES
(NSM SERIES)

Kubota

TO THE READER

This Workshop Manual has been prepared to provide servicing personnel with information on the mechanism, service and maintenance of KUBOTA Diesel Engine 68 mm STROKE SERIES. It is divided into two parts, "Mechanism" and "Disassembling and Servicing".

■ **Mechanism**

Information on construction and functions are included for each engine section. This part should be understood before proceeding with trouble-shooting, disassembling and servicing.

■ **Disassembling and Servicing**

Under the heading "General" come general precautions, troubleshooting, lists of servicing specifications and periodic inspection items. For each engine section, there are "Checking and Adjustment", "Disassembling and Assembling", and "Servicing" which cover procedures, precautions, factory specification and allowable limits.

All the engines that have been menufactured since January of 1994 are clean exhaust engines.

The mark [E] in the WSM refers to the said clean engine.

All information, illustrations and specifications contained in this manual are based on the latest production information available at the time of publication. The right is reserved to make changes in all information at any time without notice.

July 1990

CONTENTS

M. MECHANISM

S. DISASSEMBLING AND SERVICING

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.

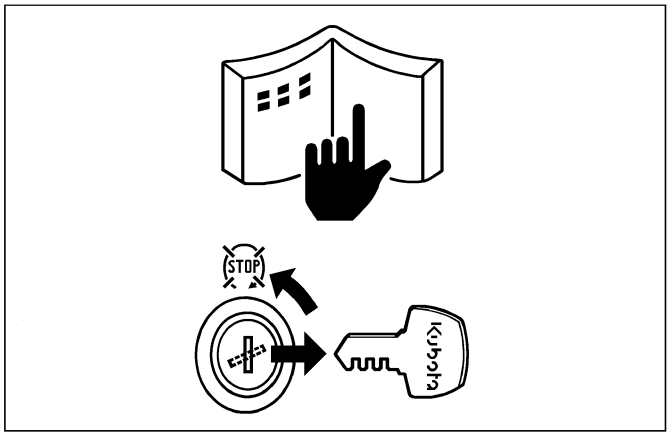
DANGER : Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.

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.

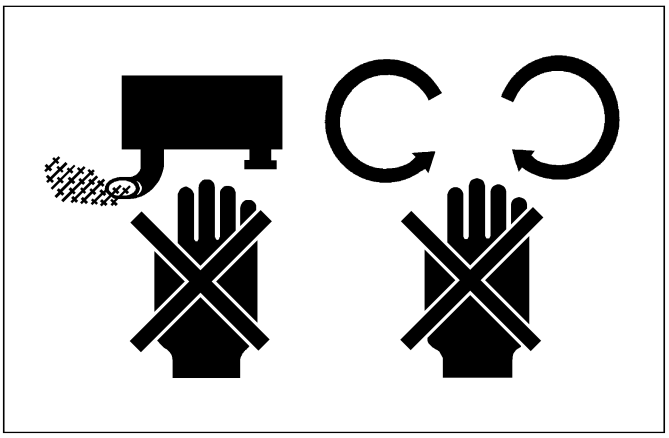


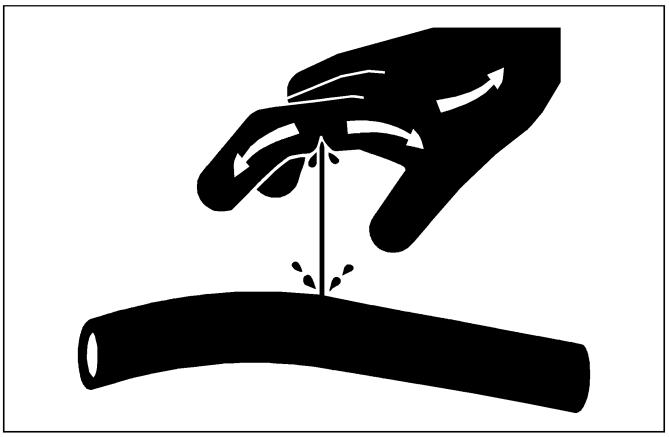
BEFORE SERVICING AND REPAIRING

- 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 firm and level ground.
- Allow the engine to cool before proceeding.
- Stop the engine, and remove the key.
- Disconnect the battery negative cable.

SAFETY STARTING

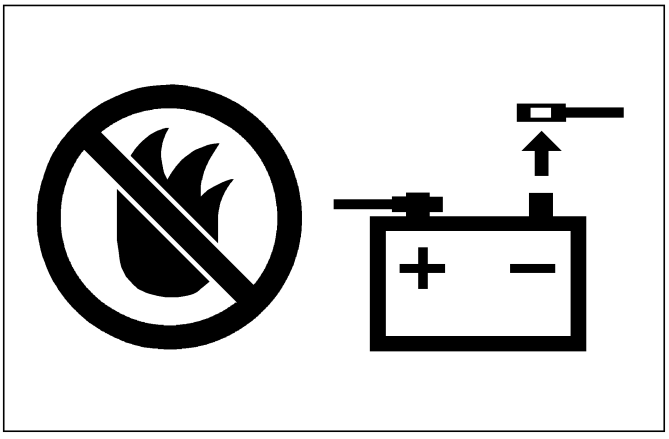
- Do not start the engine by shorting across starter terminals or bypassing the safety start switch.
- Unauthorized modifications to the engine may impair the function and / or safety and affect engine life.





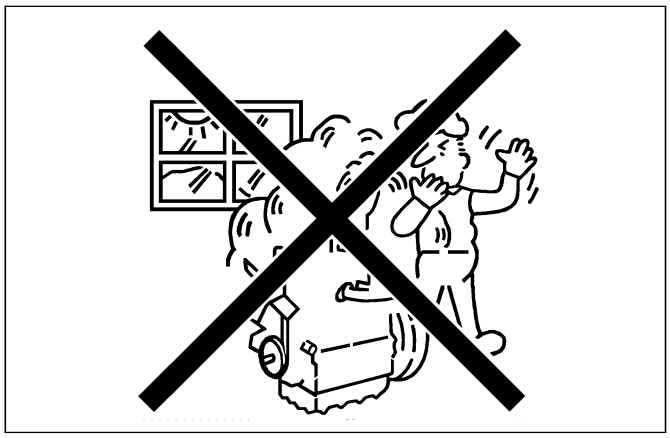
SAFETY WORKING

- Do not work on the machine while under the influence of alcohol, medication, or other substances or while fatigued.
- Wear close fitting clothing and safety equipment appropriate to the job.
- Use tools appropriate to the work. Makeshift tools, parts, and procedures are not recommended.
- When servicing is performed together by two or more persons, take care to perform all work safely.
- Do not touch the rotating or hot parts while the engine is running.
- Never remove the radiator cap while the engine is running, or immediately after stopping. Otherwise, hot water will spout out from radiator. Only remove radiator cap when cool enough to touch with bare hands. Slowly loosen the cap to first stop to relieve pressure before removing completely.
- Escaping fluid (fuel or hydraulic oil) under pressure can penetrate the skin causing serious injury. Relieve pressure before disconnecting hydraulic or fuel lines. Tighten all connections before applying pressure.
- Wear a suitable hearing protective device such as earmuffs or earplugs to protect against objectionable or uncomfortable loud noises.



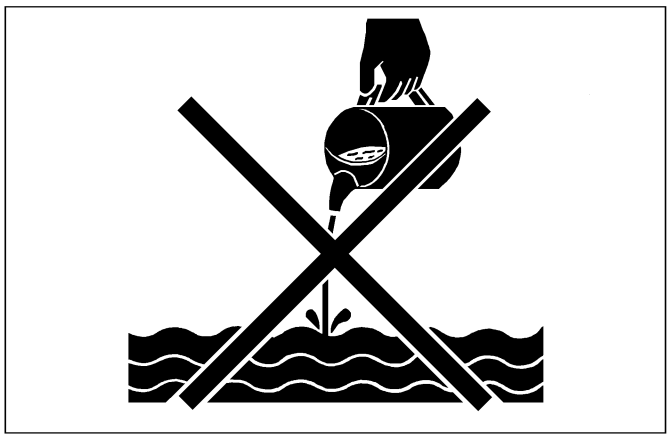
AVOID FIRES

- Fuel is extremely flammable and explosive under certain conditions. Do not smoke or allow flames or sparks in your working area.
- To avoid sparks from an accidental short circuit, always disconnect the battery negative cable first and connect it last.
- Battery gas can explode. Keep sparks and open flame away from the top of battery, especially when charging the battery.
- Make sure that no fuel has been spilled on the engine.



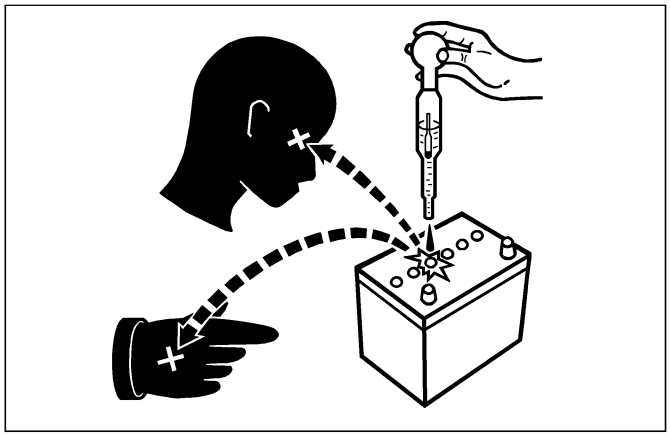
VENTILATE WORK AREA

- If the engine must be running to do some work, make sure the area is well ventilated. Never run the engine in a closed area. The exhaust gas contains poisonous carbon monoxide.



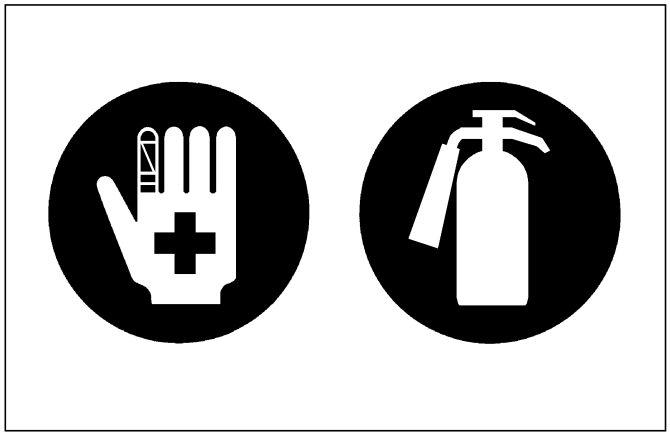
DISPOSE OF FLUIDS PROPERLY

- Do not pour fluids into the ground, down a drain, or into a stream, pond, or lake. Observe relevant environmental protection regulations when disposing of oil, fuel, coolant, electrolyte and other harmful waste.



PREVENT ACID BURNS

- Sulfuric acid in battery electrolyte is poisonous. It is strong enough to burn skin, clothing and cause blindness if splashed into eyes. Keep electrolyte away from eyes, hands and clothing. If you spill electrolyte on yourself, flush with water, and get medical attention immediately.



PREPARE FOR EMERGENCIES

- Keep a first aid kit and fire extinguisher handy at all times.
- Keep emergency numbers for doctors, ambulance service, hospital and fire department near your telephone.

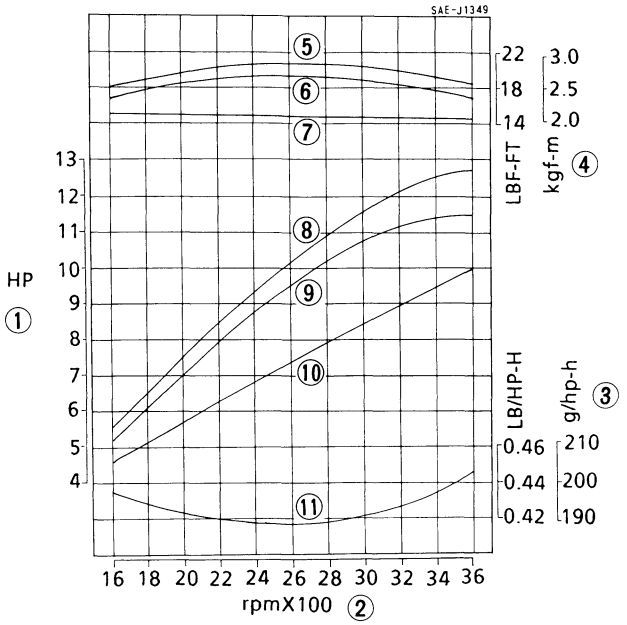
SPECIFICATIONS

Model		Z442-B (E)	Z482-B (E)	D662-B (E)	D722-B (E)
Type		Vertical, liquid cooled, 4-cycle diesel engine			
Number of Cylinders		2	2	3	3
Bore x Stroke	mm (in.)	64 x 68 (2.52 x 2.68)	67 x 68 (2.64 x 2.68)	64 x 68 (2.52 x 2.68)	67 x 68 (2.64 x 2.68)
Total Displacement	CC (cu. in.)	437 (26.70)	479 (29.23)	656 (40.05)	719 (43.89)
Brake Horse Power	SAE Net Cont. H.P.	7.5 kW/3600 rpm 10.0 HP/3600 rpm	8.1 kW/3600 rpm 10.8 HP/3600 rpm	11.2 kW/3600 rpm 15.0 HP/3600 rpm	12.2 kW/3600 rpm 16.3 HP/3600 rpm
	SAE Net Intermittent H.P.	8.6 kW/3600 rpm 11.5 HP/3600 rpm	9.3 kW/3600 rpm 12.5 HP/3600 rpm	12.9 kW/3600 rpm 17.3 HP/3600 rpm	14.0 kW/3600 rpm 18.8 HP/3600 rpm
	SAE Gross Intermittent H.P.	9.5 kW/3600 rpm 12.7 HP/3600 rpm	10.4 kW/3600 rpm 13.9 HP/3600 rpm	14.3 kW/3600 rpm 19.2 HP/3600 rpm	15.6 kW/3600 rpm 20.9 HP/3600 rpm
	DIN 6271-NA	7.4 kW/3600 rpm 10.0 PS/3600 rpm	7.9 kW/3600 rpm 10.8 PS/3600 rpm	11.0 kW/3600 rpm 15.0 PS/3600 rpm	12.1 kW/3600 rpm 16.4 PS/3600 rpm
	DIN 6271-NB	8.2 kW/3600 rpm 11.1 PS/3600 rpm	8.9 kW/3600 rpm 12.1 PS/3600 rpm	12.3 kW/3600 rpm 16.7 PS/3600 rpm	13.3 kW/3600 rpm 18.1 PS/3600 rpm
	DIN 70020	8.9 kW/3600 rpm 12.1 PS/3600 rpm	9.7 kW/3600 rpm 13.2 PS/3600 rpm	13.5 kW/3600 rpm 18.3 PS/3600 rpm	14.6 kW/3600 rpm 19.9 PS/3600 rpm
Maximum Bare Speed		3800 rpm			
Minimum Bare Idling Speed		900 to 1000 rpm			
Combustion Chamber		Spherical type			
Fuel Injection Pump		Bosch MD mini Pump			
Governor		Centrifugal Ball Mechanical Governor			
Direction of Rotation		Counter-clockwise (viewed from flywheel)			
Injection Nozzle		Bosch Throttle Type			
Injection Timing		0.35 to 0.38 rad. (20° to 22°) before T.D.C.			
Injection Order		1-2	1-2	1-2-3	1-2-3
Injection Pressure		13.73 MPa (140 kgf/cm^2, 1991 psi)			
Compression Ratio		23:1			
Lubricating System		Forced Lubrication by Pump			
Oil Pressure Indication		Electrical Type Switch			
Lubricating Filter		Full Flow Paper Filter (Cartridge Type)			
Cooling system		Pressurized Radiator (not included in the basic model), Forced Circulation with Water Pump			
Starting System		Electric Starting With Cell Starter			
		12 V, 0.8 kW			
Starting Support Device		by Glow Plug in Combustion Chamber			
Battery		12V, 35AH, equivalent			
Generator for Charging		12 V, 150 W			
Fuel		Diesel Fuel No.2-D (ASTM D975)			
Lubricating Oil		Class CF lubricating oil as per API classification is recommended. If this class of lubricating oil is not available, preferably use Class CD or CE lubricating oil. For details on recommended lubricating oils, see page S-12, 15.			
Lubricating Oil Capacity		2.1 ℓ (2.2 U.S.qts., 1.85 Imp. qts)		3.2 ℓ (3.4 U.S.qts., 2.81 Imp. qts)	
		2.5 ℓ (2.6 U.S.qts., 2.21 Imp. qts)		3.8 ℓ (4.0 U.S.qts., 3.31 Imp. qts)	
Weight (Dry)		53.1 kg (117.1 lbs)	53.1 kg (117.1 lbs)	63.7 kg (140.4 lbs)	63.1 kg (139.1 lbs)
Application		General Power Source			

PERFORMANCE CURVES

■ Z442-B (E)

(SAE)



