# 4. FUEL SYSTEM

## CONTENTS

# FUEL SYSTEM

## 1. GENERAL

The fuel system feeds fuel from the fuel tank to the combustion chamber.
It contains a precision injection pump and injection system that greatly affects combustion performance.
A continuous supply of good quality filtered fuel is needed for these parts to function properly.
To make the exhaust gas emissions of engines meet regulations in each nation or region, the fuel injection system must be carefully controlled. Use of the poor fuel, inadequate maintenance of the fuel injection system, and replacement of the injection system with any other one than those recommended by KUBOTA may significantly affect the emissions.
The engine may discharge excessive bad levels of controlled constituents exhaust gas, consequently resulting in non-conformance with applicable emission standards.

**【Fuel System】**

The general fuel system of KUBOTA diesel engines shown in the diagram below. Fuel from the tank flows in the passage and is injected from the nozzle via the fuel injection pump. Overflow fuel returns to the tank. The system includes filters to protect it from entrance of air, water and dust.

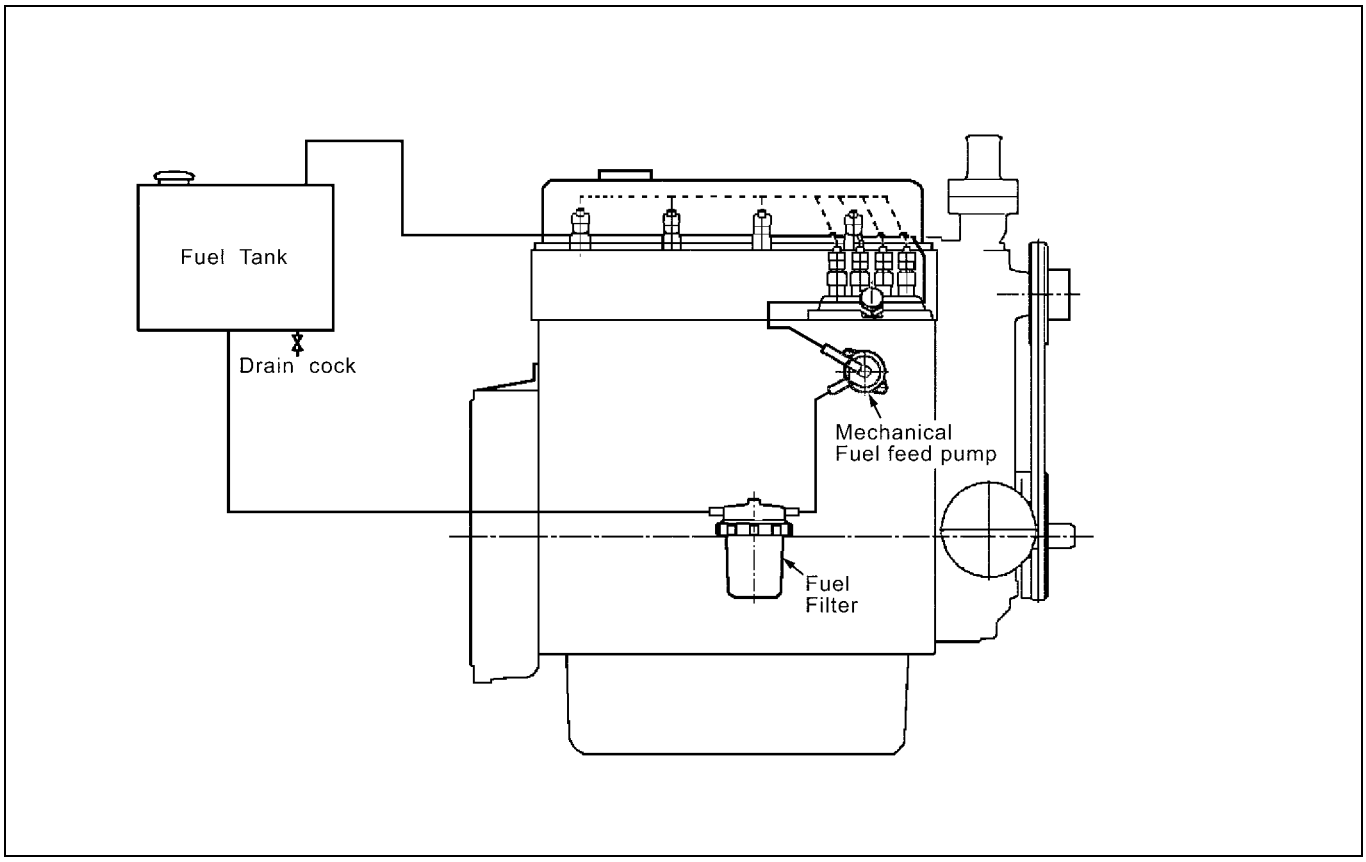



Fig. 4-1 Fuel system

While the engine is running, fuel is fed into the pump by the fuel feed pump after passing through the fuel filter where any foreign matter is removed. The fuel camshaft actuates the injection pump and force feeds fuel to the injection nozzle through the injection pipe.
Fuel is then sprayed through the nozzle into the combustion chamber. The fuel discharged after lubricating and cooling the injection nozzle is returned to the fuel tank automatically through the over-flow pipe.