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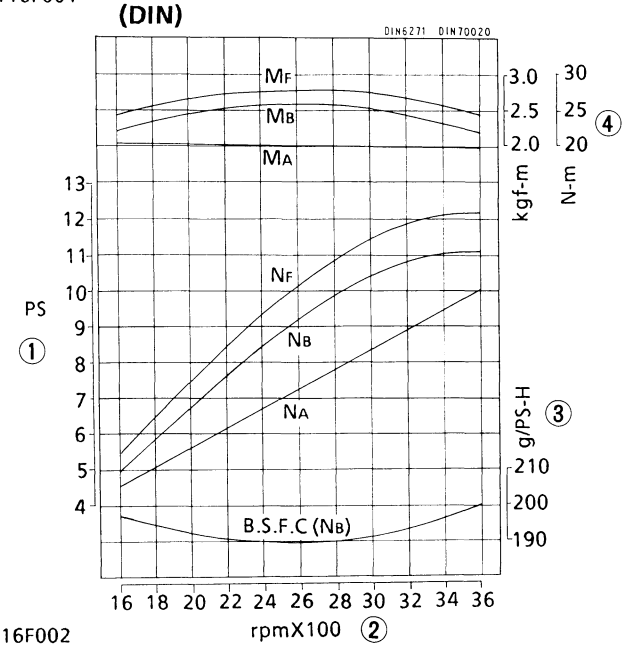
(DIN)



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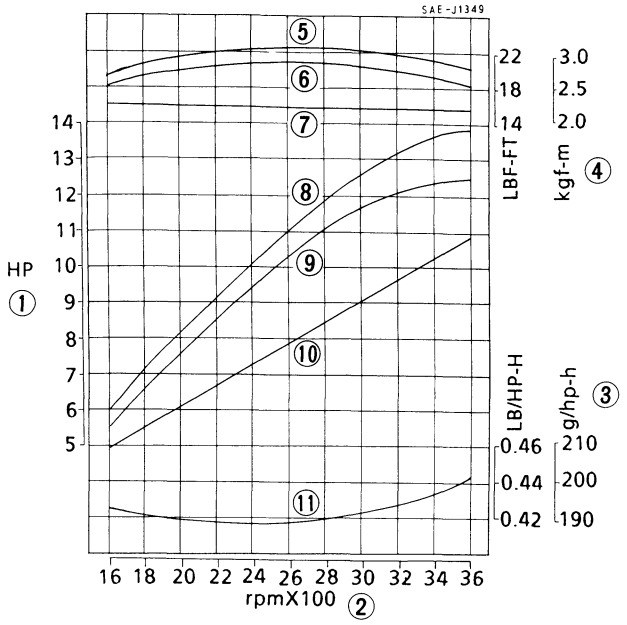
■ Z482-B (E)

(SAE)



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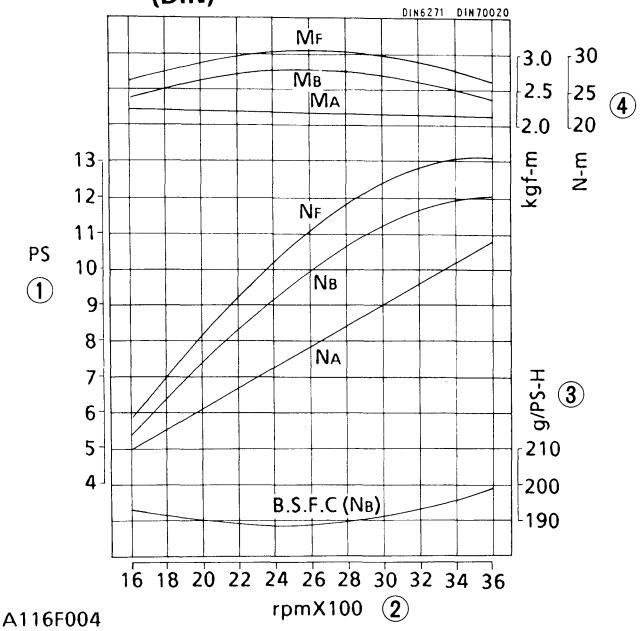

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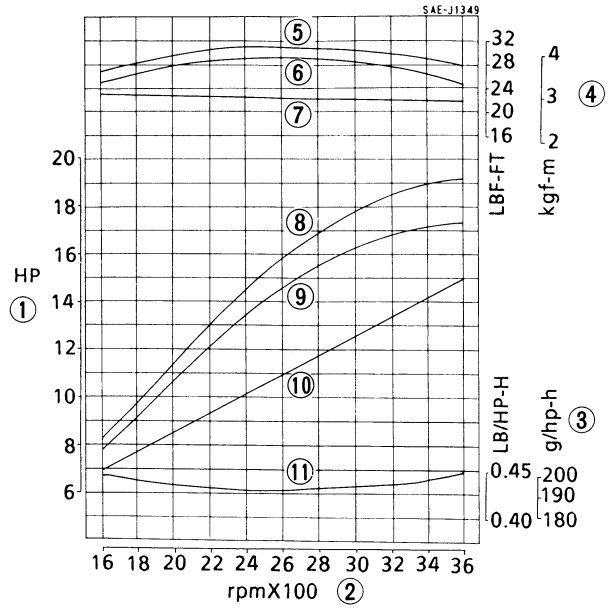
(1) Brake Horsepower
(2) Engine Speed
(3) B.S.F.C.
(4) Torque
(5) Gross Intermittent Torque
(6) Net Intermittent Torque
(7) Net Cont. Torque
(8) Gross Intermittent B.H.P.
(9) Net Intermittent B.H.P.
(10) Net Cont. B.H.P.
(11) B.S.F.C. (Net Intermittent)

■ D662-B (E)

(SAE)



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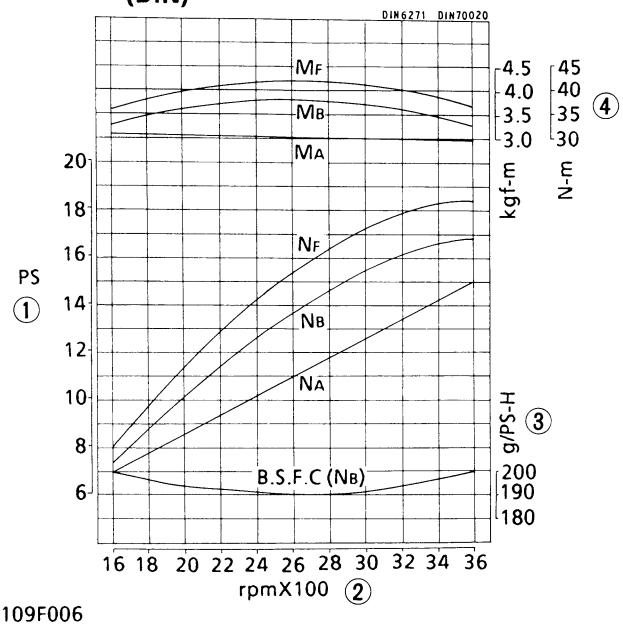

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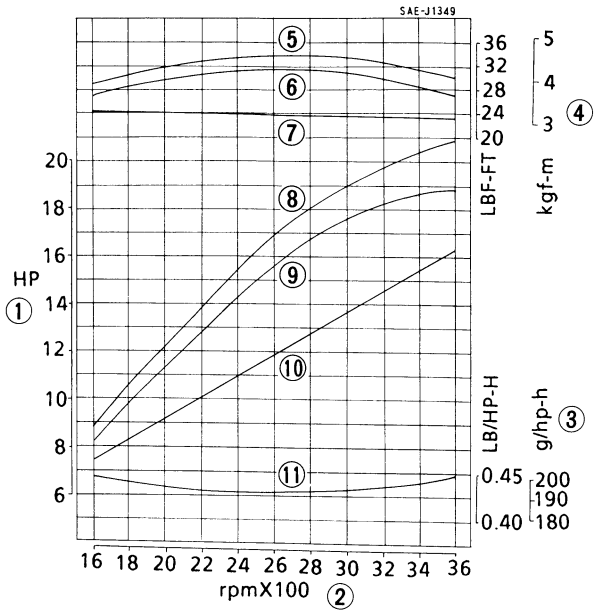
■ D722-B (E)

(SAE)



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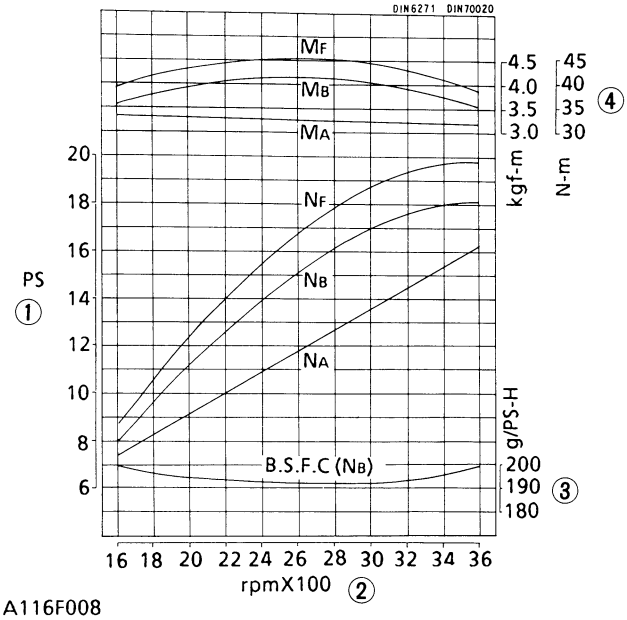


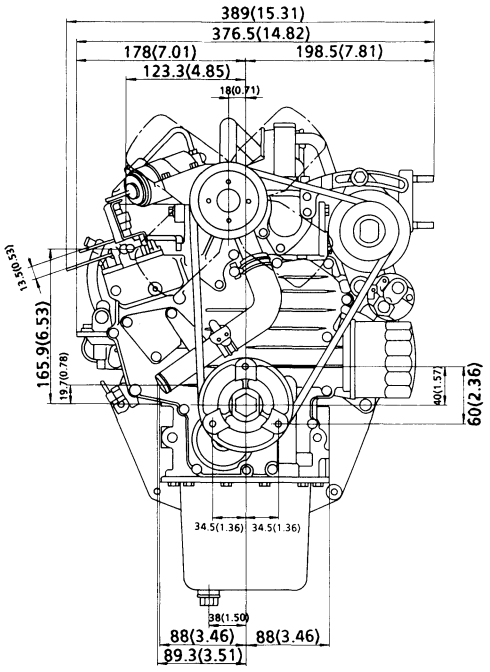
A116F008

(1) Brake Horsepower
(2) Engine Speed
(3) B.S.F.C.
(4) Torque
(5) Gross Intermittent Torque
(6) Net Intermittent Torque
(7) Net Cont. Torque
(8) Gross Intermittent B.H.P.
(9) Net Intermittent B.H.P.
(10) Net Cont. B.H.P.
(11) B.S.F.C. (Net Intermittent)

DIMENSIONS

■ Z442-B (E), Z482-B (E)

Unit: mm (in.)



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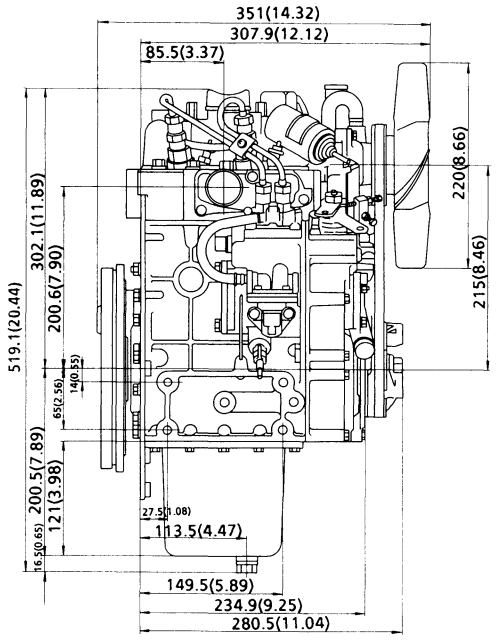

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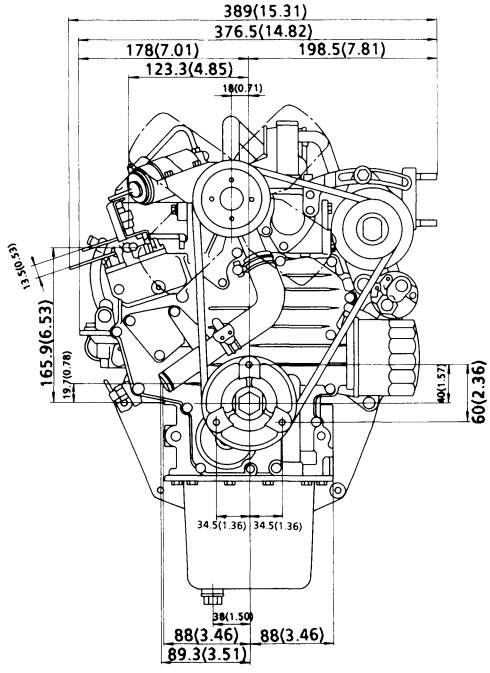
■ D662-B (E), D722-B (E)



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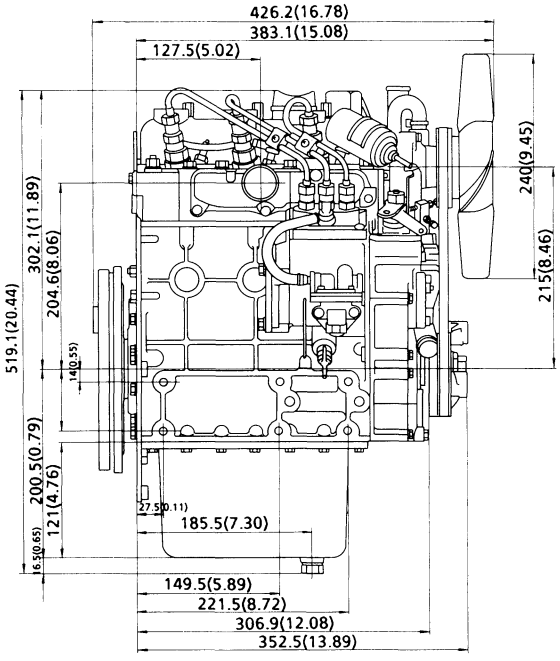

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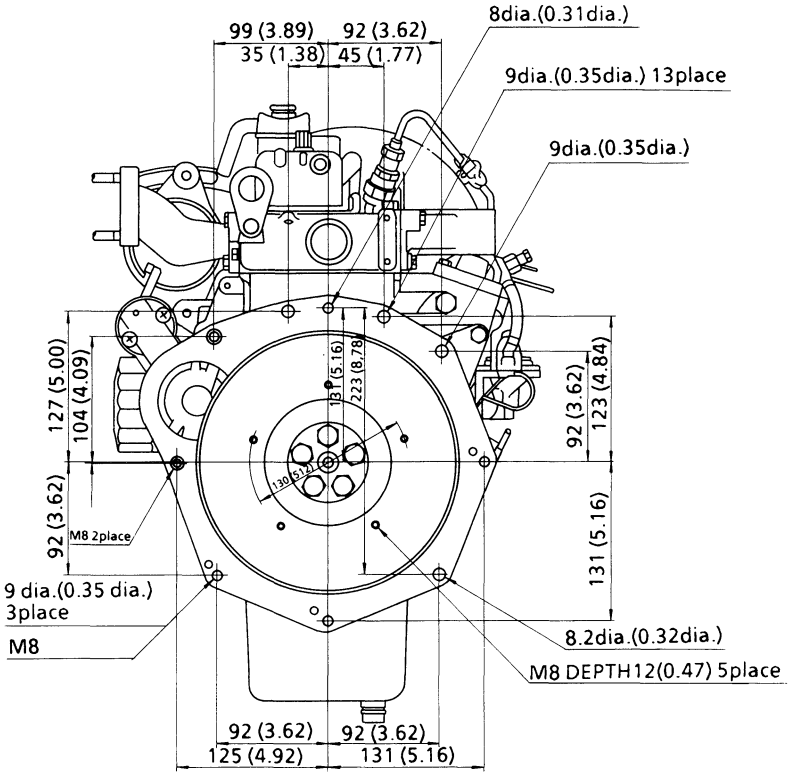
■ Z442-B (E), Z482-B (E)
D662-B (E), D722-B (E)

Unit: mm (in.)