# 2. FUEL INJECTION PUMP

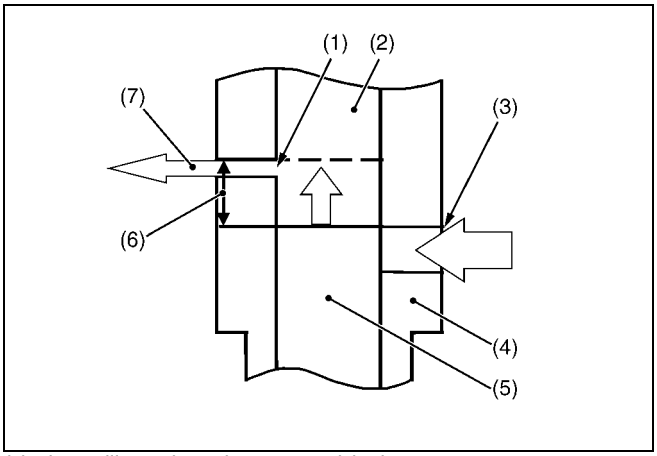
The fuel injection pump is modified to fit KUBOTA engines.
The fuel injection pump is an extremely precise unit, so it must be handled very carefully. Water entering in the fuel system will cause seizure, rusting or early wear of the injection pump plunger, cylinder, nozzle, needle valve, etc. Normal fuel has an appropriate viscosity to maintain good lubrication.

In the fuel pump of 03-M, 07 and V3 engines, F.S.P(Fine Spill Port), which has such functions as timer and injection rate control, has been employed.
Also, in the 07 series engines, CPV(Constant Pressure Valve) has been employed in the fuel pump to prevent the secondary injection by keeping constant the residual pressure in the high-pressure pipes after fuel is injected.
And in the E3 engines, the fuel injection timing, which most heavily influences the emission, is controlled to be within 0.5 degrees.

In SM, 05 series engine, a Bosch MD type mini pump is used for the injection pump, while in 03-M, 07 and V3 series engine, a Bosch KD type mini pump is used for the injection pump. These are small, lightweight and easy to handle,

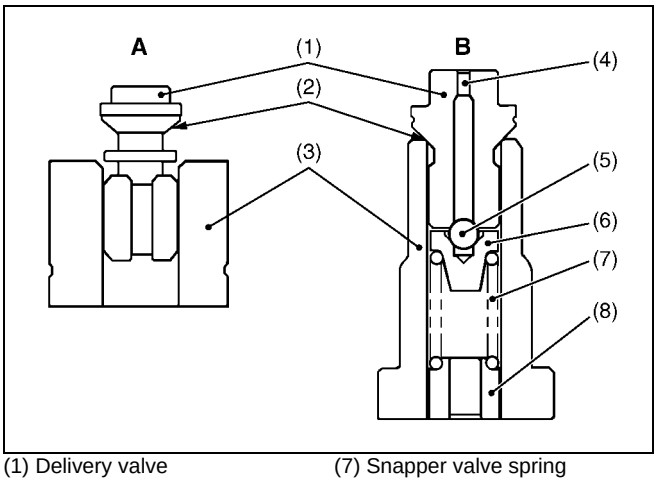
【SM, 05 and 03-M series engine】
Injection timing can be adjusted by varying shim thickness.
Increasing or decreasing shim thickness by 0.025mm (0.00098") will delay or advance injection timing by approx. 0.25° (0.0044 rad).

【07 Series and V3 Series】
Injection timing can be adjusted by rotating the injection pump unit clockwise or anti-clockwise, this can be achieved once the high pressure injection pipes are removed and the unit injection pump mounting bolts are loosened.




(1) Fine spill port (F.S.P)
(2) Plunger chamber
(3) Main port
(4) Cylinder
(5) Plunger
(6) F.S.P Stroke
(7) Leaking fuel at initial fuel pressure-feed stage

Fig. 4-2 F.S.P (Fine spill port)