A: 16 dia. (0.63 dia.)
B: 25.4 dia. (1.00 dia.)
C: 12 (0.47)
D: 8 (0.31)



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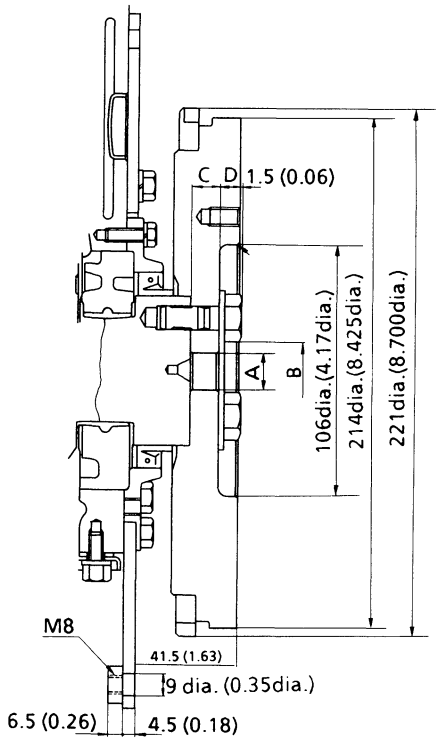

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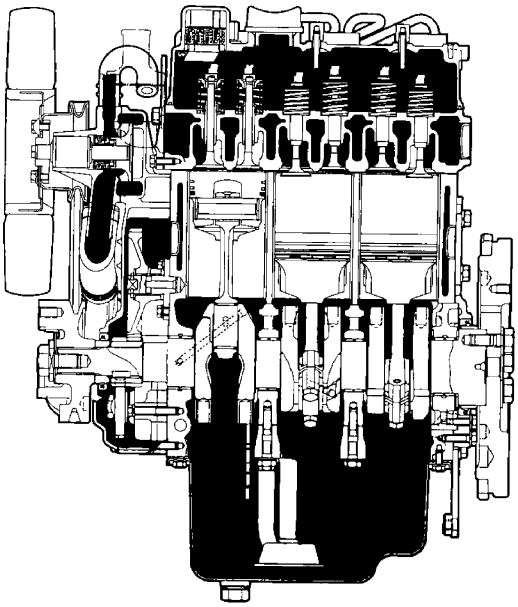
F FEATURE



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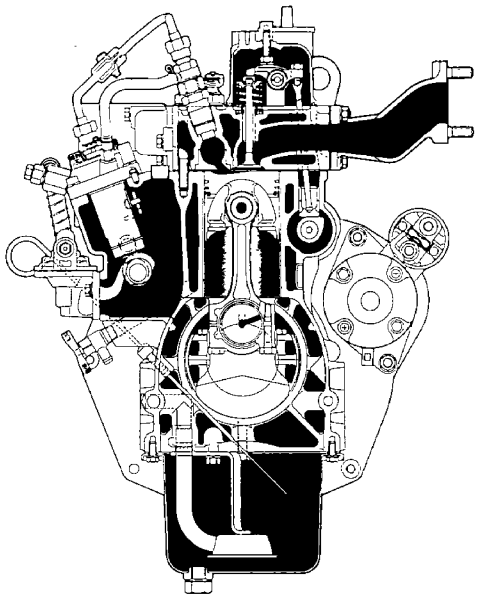

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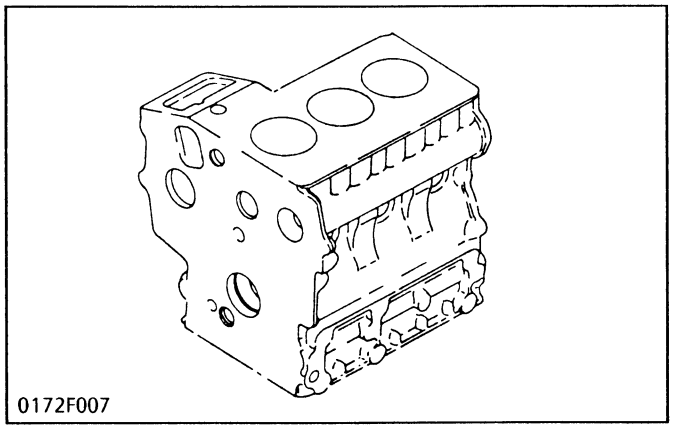
The Z442-B, Z482-B, D662-B, D722-B are vertical, liquid-cooled, 4-cycle diesel engines.
They incorporate KUBOTA's foremost technologies. With KUBOTA's the "NTVCS" (New Three Vortex Combustion System), well-known Bosch MD mini type injection pump and the well-balanced design, they give greater power, low fuel consumption, little vibration and quiet operation.

■ **NOTE**

- **Since January 1994, E-TVCS has been used for the combustion chamber of our products instead of traditional N-TVCS.**
  E-TVCS was developed with an eye toward clean exhaust gas which is more environmentally friendly.
  The combustion chamber models mentioned hereinafter refers to E-TVCS.
  Model of combustion chamber :
  N-TVCS (Engine Serial Number ; 489290 or lower)
  E-TVCS (Engine Serial Number ; 489291 or higher)

1 ENGINE BODY

[1] CYLINDER BLOCK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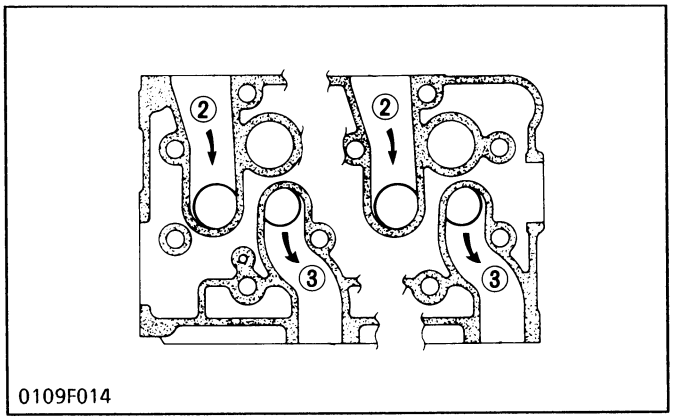
The engine has a high durability tunnel-type cylinder block in which the crank bearing component is a constructed body. Furthermore, liner less type, allow effective cooling, less distortion, and greater wear-resistance. The noise level is reduced to a minimum because each cylinder has its own chamber.

[2] CYLINDER HEAD



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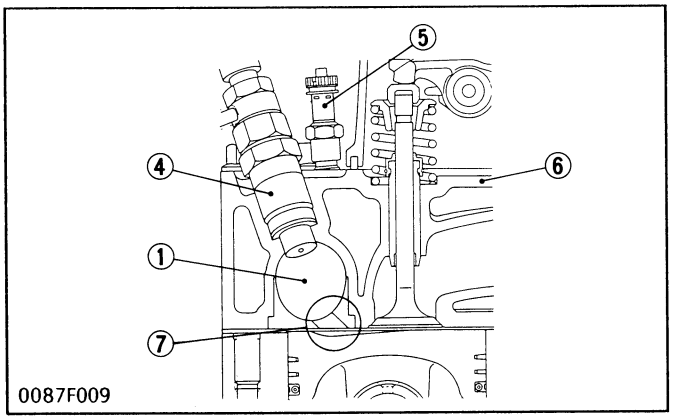

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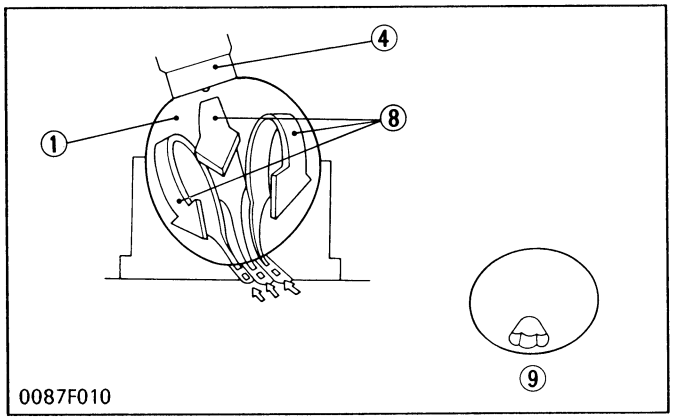


0087F010

The cross-flow type intake/exhaust ports in this engine have their openings at both sides of the cylinder head. Because overlaps of intake/exhaust ports are smaller than in ports of other types which have openings on one side, the suction air can be protected from being heated and expanded by heated exhaust air. The cool, high density suction air has high volume efficiency and raises the power of the engine. Furthermore, distortion of the cylinder head by heated exhaust gas is reduced because intake ports are arranged alternately. The combustion chamber is of KUBOTA's exclusive New TVCS combustion chamber type. Suction air is whirled to be mixed effectively with fuel, prompting combustion and reducing fuel consumption.

In the combustion chamber are installed throttle type injection nozzle and rapid heating sheathed type glow plug. This glow plug assures easier than ever engine starts even at −15°C (5°F).

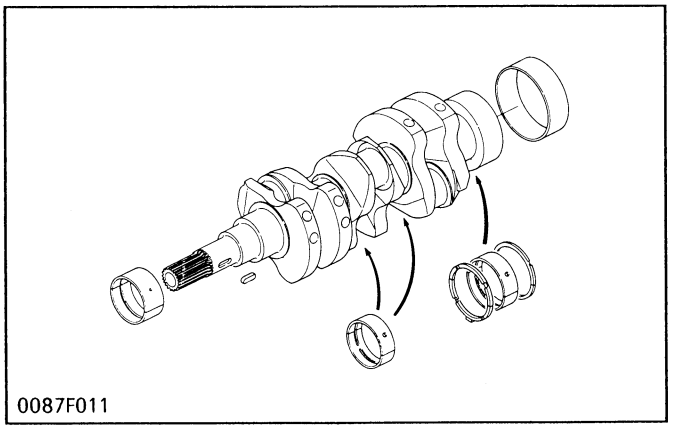
(1) Combustion Chamber
(2) Intake Port
(3) Exhaust Port
(4) Nozzle Assembly
(5) Glow Plug
(6) Cylinder Head
(7) Fan-shaped Concave
(8) Stream
(9) Air Inlet

■ Combustion System

These engine use the "NTVCS" (New Three Vortex Combustion System) to achieve perfect combustion for maximum power. The NTVCS combustion system provides unique shape of throat in the air inlet (9) for combustion chamber, to produce three streams (8) of air in the chamber (1) when compressing, giving an ideal mixture of air and fuel.

In addition, a fan-shaped concave (7) is provided on top of the piston to allow a smooth ejection of the exhaust gas, offering highly efficient combustion.

[3] CRANKSHAFT


0087F011

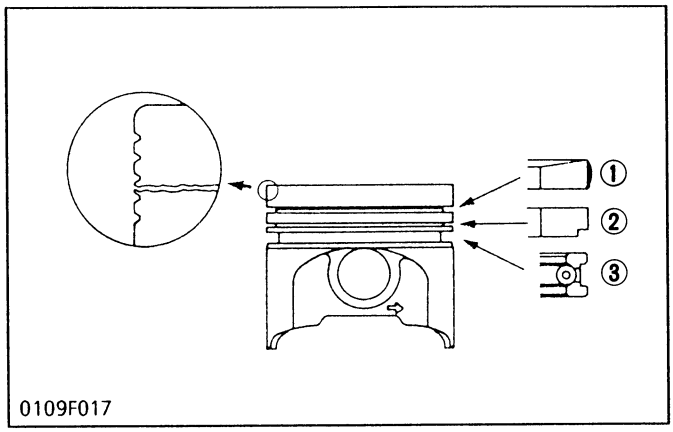
The crankshaft with the connecting rod converts the reciprocating motion of the piston into the rotating motion.

The crankshaft is made of tough special alloy steel, and the journals, pins and oil seal sliding portions are induction hardened to increase the hardness for higher wear resistance.

The front journal is supported by a solid type bearing, the intermediate journal by a split type, and the rear journal by a split type with thrust bearings.

The crankshaft is provided with an oil gallery, through which engine oil is fed to the crank pin portion, and lubricate it.

[4] PISTON AND PISTON RINGS



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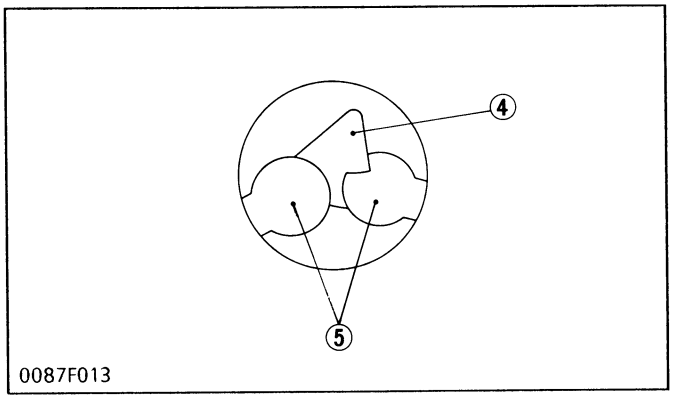

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The piston is made of aluminum alloy.

Two recesses for the valves are provided on top of the piston. A fan-shaped depression is also given atop the piston in order to allow combustion gas to jet smoothly. The piston pin is slightly out of the center of the piston. In this design, the run-out of the piston at the top and bottom dead points can be reduced, thereby resulting in lower operating noise.

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

Three rings are installed in grooves in the piston.

The top ring (1) is a keystone type, which can stand against heavy loads, and the barrel face on the ring fits well to the cylinder wall.

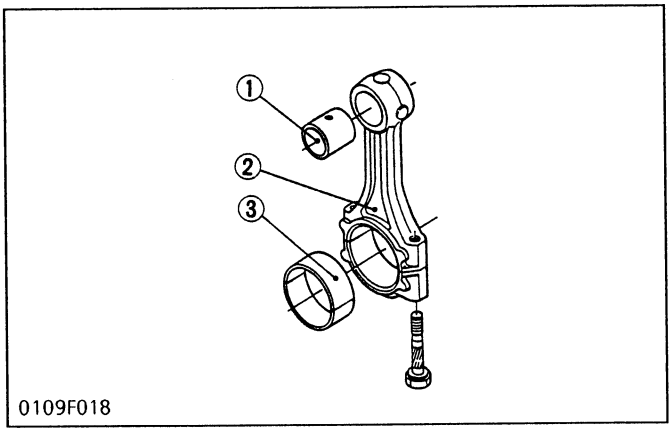
The second ring (2) is an undercut type, which effectively prevents the oil from being carried up.

The oil ring (3) has chamfered contact faces and an expander ring, which increase the pressure of the oil ring against the cylinder wall.

Several grooves are cut on the topland to help heat dissipate and to prevent scuffing.

(1) Top Ring
(2) Second Ring
(3) Oil Ring
(4) Fan-Shaped Concave
(5) Valve Recess

[5] CONNECTING ROD

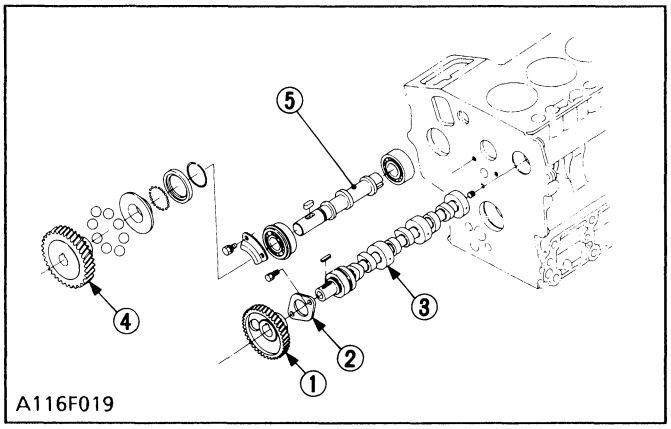


0109F018

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

(1) Small End Bushing
(2) Connecting Rod
(3) Crank pin Bearing

[6] CAMSHAFT

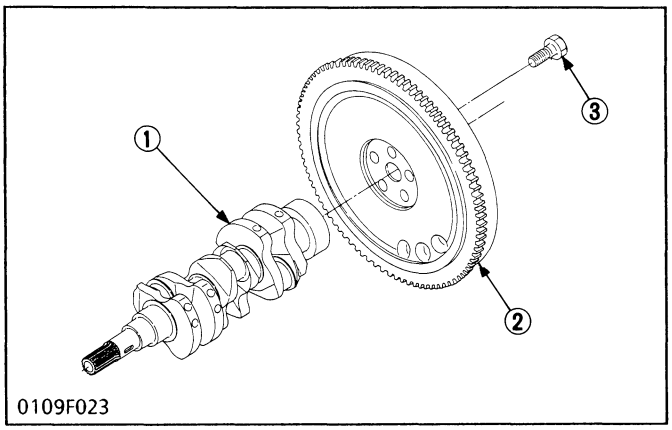


A116F019

The camshaft (3) is made of special cast iron and the journal and cam sections are chilled to resist wear. The journal sections are force-lubricated. The fuel camshaft (5) controls the reciprocating movement of the injection pump. The fuel camshaft is made of carbon steel and the cam sections are quenched and tempered to provide greater wear resistance.

(1) Cam Gear
(2) Camshaft Stopper
(3) Camshaft
(4) Injection Pump Gear
(5) Fuel Camshaft

[7] FLYWHEEL



0109F023

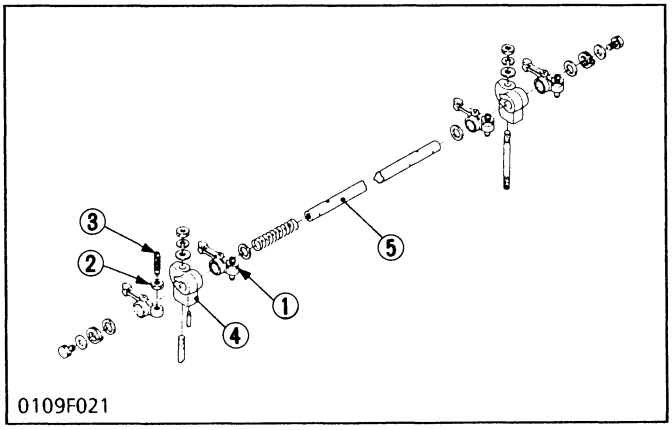
The flywheel stores the rotating force in the combustion stroke as inertial energy, reduces crankshaft rotating speed fluctuation and maintains the smooth rotating conditions.