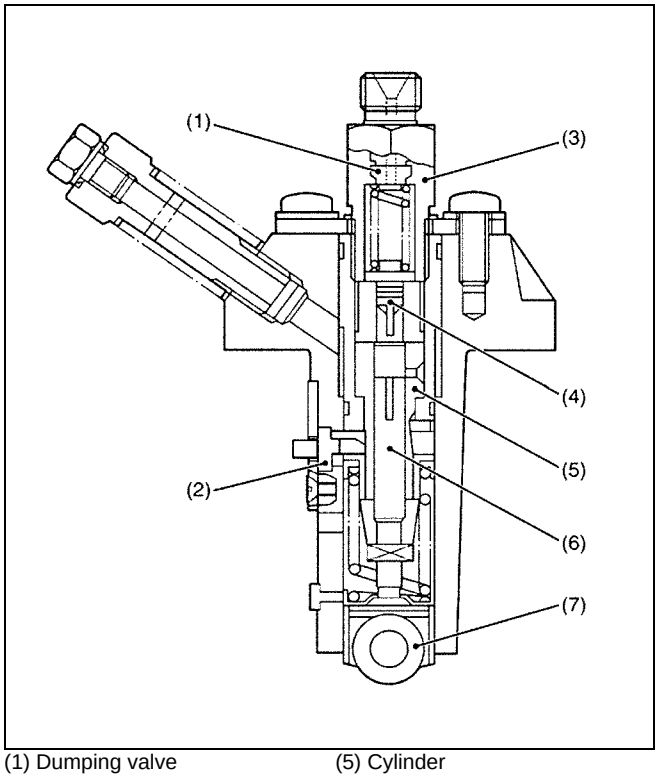



(1) Delivery valve
(2) Seat surface
(3) Valve seat
(4) Orifice
(5) Steel ball
(6) Snapper valve
(7) Snapper valve spring
(8) Snapper valve seat

**A : Current delivery valve**
**B : CPV Equipped delivery valve**

Fig. 4-3 CPV (Constant pressure valve)

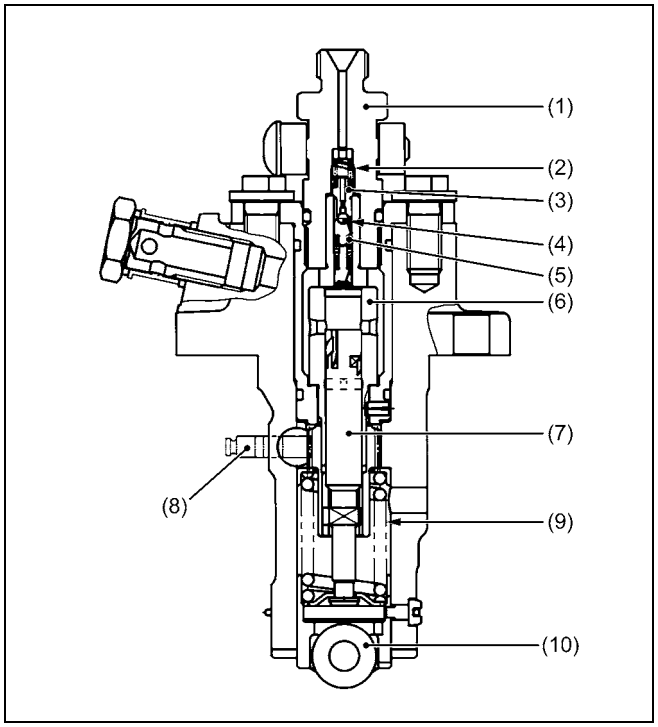
• S.M. series, 05 series




(1) Dumping valve
(2) Control rack
(3) Delivery valve holder
(4) Delivery valve
(5) Cylinder
(6) Plunger
(7) Tappet roller

Fig. 4-4 Fuel injection pump

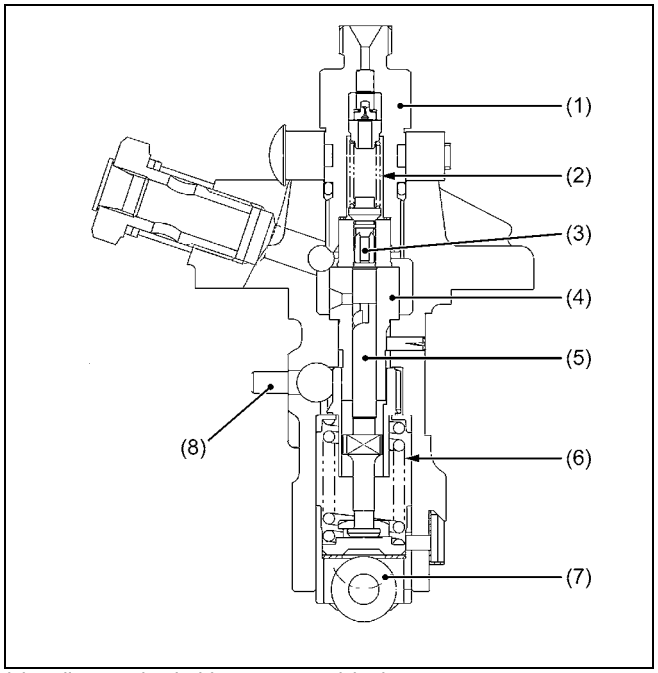
• 07 series




(1) Delivery valve holder
(2) Delivery valve spring
(3) Delivery valve
(4) Sfeel ball
(5) Snapper valve
(6) Cylinder
(7) Plunger
(8) Control rack
(9) Plunger spring
(10) Tappet roller