The flywheel periphery is inscribed with the marks showing top dead center mark **TC**.

The flywheel has gear teeth around its outer rim, which mesh with the drive pinion of the starter.

(1) Crankshaft
(2) Flywheel
(3) Flywheel Screw

[8] ROCKER ARM



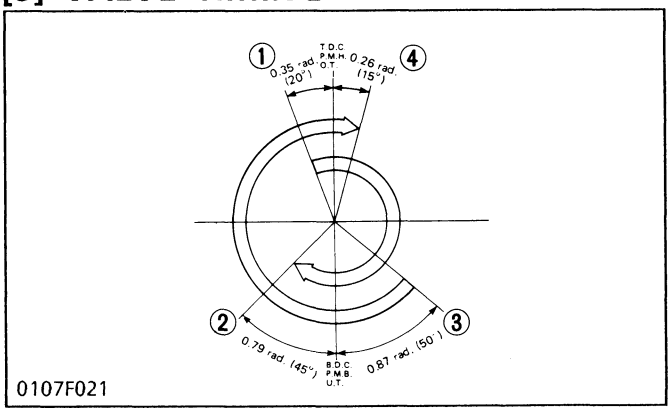
0109F021

The rocker arm assembly includes the rocker arms (1), rocker arm brackets (4) and rocker arm shaft (5) and converts the reciprocating movement of the push rods to an open/close movement of the inlet and exhaust valves.

Lubricating oil is pressurized through the bracket to the rocker arm shaft, which serves as a fulcrum so that the rocker arm and the entire system are lubricated sufficiently.

(1) Rocker Arm
(2) Lock Nut
(3) Adjusting Screw
(4) Rocker Arm Bracket
(5) Rocker Arm Shaft

[9] VALVE TIMING



0107F021

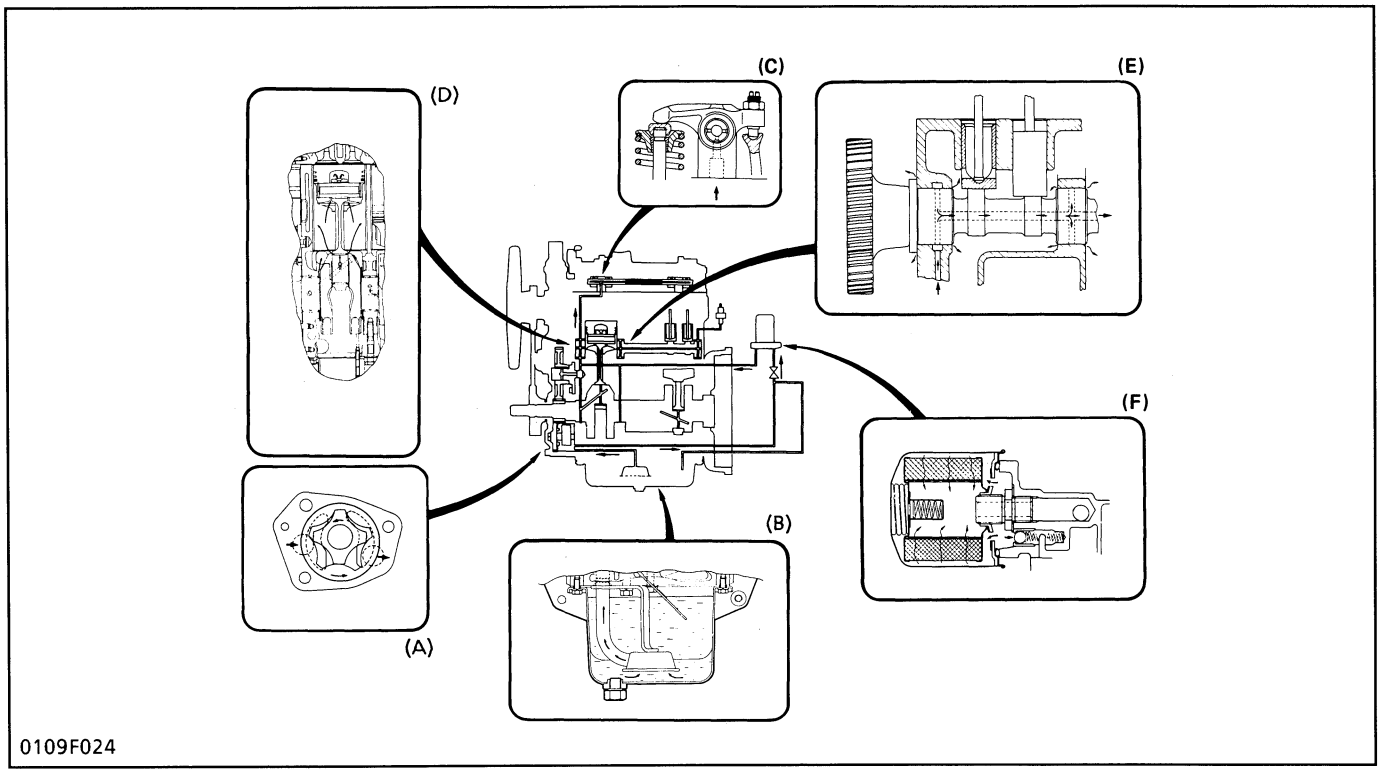
The timing for opening and closing the valve is extremely important to achieve effective air intake and sufficient gas exhaust.

The appropriate timing can be obtained by aligning the marks on the crank gear and the cam gear when assembling.

Inlet valve open ①	0.35 rad. (20°) before T.D.C.
Inlet valve close ②	0.79 rad. (45°) after B.D.C.
Exhaust valve open ③	0.87 rad. (50°) before B.D.C.
Exhaust valve close ④	0.26 rad. (15°) after T.D.C.

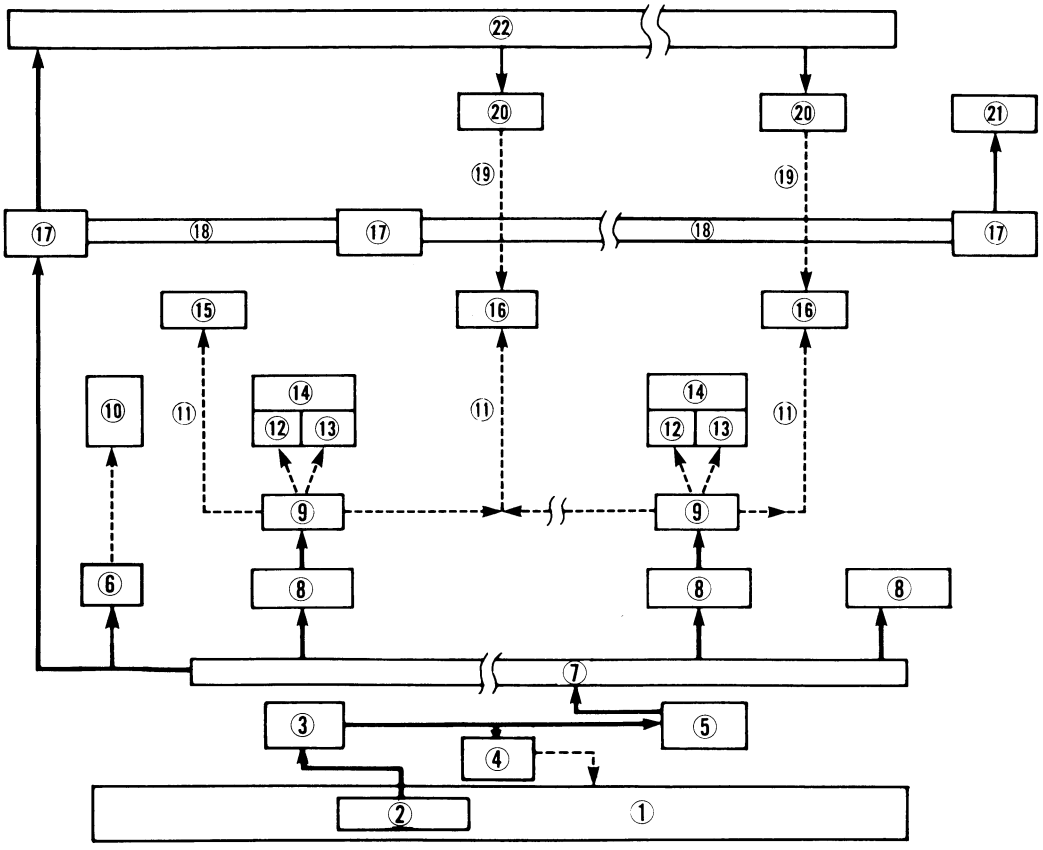
2 LUBRICATING SYSTEM

[1] GENERAL



[A] Oil Pump
[B] Oil Strainer
[C] Rocker Arm and Rocker Arm Shaft
[D] Piston
[E] Camshaft
[F] Oil Filter Cartridge and Relief Valve

This engine's lubricating system consists of oil strainer, oil pump, relief valve, oil filter cartridge and oil switch. The oil pump sucks lubricating oil from the oil pan through the oil strainer and the oil flows down to the filter cartridge, where it is further filtered. Then the oil is forced to crankshaft, connecting rods, idle gear, camshaft and rocker arm shaft to lubricate each part. Some part of oil, splashed by the crankshaft or leaking and dropping from gaps of each part, lubricates these parts: pistons, cylinders, small ends of connecting rods, tappets, pushrods, inlet and exhaust valves and timing gears.

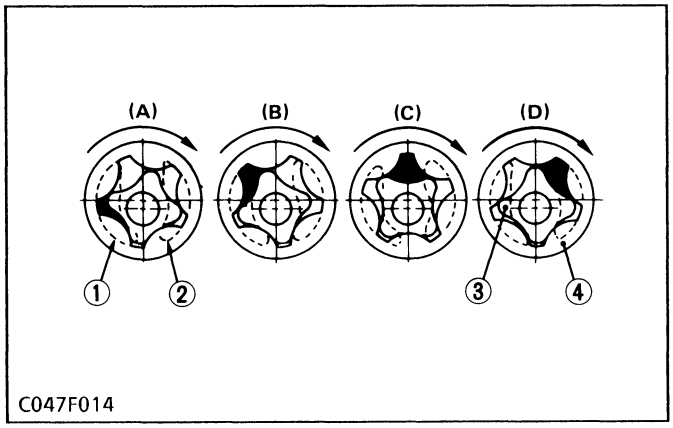


0107F025

Engine Oil Flow

(1) Oil Pan
(2) Oil Strainer
(3) Oil Pump
(4) Relief Valve
(5) Oil Filter Cartridge
(6) Idle Gear
(7) Main Oil Gallery
(8) Main Bearing
(9) Big End
(10) Timing Gear
(11) Splash
(12) Bore
(13) Small End
(14) Piston
(15) Fuel Camshaft
(16) Tappets
(17) Camshaft Bearing
(18) Camshaft
(19) Drain
(20) Rocker Arm
(21) Oil Switch
(22) Rocker Arm Shaft

[2] OIL PUMP



C047F014

(1) Inlet Port
(2) Outlet Port
(3) Inner Rotor
(4) Outer Rotor

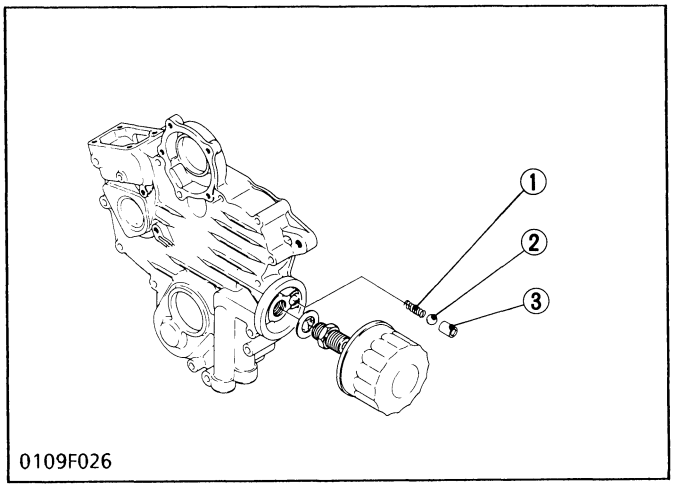
The oil pump is a trochoid pump, whose rotors have trochoid lobes. The inner rotor (3) has 4 lobes and the outer rotor (4) has 5 lobes, and they are eccentrically engaged with each other. The inner rotor, which is driven by the crankshaft through the gears, rotates the outer rotor in the same direction, varying the space between the lobes.

While the rotors rotate from (A) to (B), the space leading to the inlet port increases, which causes the vacuum to suck in the oil from the inlet port.

When the rotors rotate to (C), the space between both rotors switches from the inlet port to the outlet port.

At (D), the space decreases and the sucked oil is discharged from the outlet port.

[3] RELIEF VALVE



0109F026

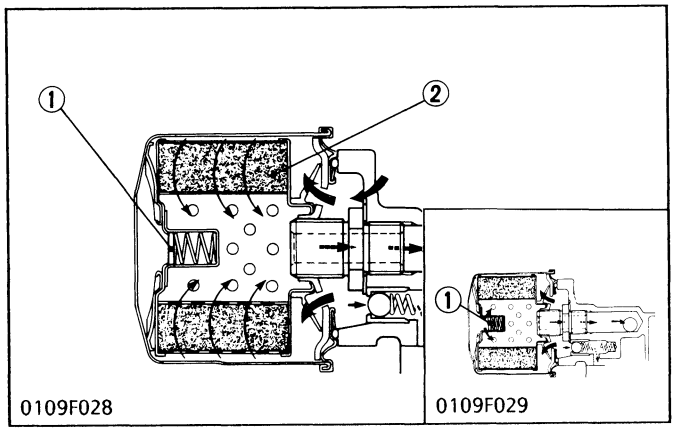
The relief valve prevents the damage to the lubricating system due to the high pressure of the oil.

The relief valve is 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

[4] OIL FILTER CARTRIDGE



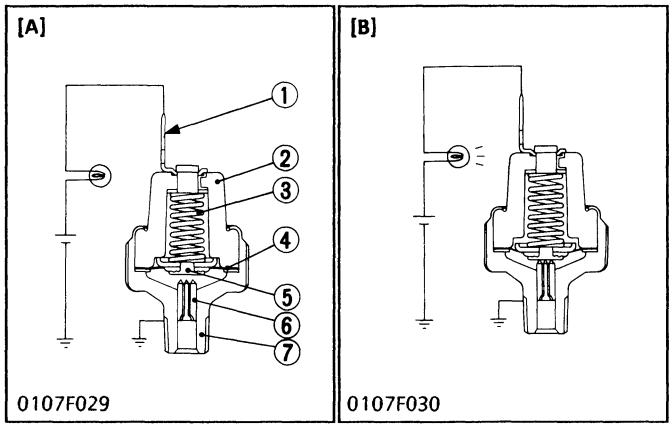
0109F028 0109F029

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

[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.