Fig. 4-5 Fuel injection pump

• 03-M series, V3 series




(1) Delivery valve holder
(2) Delivery valve spring
(3) Delivery valve
(4) Cylinder
(5) Plunger
(6) Plunger spring
(7) Tappet roller
(8) Control rack

Fig. 4-6 Fuel injection pump

# 3. FUEL INJECTION NOZZLE

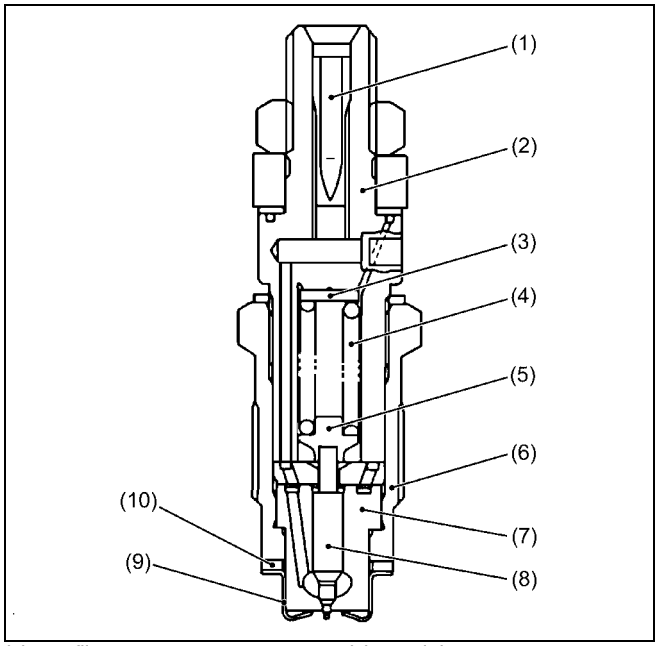
Kubota's engines employ two types of nozzles, Pin type nozzles and Hole type nozzles, depending on the difference in their combustion chambers.
There are two types of the Pin type nozzle, Pintle type one and Throttle type one, among which Kubota employs the Throttle type.
Throttle type of nozzle is designed to control the injection quantity when the lift rate is low at start of the injection, and to cut down on the knocking sound caused by excessive fuel injection by giving the needle valve section more taper than before to prevent the rapid increase in the injection quantity when the initial injection turns into the full-force injection.
The injection pressure is adjusted in the range of 13.7 to 14.7MPa(140 to 150kgm$^2$, 1990 to 2133psi), in which the injection pressure can be adjusted by changing the shim thickness, if necessary.
The heat seal is employed to improve the durability and reliability of the nozzle.

In the Hole type nozzles, the Two-stage type injection nozzles have been employed to respond to the emission and noise regulations, in addition to the conventional type nozzles.
The Two-stage type injection nozzle injects in two stages of the primary injection and the secondary injection, which is especially effective in reducing NOx (nitrogen oxides) and PM in emission.

As for the injection pressures, the primary injection pressure is set at 18.64 to 19.61Mpa (190.0 to 200.0 kgf/cm$^2$,2703 to 2844psi.) and the secondary injection pressure is set at 23.54 to 24.52MPa (240 to 250 kgf/cm$^2$, 3414 to 3556 psi.) depending on the models. Because the structure is so complicated that the injection pressure readjustment is not possible, it becomes necessary to change the nozzle as a nozzle main body assy, in the case of an occurrence of injection pressure drop or atomization failure.

**(1) IDI**

• Throttle nozzle

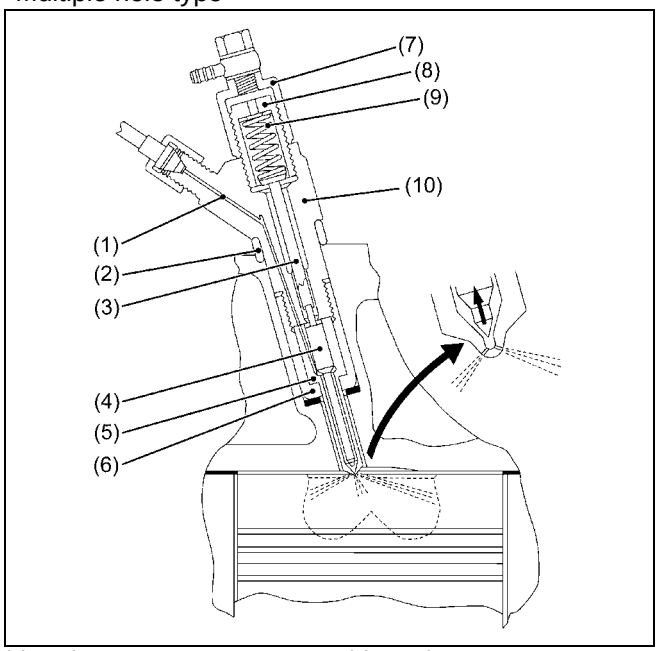



(1) Bar filter
(2) Nozzle holder body
(3) Adjusting washer
(4) Nozzle spring
(5) Push rod
(6) Retaining nut
(7) Nozzle piece
(8) Needle valve
(9) Heat seal
(10) Gasket