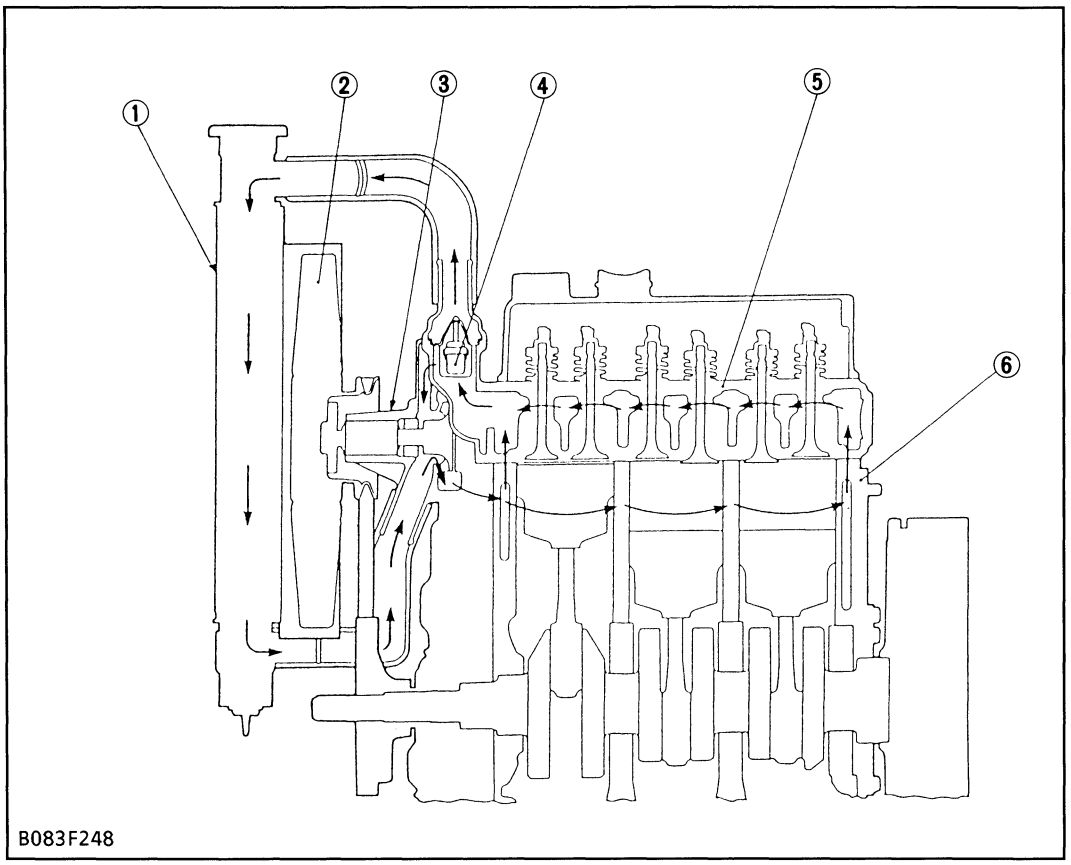
[A] At the proper oil pressure

[B] At lower oil pressure, 49 kPa (0.5 kgf/cm², 7 psi) or less

(1) Terminal
(2) Insulator
(3) Spring
(4) Rubber gasket
(5) Contact rivet
(6) Contact
(7) Oil Switch Body

3 COOLING SYSTEM

[1] GENERAL



B083F248

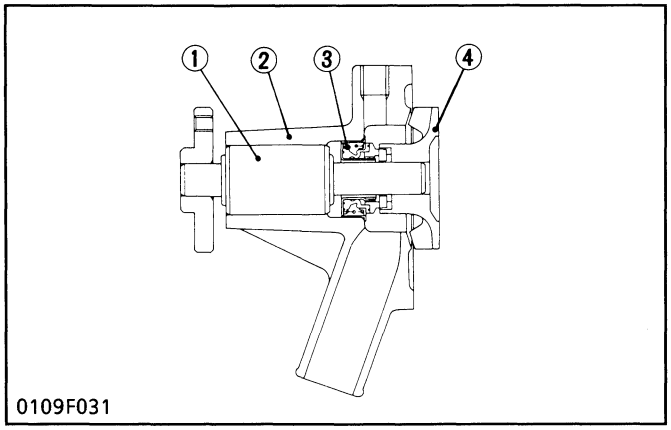
(1) Radiator
(2) Suction Fan
(3) Thermostat
(4) Water Pump
(5) Cylinder Head
(6) Cylinder Block

The cooling system consists of a radiator (1) (not included in the basic engine), centrifugal water pump (4), suction fan (2) and thermostat (3).

The water is cooled through the radiator core, and the fan set behind the radiator pulls cooling air through the core to improve cooling.

The water pump sucks the cooled water, forces it into the cylinder block and draws out the hot water. Then the cooling is repeated. Furthermore, to control temperature of water, a thermostat is provided in the system. When the thermostat opens, the water moves directly to radiator, but when it closes, the water moves toward the water pump through the bypass between thermostat and water pump. The opening temperature of thermostat is approx. 71°C (160°F).

[2] WATER PUMP

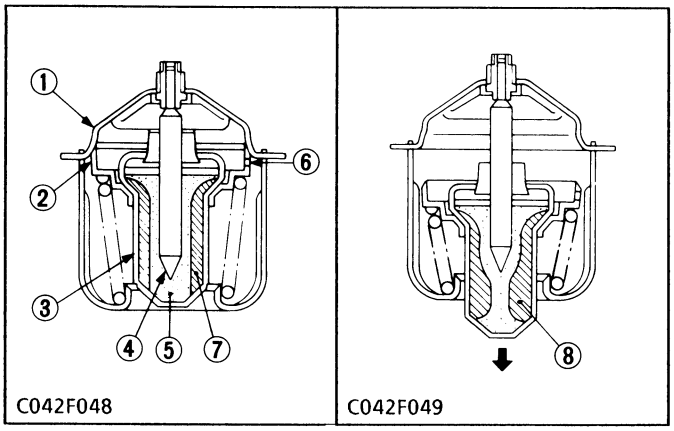


0109F031

The water pump is driven by the crankshaft via a V-belt. Water cooled in the radiator is sucked into the water pump from its lower portion and is sent from the center of the water pump impeller (4) radially outward into the water jacket in the crankcase.

(1) Bearing Unit
(2) Water Pump Body
(3) Mechanical Seal
(4) Water Pump Impeller

[3] THERMOSTAT



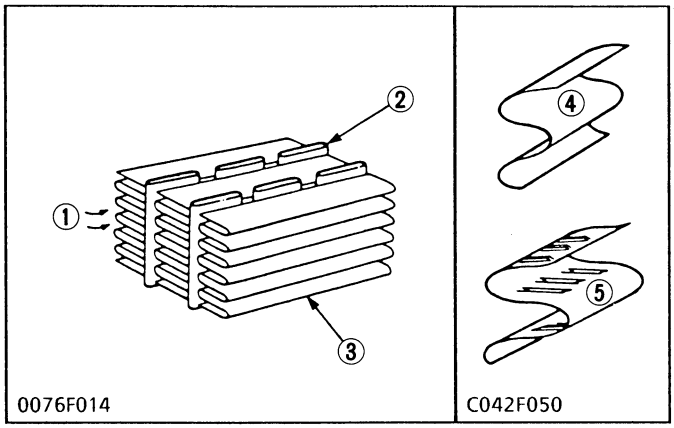
(1) Seat
(2) Valve
(3) Pellet
(4) Spindle
(5) Synthetic Rubber
(6) Leak Hole
(7) Wax (solid)
(8) Wax (liquid)

The thermostat maintains the cooling water at correct temperature. KUBOTA's engine uses a wax pellet type thermostat. Wax is enclosed in the pellet. The wax is solid at low temperatures, but turns liquid at high temperatures, expands and opens the valve.

(A) At low temperatures (lower than 71°C (160°F)). As the thermostat is closed, cooling water circulates in the engine through the water return pipe without running to the radiator. Air in the water jacket escapes to the radiator side through leak hole (6) of the thermostat.

(B) At high temperatures (higher than 71°C (160°F)). When the temperature of cooling water exceeds 71°C (160°F), wax in the pellet turns liquid and expands. Because the spindle (4) is fixed, the pellet (3) is lowered, the valve (2) is separated from the seat (1), and then cooling water is sent to the radiator.

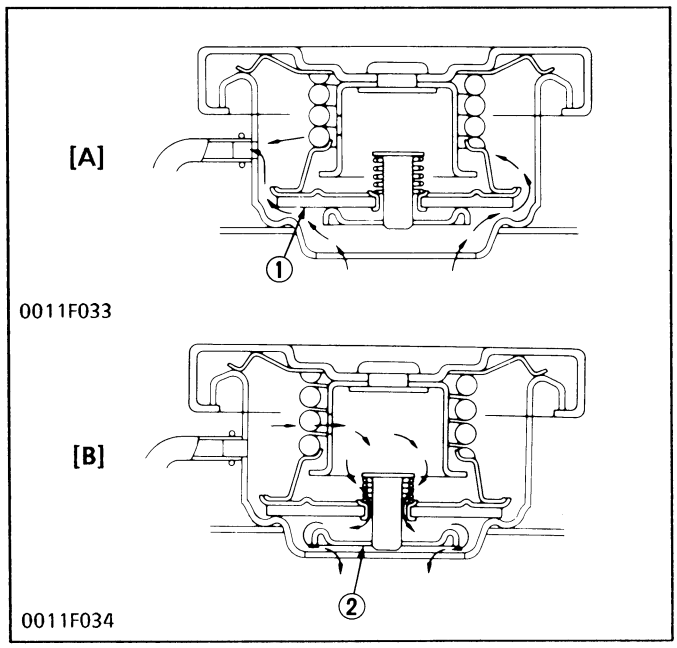
[4] RADIATOR (not included in the basic engine)



The radiator core consists of water carrying tubes and fins (3) at a right angle to the tubes (2). Heat of hot water in the tubes is radiated from the tube walls and fins. KUBOTA's engine uses corrugated fin type core which has a light weight and high heat transfer rate. Clogging is minimized by the louverless corrugated fins.

(1) Cooling Air
(2) Tube
(3) Fin
(4) Louverless Corrugated Fin
(5) Louvered Corrugated Fin

[5] RADIATOR CAP



The radiator cap is for sustaining the internal pressure of the cooling system at the specified level 88 kPa (0.9 kgf/cm^2, 13 psi) when the engine is in operation. The cap consists of a pressure valve (1) a vacuum valve (2), valve springs, gasket, etc.

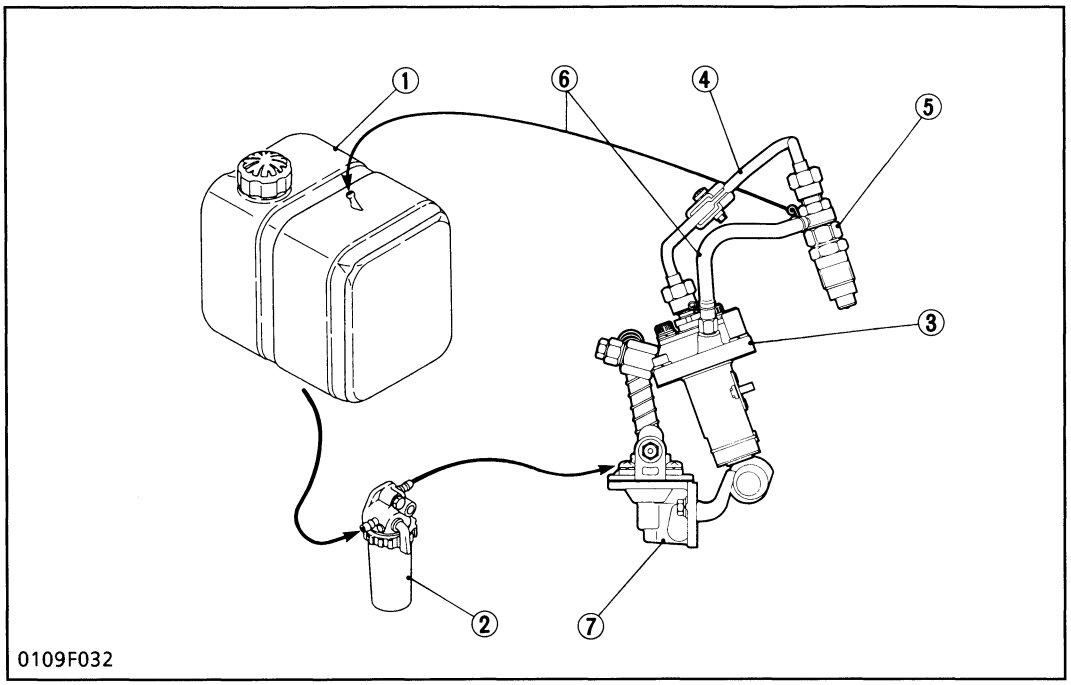
Cooling water is pressurized by thermal expansion of steam, and as its boiling temperature rises, generation of air bubbles will be suppressed. (Air bubbles in cooling water lowers the cooling effect.)

[A] When radiator internal pressure is high
[B] When radiator internal pressure is negative

(1) Pressure Valve
(2) Vacuum Valve

4 FUEL SYSTEM

[1] GENERAL



0109F032

*(1) Fuel Tank
(2) Fuel Filter
(3) Injection Pump
(4) Injection Pipe
(5) Injection Nozzle
(6) Fuel Overflow Pipe
**(7) Fuel Feed Pump

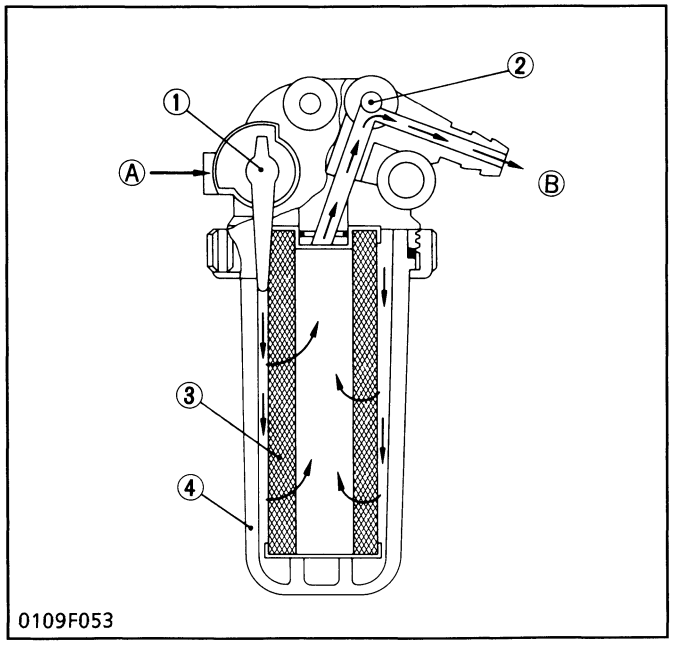
Fuel from the fuel tank (1) passes through the fuel filter (2), and then enters the injection pump (3) after impurities such as dirt, water, etc. are removed.

The fuel pressurized by the injection pump to the opening pressure (13.73 to 14.71 MPa, 140 to 150 kgf/cm^2, 1991 to 2062 psi), of the injection nozzle (5) is injected into the combustion chamber.

Part of the fuel fed to the injection nozzle (5) lubricates the moving parts of the plunger inside the nozzle, then returns to the fuel tank through the fuel overflow pipe (6) from the upper part of the nozzle holder.

■ **NOTE**
- **Component marked * is not included in the basic model.**
- **Component marked ** is included only in the basic model.**

[2] FUEL FILTER (not included in the basic model)



0109F053

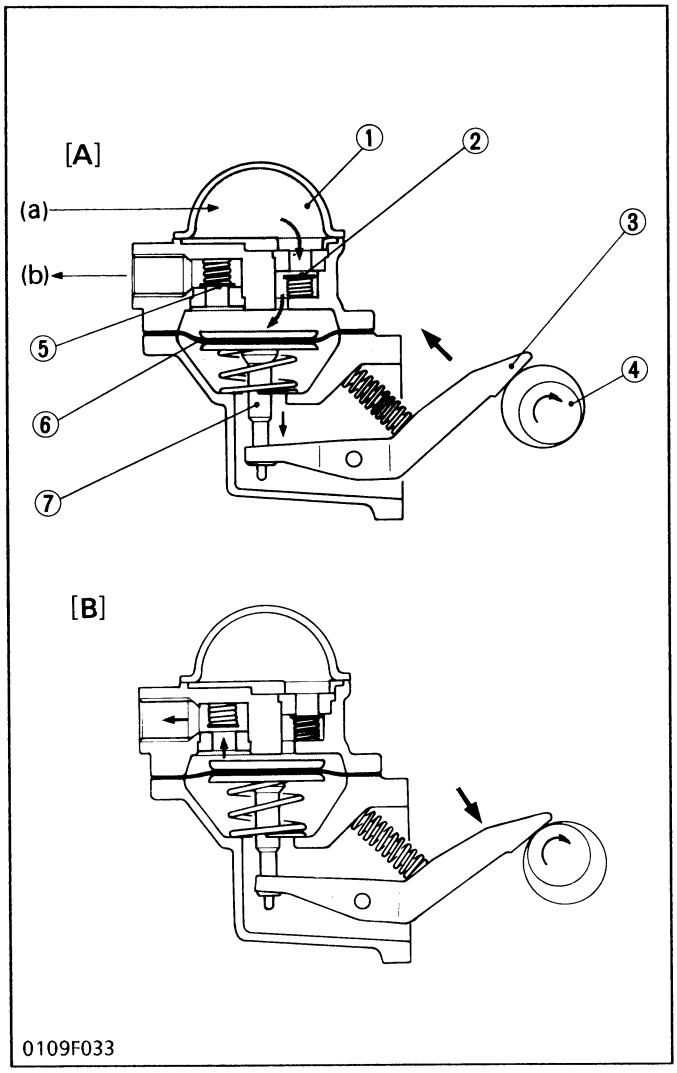
Each moving part of the injection pump and nozzle is extremely precision machined, and clearances of their sliding parts are extremely small. Fuel itself serves as lubricating oil. For this reason, it is extremely important to completely remove water and dirt contained in fuel.

This fuel filter, which uses very fine filter paper, serves to separate and filter dirt in fuel and water accumulated in the tank.

Air vent plug is fitted to the cock body. Before starting or after disassembling and reassembling, loosen this plug and bleed the air in the fuel system.

(A) Inlet
(B) Outlet
(1) Fuel Cock
(2) Air Vent Plug
(3) Filter Element
(4) Filter Cup

[3] FUEL FEED PUMP



The filtered fuel is fed to the injection pump by the fuel fed pump.

The chamber (1) is enclosed with the inlet valve (2), the outlet valve (5) and the diaphragm (6), which is linked to the rocker arm with the pull rod (7). The rocker arm is swinged by the eccentric cam on the fuel camshaft (4).

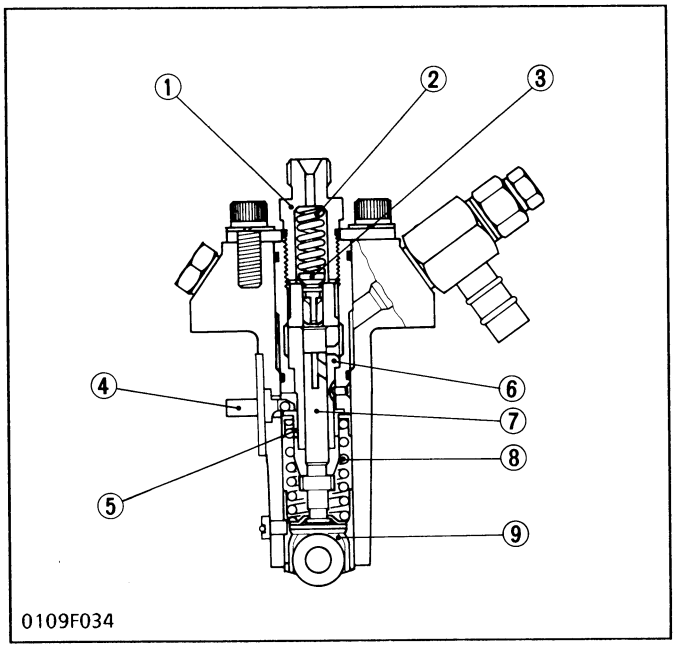
When the diaphgram is pulled down, vaccum in the chamber (1) causes the outlet valve (5) to close and the atomospheric pressure in the fuel tank to force the fuel into the chamber, opening the inlet valve (2).

When the diaphragm is pushed up by the cam, the pressure in the chamber causes the inlet valve to close and forces out the fuel, opening the outlet valve.

(A) Inlet Stroke
(a) from fuel filter
(1) Chamber
(2) Inlet Valve
(3) Rocker Arm
(4) Fuel Camshaft

(B) Discharge Stroke
(b) to injection pump
(5) Outlet Valve
(6) Diaphragm
(7) Pull Rod

[4] INJECTION PUMP

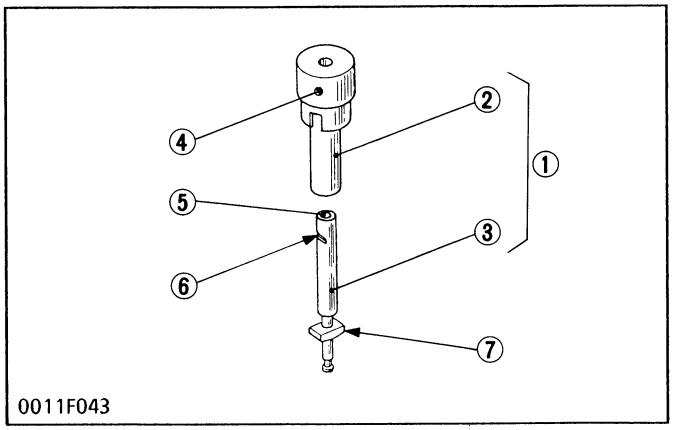


A Bosch MD type mini pump is used for the injection pump. It is small, lightweight and easy to handle.

The plunger (7) with a right-hand lead reciprocates via the tappet roller (9) by means of the camshaft fuel cam, causing the fuel to be delivered into the injection nozzle.

(1) Delivery Valve Holder
(2) Delivery Valve Spring
(3) Delivery Valve
(4) Control Rod
(5) Control Sleeve
(6) Cylinder
(7) Plunger
(8) Plunger Spring
(9) Tappet

(1) Pump Element



0011F043

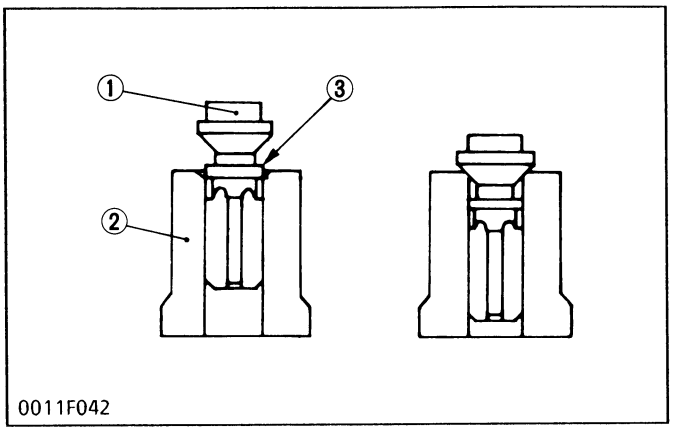
The pump element (1) is consist of the plunger (3) and cylinder (2).

The sliding surfaces are super-precision machined to maintain injection pressure at engine low speeds. Since the driving face (7) fits in the control sleeve, the plunger (3) is rotated by the movement of the control rack to increase or decrease of fuel delivery.

As described above, the plunger (3) is machined to have the slot (5) and the control groove (6).

(1) Pump Element
(2) Cylinder
(3) Plunger
(4) Feed Hole
(5) Slot
(6) Control Groove
(7) Driving Face

(2) Delivery Valve



0011F042

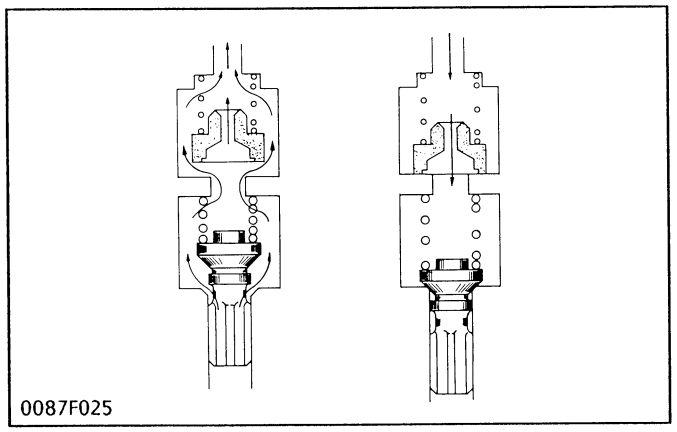
The delivery valve consists of the valve (1) and the Valve seat (2).

The delivery valve prevents the fuel from flowing back into the delivery chamber through the injection pipe. It also prevents the fuel from dribbling at the injection nozzle.

When the delivery stroke ends the relief plunger moves into the bore of the valve seat and seals the delivery line from the delivery chamber. The relief plunger lowers further until the valve seats suck back the fuel to prevent dribbling at the injection nozzle.

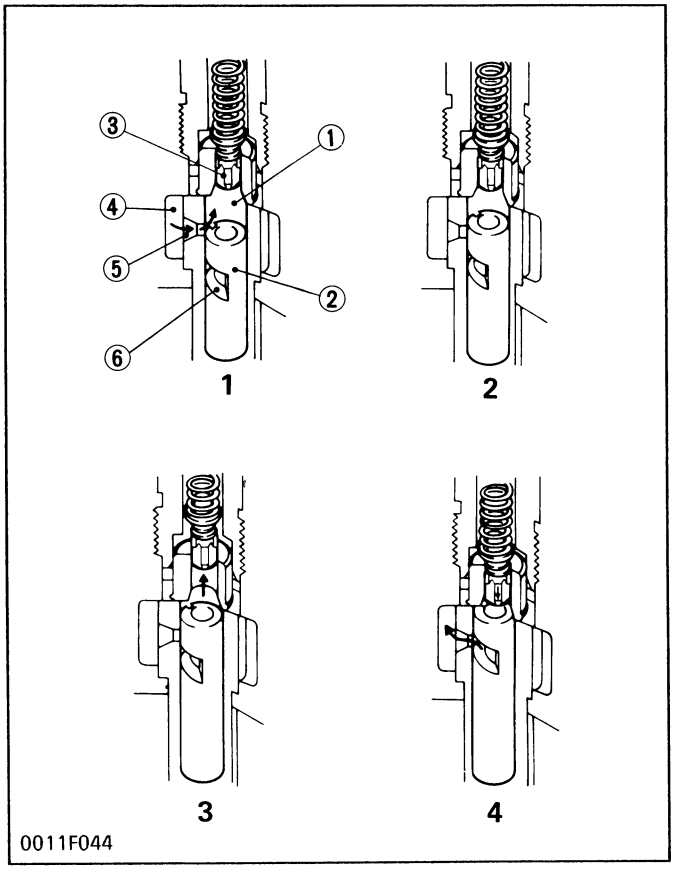
(1) Valve
(2) Valve Seat
(3) Relief Plunger

(3) Dumping Valve


0087F025

1. **At fuel injection**
   Since dumping valve is pushed up to press the spring, fuel is pressure-fed to injection nozzle the same as without dumping valve.
2. **At suck-back**
   At suck-back by delivery valve after fuel injection fuel returns through dumping valve orifice Generally second injection is apt to occur by reflex pressure due to reaction of sudden pressure drop when changing into suck-back by delivery valve from high injection pressure. As a result of preventing this second injection perfectly by dumping valve and dissolving nozzle clogging, durability of injection nozzle is improved.

(4) Operation of Pump Element



1. Before delivery
As the tappet lowers, the plunger (2) also lowers and fuel is drawn into the delivery chamber (1) through the feed hole (5) from the fuel chamber (4).

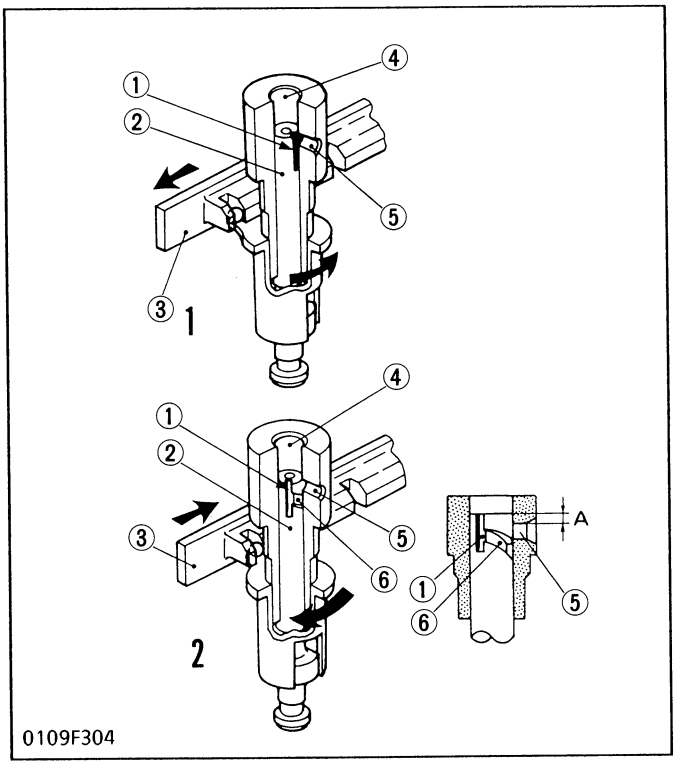
2. Beginning of delivery
When the plunger is pushed up by the cam and the head of the plunger closes the feed hole, the pressure in the delivery chamber rises to push the relief plunger (3) open.
Fuel is then force-fed into the injection pipe.

3. Delivery
While the plunger is rising, the delivery of fuel continues.

4. End of delivery
When the plunger rises further and the control groove (6) on its periphery meets the feed hole,the fuel returns to the fuel chamber from the delivery chamber through the control groove and the feed hole.

(1) Delivery Chamber
(2) Plunger
(3) Relief Plunger
(4) Fuel Chamber
(5) Feed Hole
(6) Control Groove

(5) Injection Control

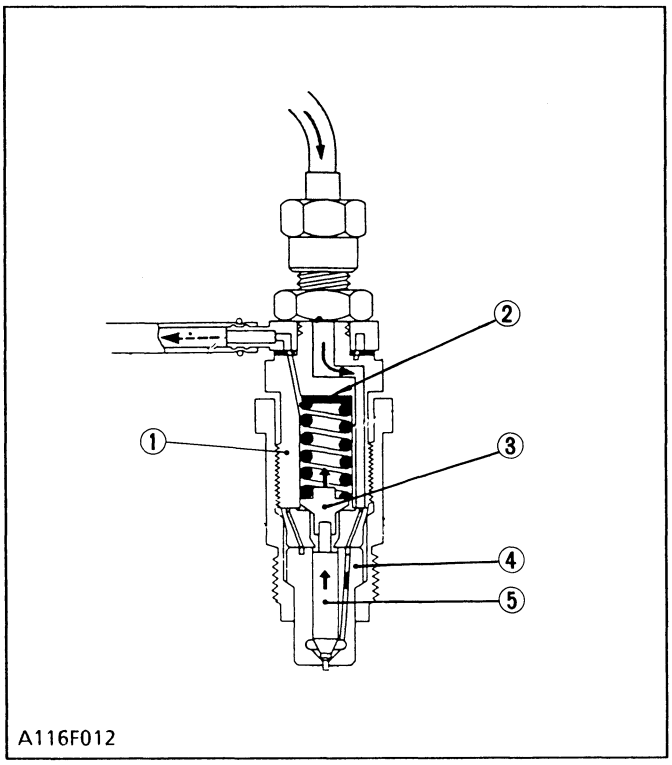


1. No fuel delivery
At the engine stop position of the control rod (3), the lengthwise slot (1) on the plunger (2) aligns with the feed hole (5). And the delivery chamber (4) is led to the feed hole during the entire stroke of the plunger.
The pressure in the delivery chamber does not build up and no fuel can be forced to the injection nozzle.

2. Fuel delivery
The plunger (2) is rotated (See figure) by the control rod (3). When the plunger is pushed up, the hole (5) is closed. The pressure in the delivery chamber (4) builds up and forcefeeds the fuel to the injection nozzle until the control groove (6) meets the feed hole (5).
The amount of the fuel corresponds to the distance "**A**".

(1) Slot
(2) Plunger
(3) Control Rod
(4) Delivery Chamber
(5) Feed Hole
(6) Control Groove

[5] INJECTION NOZZLE



A116F012

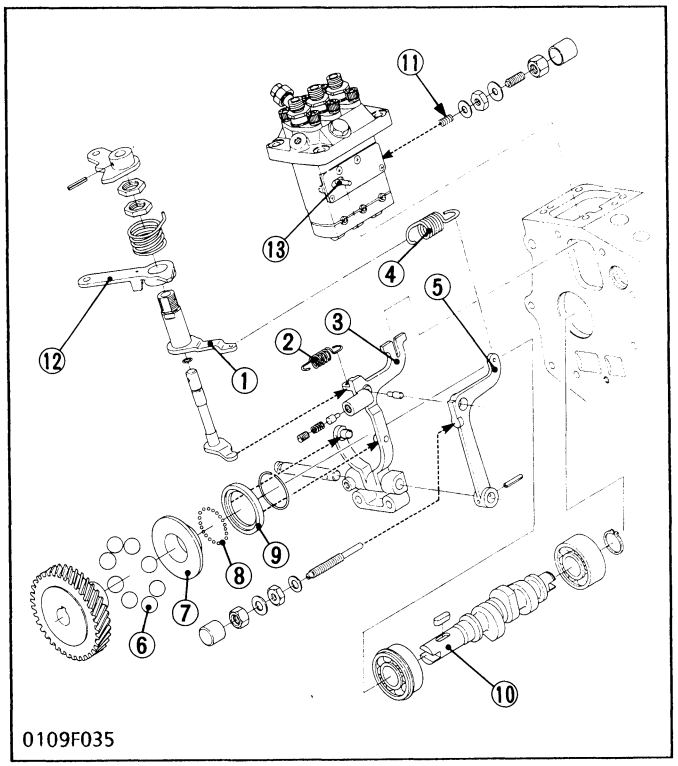
This nozzle is throttle-type. The needle valve (5) is pushed against the nozzle body (4) by the nozzle spring via the push rod (3). Fuel pressurized by the injection pump pushes the needle valve up and then is injected into the sub-combustion chamber.

Excessive flow passes from nozzle holder center through the eye joint and the fuel overflow pipe to the fuel tank.

The injection pressure is 13.73 to 14.71 MPa (140 to 150 kgf/cm^2, 1991 to 2133 psi), and is adjusted with adjusting washers (2).

(1) Nozzle Holder Body
(2) Adjusting Washer
(3) Push Rod
(4) Nozzle Body
(5) Needle Valve

[6] GOVERNOR



0109F035

(1) Governor Lever
(2) Start Spring
(3) Fork Lever 1
(4) Governor Spring
(5) Fork Lever 2
(6) Steel Ball
(7) Governor Sleeve
(8) Steel Ball
(9) Governor Ball Case
(10) Fuel Camshaft
(11) Idling Ajust Spring
(12) Speed Control Lever
(13) Control Rod

The governor controls the amount of the fuel to be fed in the entire speed range to prevent the engine from changing its speed according to the load.

The fork lever 1 (3) is held where two forces on it are balanced. One is the force that fork lever 2 pushes, which is caused by the tension of the governor spring (4) between the governor lever (1) and fork lever 2 (5). Another is the component of the centrifugal force produced by the steel balls (6) which are rotated by the fuel camshaft (10).

■ At start

The steel ball (6) has no centrifugal force.