Fig. 4-7

**(2) DI**

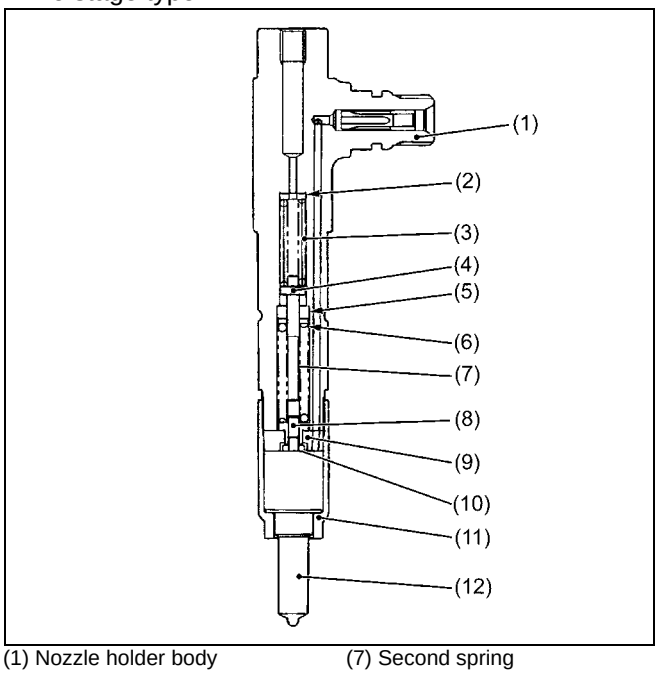
• Multiple hole type




(1) Fuel passage
(2) Seal ring
(3) Push rod
(4) Needle valve
(5) Nozzle body
(6) Nozzle nut
(7) Nut
(8) Adjusting screw
(9) Nozzle spring
(10) Nozzle holder

Fig. 4-8

• Two stage type

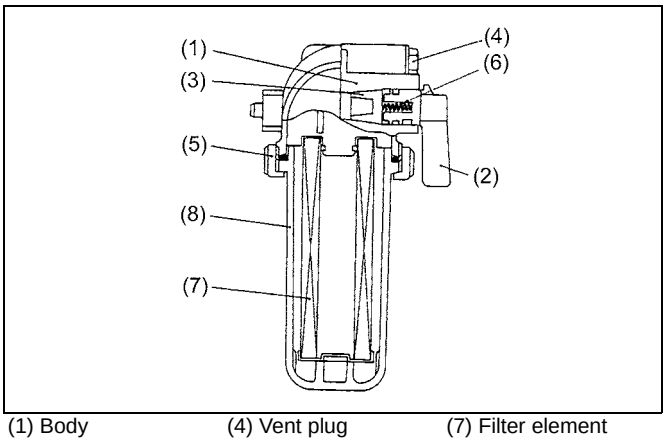



(1) Nozzle holder body
(2) 1st stage injection pressure adjusting shim
(3) First spring
(4) Pressure pin
(5) Spring seat
(6) 2nd stage injection pressure adjusting shim
(7) Second spring
(8) Pre-lift adjusting spring seat
(9) Chip-packing
(10) Max-lift adjusting washer
(11) Retaining nut
(12) Nozzle

Fig. 4-9

# 4. FUEL FILTER

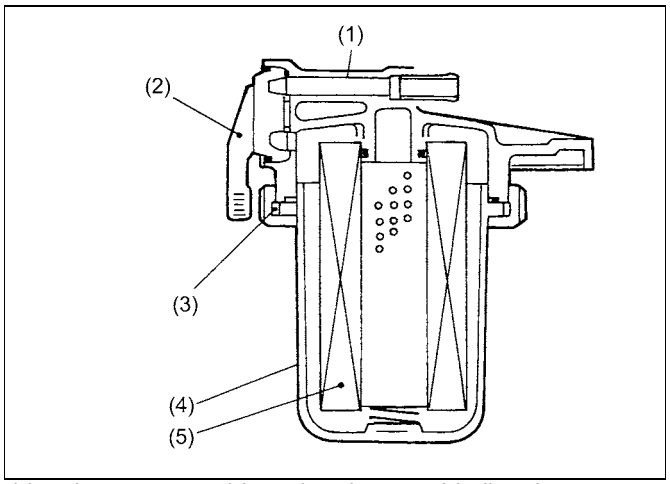
The fuel filter located between the tank and the injection pump prevents foreign matter from entering the injection pump. A standard KUBOTA filter uses a paper element (filtration diameter less than 15 $\mu$). Filtration surface areas available in KUBOTA filters are 250 $cm^2$ (38.75 sq.in.), 1100 $cm^2$ (170.5 sq.in.) and 1660 $cm^2$ (257.28 sq.in.), according to engine model.
Normally filter elements or cartridges must be changed every 400 hours. Three types of filters are shown.
Fig 4-10 type filter is ordinary type. Air traped in the filter is purged by the vent plug (4).




(1) Body (4) Vent plug (7) Filter element
(2) Lever (5) Ring nut (8) Cup
(3) Valve (6) Spring

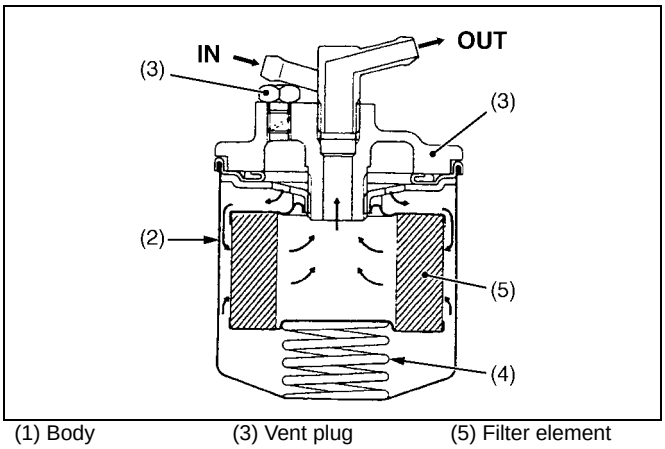
Fig. 4-10 Fuel filter

Fig. 4-11 type filter has an automatic venting mechanism that can complete venting in about one minute with the lever in the open position.




(1) Body (3) Retainer ring (5) Filter element
(2) Lever (4) Cup

Fig. 4-11 Fuel filter




(1) Body (3) Vent plug (5) Filter element
(2) Cup (4) Spring

Fig. 4-12 Fuel filter

**Note :**
**Make sure the fuel IN/OUT pipings are properly connected. Otherwise, the performance of filter will deteriorate.**

Proper location of the pre-filter, fuel pump and the main fuel filter is critical to provide adequate fuel supply. Electric fuel pump generally has less suction head capability. Therefore, it should be located as close to the fuel tank as possible. It is strongly recommended to evaluate and check the fuel pump suction and discharge head against fuel system restrictions. If the losses due to the restrictions are higher than the pump specification, the engine will have hard starting condition or will have low power complaint, especially when the filters will get plugged over time or when the fuel is at a low fuel level in the tank.

The pre-filter is necessary to protect an electric fuel pump. The pre-filter should have micron rating between 100-200 micron (see the electric fuel pump specifications for proper recommendations).

If the fuel has a high content of water or if water condensation condition may occur due to temperature fluctuations, it is recommended to use fuel water separator to prevent the fuel injection system and other problems.

Also, it is critical to mount the filter and the pump to avoid excessive vibration.

Fuel hoses, filters and pump should be located away from high heat surfaces such as exhaust system, hydraulic lines, etc. as high temperature will cause engine power loss due to lower viscosity of fuel at high temperature.

# 5. FUEL FEED PUMP

When a fuel tank is installed on higher than the fuel injection pump and low output engine is used, fuel fed to the fuel injection pump can be achieved by gravity. However, with a multi-cylinder, large displacement engine, fuel supply will be affected unless fuel is forced into the pump.
To avoid this problem, a fuel feed pump is used. Feed pumps come in two general types ; those powered mechanically by the engine, and those power electrically by the battery.

**● Mechanical fuel feed pump**

A diaphragm type feed pump can be installed under the fuel injection pump, this forces fuel into the injection pump by the pumping action of the diaphragm that reciprocates with the fuel camshaft, suction valve and pressure feed valve.

| e.g. Specifications |
|---|
| At 1500 camshaft $min^{-1}$ (rpm) |
| (engine $min^{-1}$ (rpm) : 3000) |
| Fuel feed quantity : 225 cc/min. (13.73 cu.in.) |
| Suction head : 800 mm (31.5 in.) |
| Suction head is with pump in wet condition. |

The diaphragm type feed pump is actuated by rotation of the camshaft.
This pump style will not provide quick priming.

**● Electric fuel feed pump**

An electric fuel feed pump is used when a fuel tank is positioned below the fuel pump of the engine. The pump starts when the starter switch is switched on. Fuel is supplied to the injection pump regardless of engine speed, even in cold conditions.

| e.g. Specifications |
|---|
| Discharge 400 cc (2.44 cu.in.)/min. at 12 V voltage and 1.5 A current, suction head, 400 mm (15.7 in.) |

This pump is driven by the battery. It can therefore be operated even with the engine stopped. The feed pump should be located near the fuel tank, to "PUSH" the fuel through the feed system.
Ensure that the electric pump is protected from dirt by using a strainer or sedimentor.