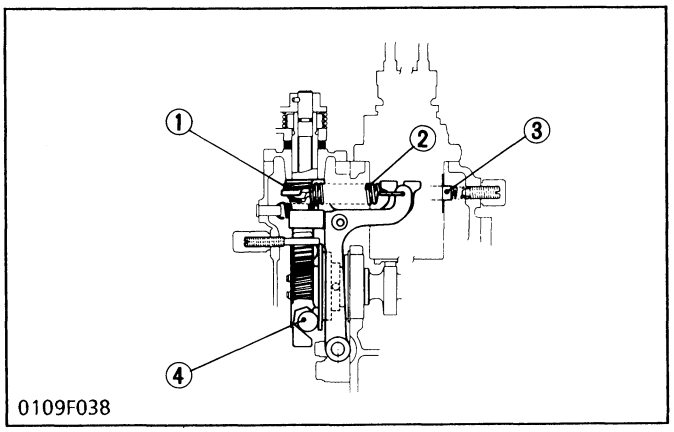
Fork lever 1 (3) is pulled by the start spring (2) and the control rod (13) moves to the maximum injection position for easy starting.

■ At idling

When the speed control lever (12) is set at the idling position, the governor spring (4) is pulled slightly.

As the camshaft rotates, the steel ball (6) increase their centrifugal force and push the governor sleeve (7). Fork lever 1 (3) pushed by the governor sleeve, pushes the control rod (13) and the control rod compresses the idling adjust spring (11).

The control rod is kept at a position where the centrifugal force is balanced with the spring tensions on the control rod, providing stable idling.



0109F038

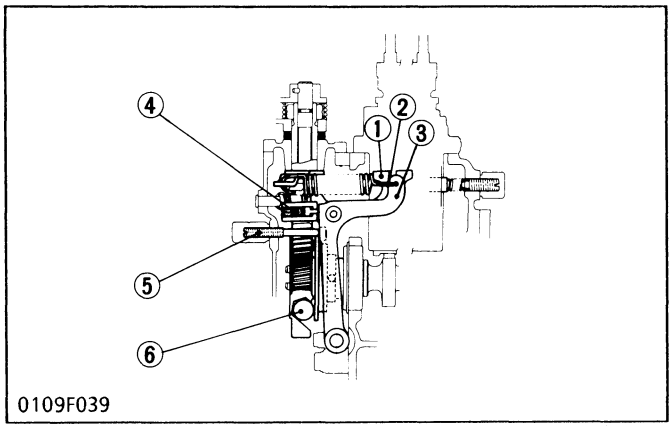
■ **At medium or high speed running**

When the speed control lever (1) is turned further, the governor spring (2) increases the tension and the control rod (3) is pulled to increase the engine speed.

The steel ball (4) increase their centrifugal force and the control rod is pushed, decreasing the engine speed, until the centrifugal force and the spring tension are balanced.

When the engine speed is dropped (A→B) with the increase of the load (a→b), the centrifugal force of the steel ball decreases and the control rod is pulled. The amount of the fuel to the injection nozzle is increased to produce a higher engine torque required for the load.

(1) Speed Control Lever
(2) Governor Spring
(3) Control rod
(4) Steel Ball



0109F039

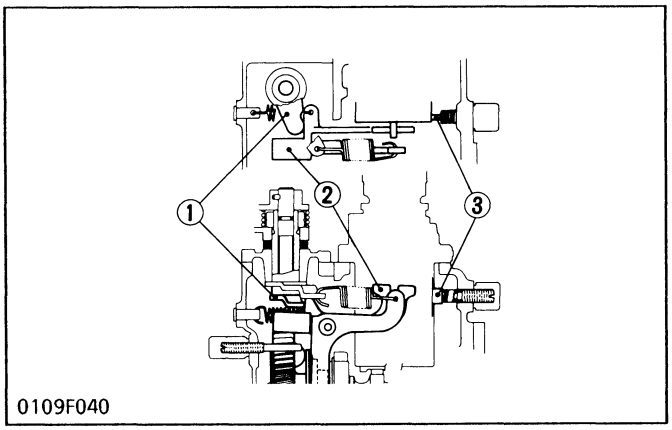
■ **At maximum speed running with an overload**

When the engine is overloaded at the high speeds and the engine speed drops, the centrifugal force of the steel ball (6) decreases and the governor spring (2) pulls fork lever 1 (1) and 2 (3).

When fork lever 2 contacts the adjusting screw (5), the spring (4) which is built in fork lever 1 begins to push the fork lever 1 to pull the control rod.

The fuel to the injection nozzle is increased to run the engine at high speed and torque.

(1) Fork Lever 1
(2) Governor Spring
(3) Fork Lever 2
(4) Spring
(5) Adjusting Screw
(6) Steel Ball



0109F040

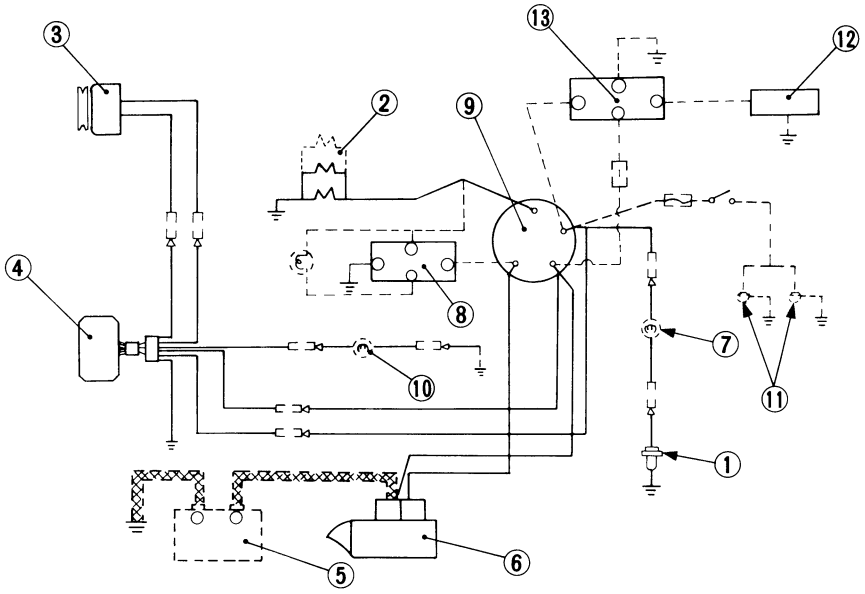
■ **To stop the engine**

When the stop lever (1) is moved to the stop position, fork lever 1 (2) is pushed and the control rod (3) is moved to stop the fuel injection.

(1) Stop Lever
(2) Fork Lever 1
(3) Control Rod

5 ELECTRICAL SYSTEM

Z442-B·Z482-B·D662-B·D722-B



A116P013

The electrical system of the engine consists of a starting system (including a starter, glow plugs and others), a charging system (including an AC dynamo, a regulator and others), a battery and an oil switch.

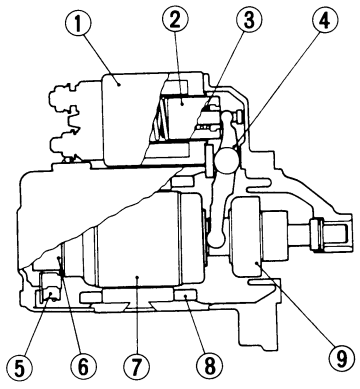
■ **NOTE**

- **Components marked * are not included in the basic model.**

(1) Oil Pressure Switch
(2) Glow Plug
(3) AC Dynamo
(4) Regulator
*(5) Battery
(6) Starter
*(7) Oil Lamp
*(8) Lamp Timer
*(9) Key Switch
*(10) Charge Lamp
*(11) Light
*(12) Solenoid
*(13) Timer

[1] STARTING SYSTEM

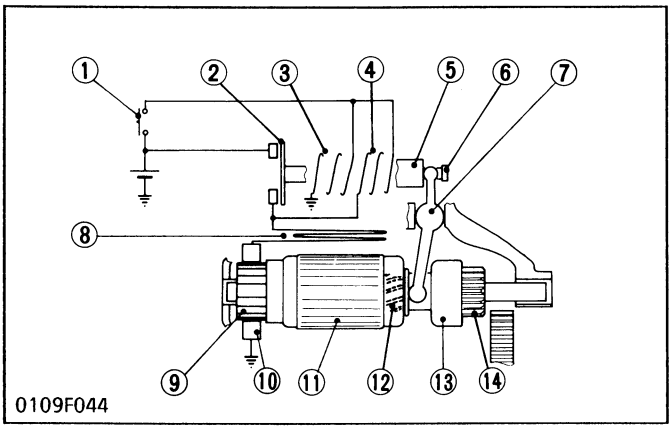
(1) Starter



0109F043

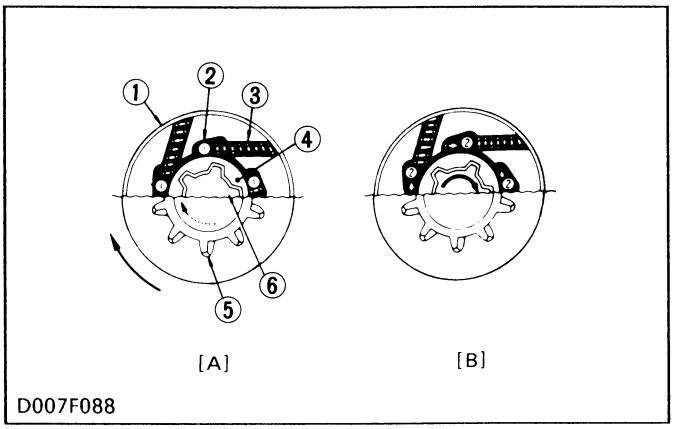
The starter is of the electromagnetic drive type.
It is composed of a starting motor and a solenoid switch.

(1) Solenoid Switch
(2) Plunger
(3) Spring
(4) Shift Lever
(5) Brush
(6) Commutator
(7) Armature
(8) Field Coil
(9) Overrunning Clutch



1. Schematic Circuit

(1) Key Switch
(2) Solenoid Switch
(3) Holding Coil
(4) Pull-in Coil
(5) Plunger
(6) Rod
(7) Shift Lever
(8) Field Coil
(9) Commutator
(10) Brush
(11) Armature
(12) Spiral Spline
(13) Overrunning Clutch
(14) Pinion



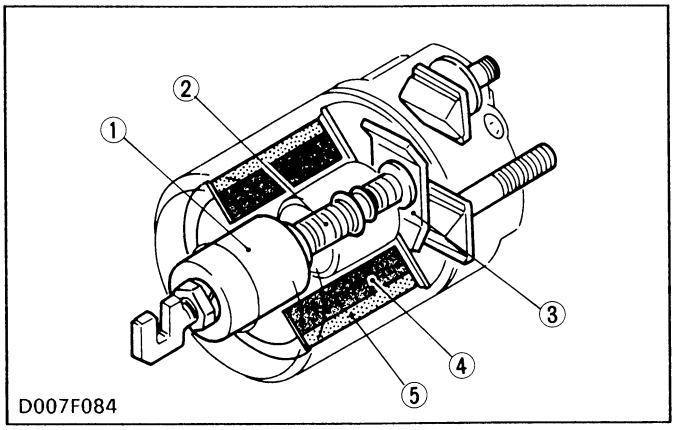
2. Overrunning Clutch

The overrunning clutch is so constructed that the power transmission relationship is automatically severed when the clutch pinion shaft (6) speed exceeds the clutch gear outer (1) speed at increased engine speeds. Therefore, the armature drives the ring gear and is never driven by the engine.

[A] When power is transmitted

[B] Idling rotation with clutch pinion shaft speed exceed that of clutch gear outer

(1) Clutch Gear outer
(2) Roller
(3) Roller Spring
(4) Spline Tube Inner
(5) Pinion Gear
(6) Clutch Pinion Shaft

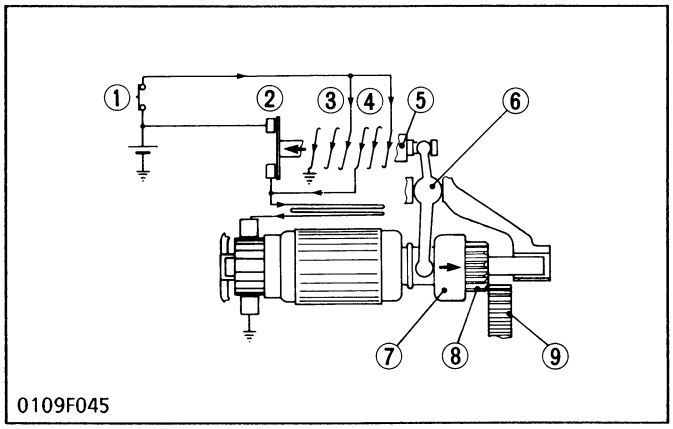


3. Solenoid Switch

The solenoid switch forces out the pinion for engaging with the ring gear, and operates as a relay to drive the armature.

It consists of a pull-in coil, a holding coil and a plunger.

(1) Plunger
(2) Spring
(3) Contact Plate
(4) Pull-in Coil
(5) Holding Coil



0109F045

4. Operating of Starter

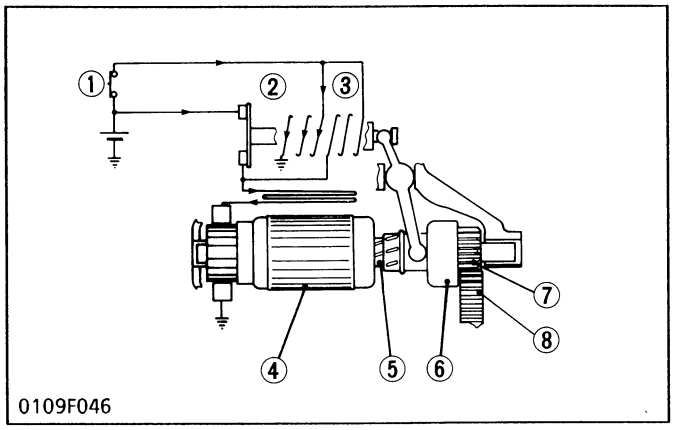
■ When Main Switch Is Turned to "START" Position

The contacts of main switch (1) close and the holding coil (3) is connected to the battery to pull the plunger (5).

The pull-in coil (4) and the starting motor are also connected to the battery.

The pinion (8) is pushed against the ring gear (9) with the overrunning clutch (7) by the drive lever (6) and the solenoid switch (2) is closed.

(1) Main Switch
(2) Solenoid Switch
(3) Holding Coil
(4) Pull-in Coil
(5) Plunger
(6) Drive Lever
(7) Overrunning Clutch
(8) Pinion
(9) Ring Gear



0109F046

■ When Solenoid Switch Is Closed

The current from the battery flows through the solenoid switch (2) to the starting motor.

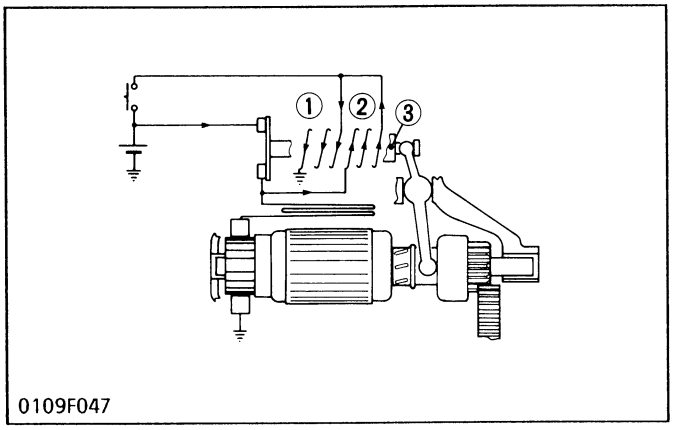
The pinion (7), which is pushed against the ring gear (8) and rotated along the spline (5), meshes with the ring gear to crank the engine.

The engine starts and increases its speed.

While the pinion spins faster than the armature, the overrunning clutch (6) allows the pinion to spin independently from the armature.

The pull-in coil (3) is short-circuited through the solenoid switch (2) and the main switch (1).

(1) Main Switch
(2) Solenoid Switch
(3) Pull-in Coil
(4) Armature
(5) Spiral Spline
(6) Overrunning Clutch
(7) Pinion
(8) Ring Gear



0109F047

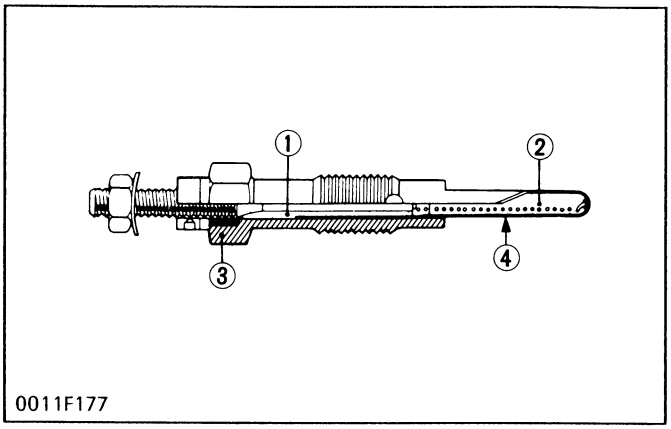
■ When Main Switch Is Released

The current from the battery flows to the holding coil (1) through the pull-in coil (2) to diminish the magnetism between them.

The plunger (3) is pushed by the spring to pull in the pinion.

(1) Holding Coil
(2) Pull-in Coil
(3) Plunger

(2) Glow Plug

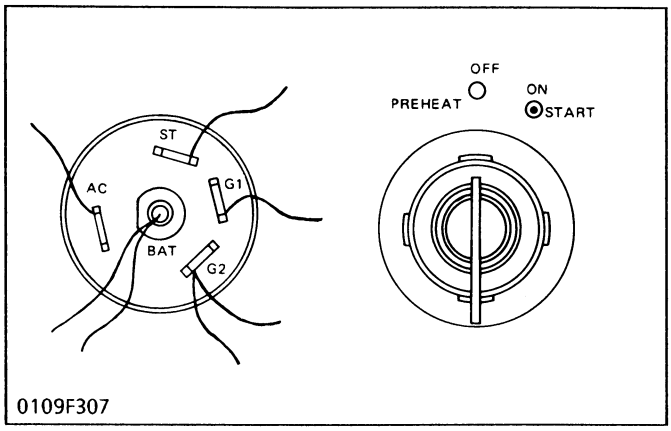


0011F177

Each sub-combustion chamber has a glow plug for easy starting. The glow plug is of the quick-heating type.

(1) Insulating Powder
(2) Metal Tube
(3) Housing
(4) Heat Coil

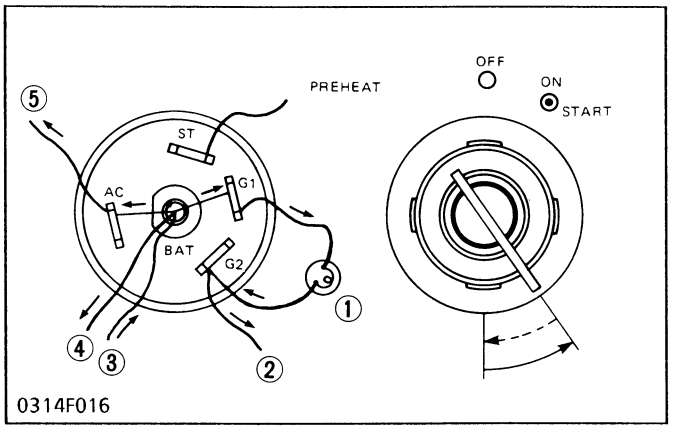
(3) Key Switch (not included in the basic model)



0109F307

The key switch has 4 positions. The terminal "BAT" is connected to the battery.

The key released at the "PREHEAT" position returns to the "OFF" position. And it released at the "START" position returns to the "ON" position.

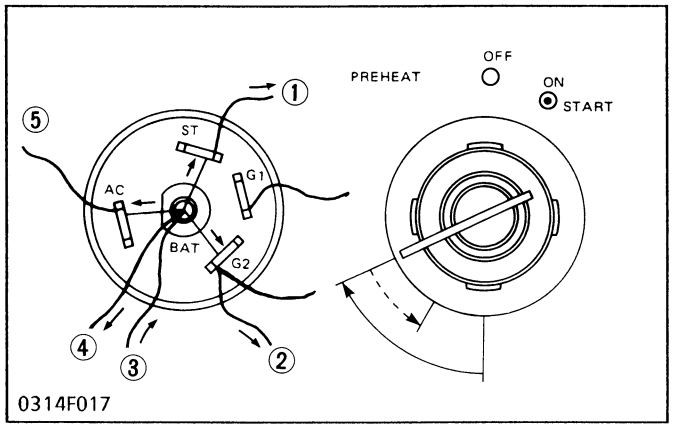


0314F016

■ PREHEAT

While the key switch is turned and held at the "PREHEAT" position, the current is supplied to the glow plugs through the lamp timer.

(1) Lamp Timer
(2) To Glow Plugs
(3) From Battery
(4) To Regulator
(5) To Oil Pressure Lamp and Accessory

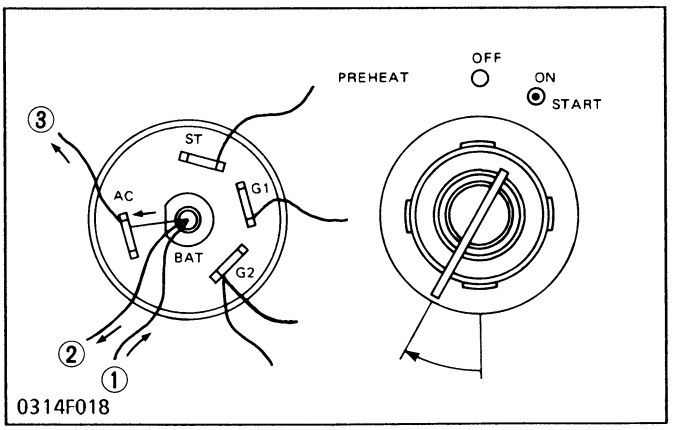


0314F017

■ START

When the key is turned to the "START" position, through the "ON" position the current is supplied to the starter.

(1) To Starter
(2) To Glow Plug
(3) From Battery
(4) To Regulator
(5) To Oil Pressure Lamp and Accessory



■ **ON**

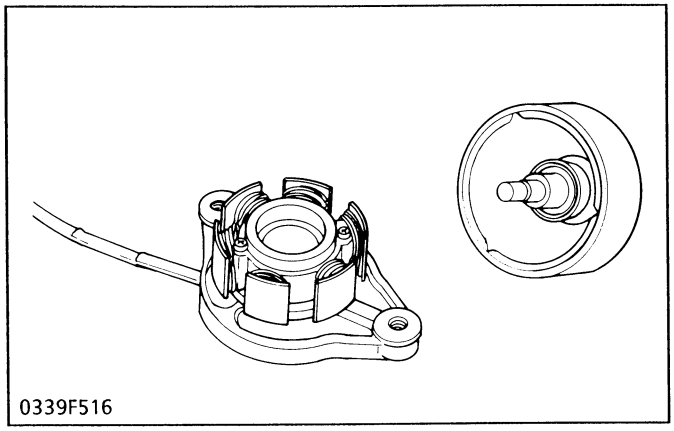
Only the terminal "AC" is connected to the battery.

At any position of the key except the "OFF" position, the terminal "AC" is connected to the "BAT" terminal.

(1) From Battery
(2) To Regulator
(3) To Oil Pressure Lamp and accessory

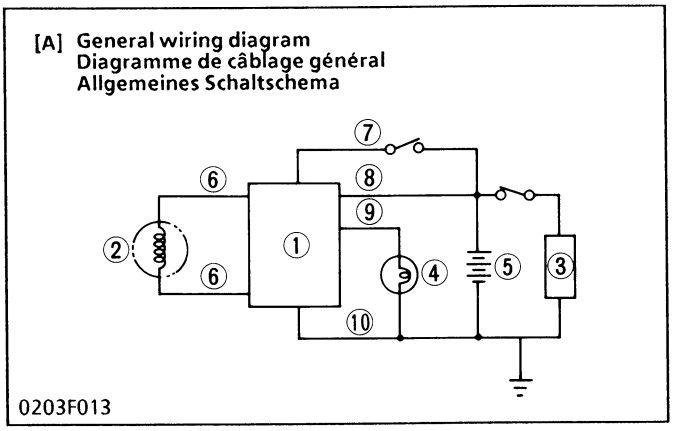
[2] CHARGING SYSTEM

(1) Dynamo



This dynamo is an 8-8 pole rotating magnet type generator. It is simple in construction, consisting of a stator and rotor. The rotor is made up of eight permanent magnet pole pieces assembled on a shaft and rotates on the center of the stator around which eight electromagnetic coils are provided for. This dynamo produces higher voltage in slow speed rotation, and charges electric current to the battery during engine idling.

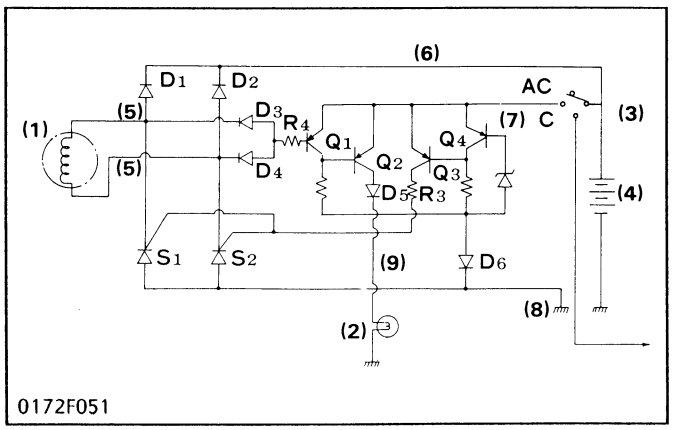
(2) Regulator



The regulator performs rectification and voltage regulation. The regulator converts AC into DC which flows through the power consuming circuits and the battery, and also charges the battery. If however, the battery voltage exceeds a certain level. The DC current is cut off from the charging circuit to prevent overcharging.

(1) Regulator
(2) Dynamo
(3) Load
(4) Charge Lamp
(5) Battery
(6) Blue Lead Wire
(7) Yellow Lead Wire
(8) Red Lead Wire
(9) Green Lead Wire
(10) Black Lead Wire

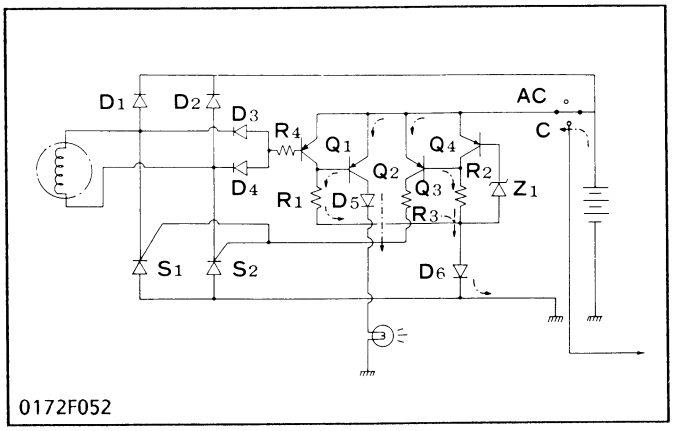
(3) Charging Mechanism



0172F051

The charging mechanism is described in four sections:
1) When key switch is ON
2) At starting
3) In charging
4) Over-charge protection

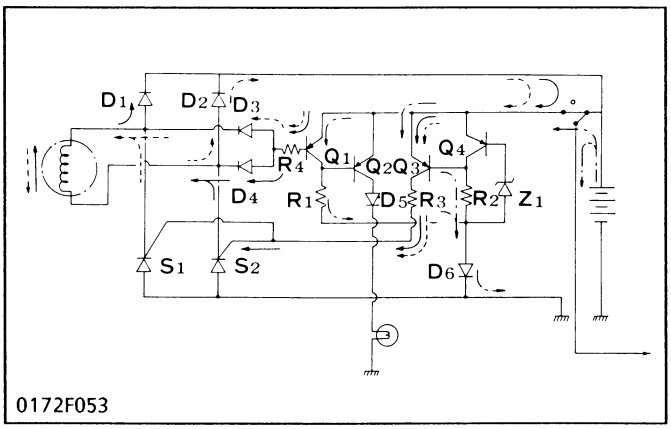
(1) GEN: Magnet type AC generator
(2) LAMP: Charge indication lamp (not included in the basic engine)
(3) KEY SW: Key switch (not included in the basic engine)
(4) BATT: Battery (not included in the basic engine)
(5) Blue: GEN connecting terminal
(6) Red: BATT + connecting terminal
(7) Yellow: BATT voltage test terminal
(8) Black: BAT – connecting terminal
(9) Green: LAMP connecting terminal
S_1, S_2: Output control/rectification thyristor (SCR)
D_1, D_2: Output rectifying diode
D_3, D_4: GEN generation detecting diode
D_5, D_6: Protection diode for wrong connecting of BATT
Z_1: BATT terminal voltage setting diode
Q_1: GEN generation detecting transistor
Q_2: LAMP on/off transistor
Q_3: Gate current control transistor
Q_4: BATT voltage detecting transistor



0172F052

1) When Key Switch is "ON"

When the engine is at standstill with key switch set at position 1, the circuit functions to light LAMP, as shown in Fig. 1. With key switch at position 1, current flows to base of Q_2 through the route of BATT --→ emitter/base of Q_2 --→ R_1 --→ D_6 --→ BATT and collector of Q_2 is then turned on. As a result, current also flows to LAMP though the route of BATT --→ emitter/collector of Q_2 --→ D_5 --→ LAMP --→ BATT lighting LAMP to indicate that charging is not carried out. At this time, though current flows to base of Q_3 through the route of BATT --→ emitter/base of Q_3 --→ R_2 --→ D_6 --→ BATT, collector of Q_3 has no current because GEN is stationary.

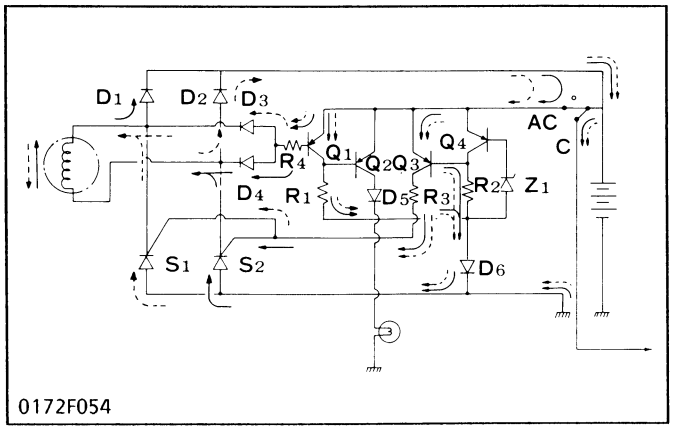


0172F053

2) At Starting

When key switch is turned to position 2, coil of starter relay is energized and starter starts engine. GEN also starts generation for charging and LAMP is turned off.

In detail, with GEN starting, current flows to base of Q_1 through the route of GEN → D_1 → emitter/base of Q_1 → R_4 → D_4 → GEN, or GEN --→ D_2 --→ emitter/base of Q_1 --→ R_4 --→ D_3 --→ GEN, and therefore current also flows through Q_1, short-circuiting emitter and base of Q_2. As a result, base current of Q_2 is interrupted, Q_2 is turned off and accordingly current to LAMP is also interrupted.



0172F054

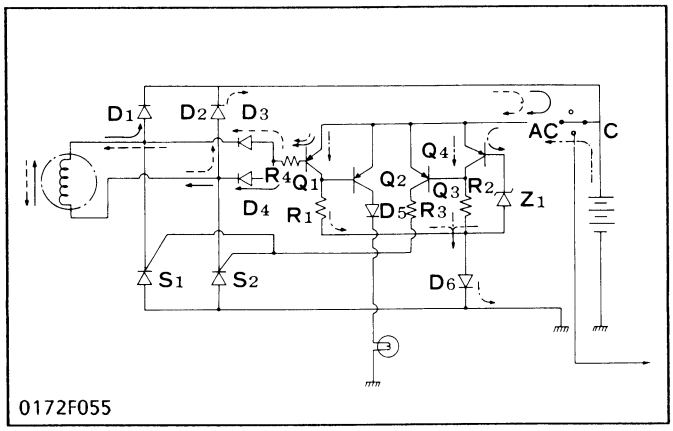
3) In Charging

Because BATT terminal voltage just after engine start is lower than setting value (14 to 15V), or lower than zener lever of Z_1, current is not supplied to base of Q_4 and Q_4 is off, as shown in Fig. 2. Q_3 is on with base current which flows through the route of BATT --→ emitter/base of Q_3 --→ R_2 --→ D_6 --→ BATT, and gate current is supplied to S_1 or S_2 through the route of GEN → D_1 → emitter/collector of Q_3 → R_3 → gate/cathode of S_2 → GEN, or GEN --→ D_2 --→ emitter/collector of Q_3 --→ R_3 --→ gate/cathode of S_1 --→ GEN.

When engine speed is increased so that GEN generation voltage becomes higher than BATT terminal voltage S_1 or S_2 is turned on and, as shown in Fig. 3, charge current is supplied to BATT through the route of GEN → D_1 → BATT → anode/cathode of S_2 → GEN, or GEN --→ D_2 --→ BATT --→ anode/cathode of S_1 --→ GEN.

After S_1 or S_2 is turned on, collector current of Q_1 and base current of Q_3 are supplied by GEN, not BATT.

When key switch is returned to position 1 after engine is started, BATT is charged, if BATT terminal voltage is lower than the setting value, or zener level of Z_1.



0172F055

4) Over-Charge Protection

When BATT terminal voltage is higher than the setting value or zener level of Z_1, BATT is not charged by the function of circuit as shown in Fig. 4. That is, Q_4 is on with base current which flows through the route of BATT --→ emitter/base of Q_4 --→ Z_1 --→ D_6 --→ BATT, shortcircuiting emitter and base of Q_3. Therefore, Q_3 is off with no base current and gate current is not supplied to S_1 and S_2. Consequently S_1 and S_2 are off and BATT is not charged.