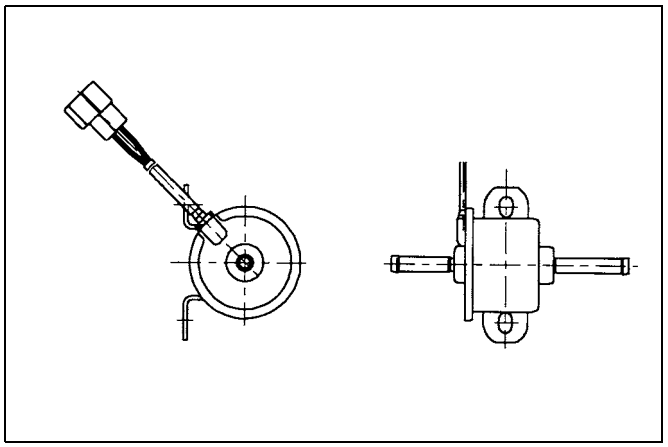
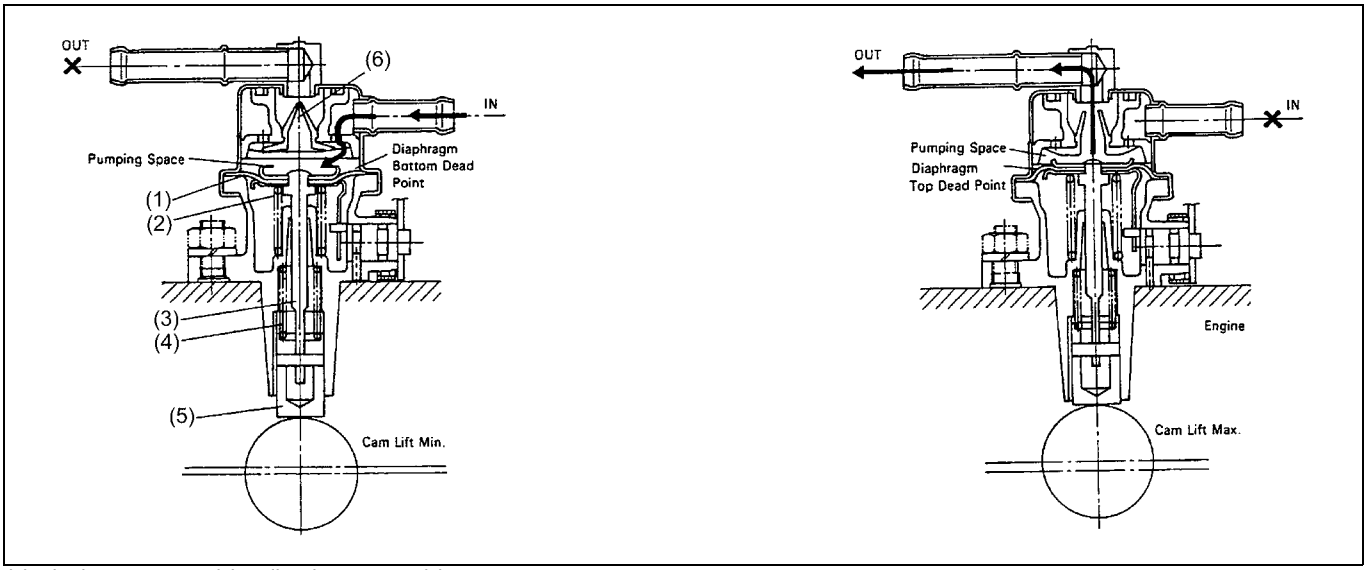


Fig. 4-14 Electric fuel feed pump




(1) Diaphragm (3) Pull rod (5) Tappet
(2) Spring A (4) Spring B (6) Valve

Fig. 4-13 Mechanical fuel feed pump action

# 6. FUEL TANK

The size, shape and position of fuel tank vary with the size and type of machine and application. Care should be taken with the following items.

**(1) Capacity of fuel tank**

The capacity of fuel tank varies with the application of machine to which the engine is installed. Generally the fuel tank capacity of mobile vehicles is small and that of stationary machines is large. To roughly estimate the required capacity, use the following formula.

Fuel tank sizing formula

Qt = Be × Pr × Hr

Qt : Approximate tank capacity (liter)

Be : Fuel consumption at the rated output (liter/kW•hr)

Be = be / (Fg × 1000)

be : Fuel consumption (g/kW•hr)

Fg : Fuel specific gravity

Pr : Applicable power (rated output) (kW)

Hr : Running hours between fill-up (desired holding hours) (hr)

To obtain an approximate value, you may assume the fuel consumption per hour is 285 g/kW•hr and the fuel specific gravity is 0.84.

Fuel consumption by engine model is shown in TECHNICAL INFORMATION.

**(2) Prevention of internal rusting**

Since the tank is not always filled with fuel, its internal surface should be protected from rusting or for long term storage.

The surface should be treated by a reliable rust prevention method.

**(3) Drain cock**

It is very effective for maintenance of each equipment of the fuel system to provide a drain cock at the bottom of fuel tank for discharging water and substances other than fuel contents.

**(4) Cap and filter of fuel tank**

The fuel inlet port requires a filter (# 60 mesh) and a cap having a breather function. If a drum has been left outdoors, water or dirt may have entered it. A filter must be used for supplying fuel into the tank, and fuel at the bottom of drum must not be supplied to the tank. Fuel pickup should be above the tank bottom about 12 mm (1/2 in.). The cap must be sufficiently sealed so as to prevent fuel from leaking during operation. An air vent for maintaining the air pressure in the tank to atmospheric pressure must be provided.

**(5) Position of fuel tank**

The position of fuel tank varies with the distance from the engine, the inclination during operation of the engine, etc. When the gravity feed system is employed, the bottom of fuel tank must be at a 150 mm (6 in.) or more higher position than the top of fuel injection pump. Otherwise the fuel in the tank cannot be completely fed.

If the bottom of fuel tank is extremely close to the top of fuel injection pump, the fuel feed pressure and amount of fuel may become insufficient, thus reducing or fluctuating output and rpm. Range of distance between the bottom of fuel tank and the top of fuel injection pump :

150 mm (6 in.) to 2000 mm (78 in.)

For further details of other fuel systems, refer to fuel piping item.

# 7. FUEL PIPE

Fuel pipe must be made of a material that will withstand the vibration expected during operation and remain durable for several years. Since it contains flammable oil, piping must be arranged carefully.

● **Material**

Since fuel pipe carries a flammable liquid, high quality oil resistant multi-layer rubber for fuel with a temperature resistance of 373 K {100 °C (212 °F )} or higher must be used. Low quality piping can expand or break which cause accidents.

● **Piping precautions**

1) Piping should not be positioned close to any rotating parts or intense vibration.
2) Piping should be routed to avoid extremely high and low temperature.
3) Sharp turning, tapers and unnecessary bending must be avoided, since they will increase flow resistance which may cause decrease in output or fluctuation of rpm.
4) The number of joints must be as small as possible to prevent leakage, and joints must be made as rigid as possible.
5) Flexible pipes must be used between parts that have different vibration sources.
6) Sags or dips in piping must be eliminated since water will collect in them.
7) Fuel pipe must not contact or cross with electric wire.

# 8. FUEL PIPING

The types of fuel piping used depends upon the application. The fuel tank and fuel injection pump, the position of fuel filter and feed pump and length of piping may make air bleeding difficult and also may cause air to be entrapped after long-term storage.
Before making the final decision, carry out sufficient checks by installing the piping on the actual machine.

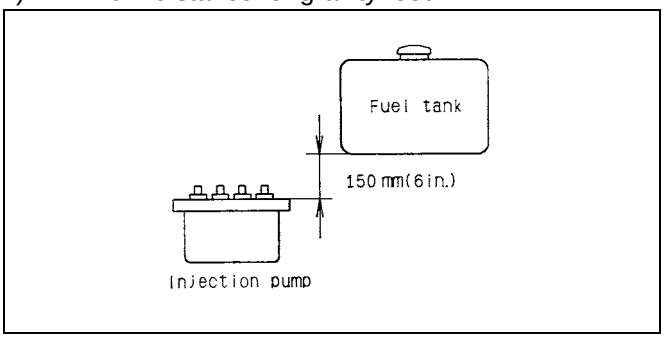
KUBOTA recommends the following standard fuel piping. For further details, see page 4-9 to 4-18.

Even in case that the fuel piping recommended by KUBOTA is adopted, it is still required to check the system for the following points after installing the engine on the equipment. The location of the fuel tank, the specifications of the mounted equipment, the length of the pipes and the location of each component will affect the flow and the inclusion and bleeding of air.

1) Make sure that air bleeding can easily be done when the fuel tank is being replenished with fuel.
2) Make sure that the engine can be operated normally when the various dynamic inclined conditions (e.g., at a horizontal position, at a maximally inclined position, and at a maximally swinging condition) are combined with the fuel levels (the upper limit and lower limit levels) in the tank.
3) Check the restarting ability when a certain time has elapsed after the engine was stopped.
4) Check the temperature in the fuel tank when the engine is operating and check decrease of the engine output and the engine workability when the fuel temperature is rising.
5) Check the starting ability in cold condition.
6) Print the following cautionary points in the instruction manual.

a) Use a high-quality fuel applicable to ambient and local conditions.
b) In the cold weather, change the fuel to the one exclusively recommended for cold season so that the sedimentor and the filter can be prevented from being blocked by precipitated wax of the fuel.
c) Periodically discharge the drain in the sedimenter.

7) Minimum distance for gravity feed.




**A When the fuel tank is mounted above the injection pump**

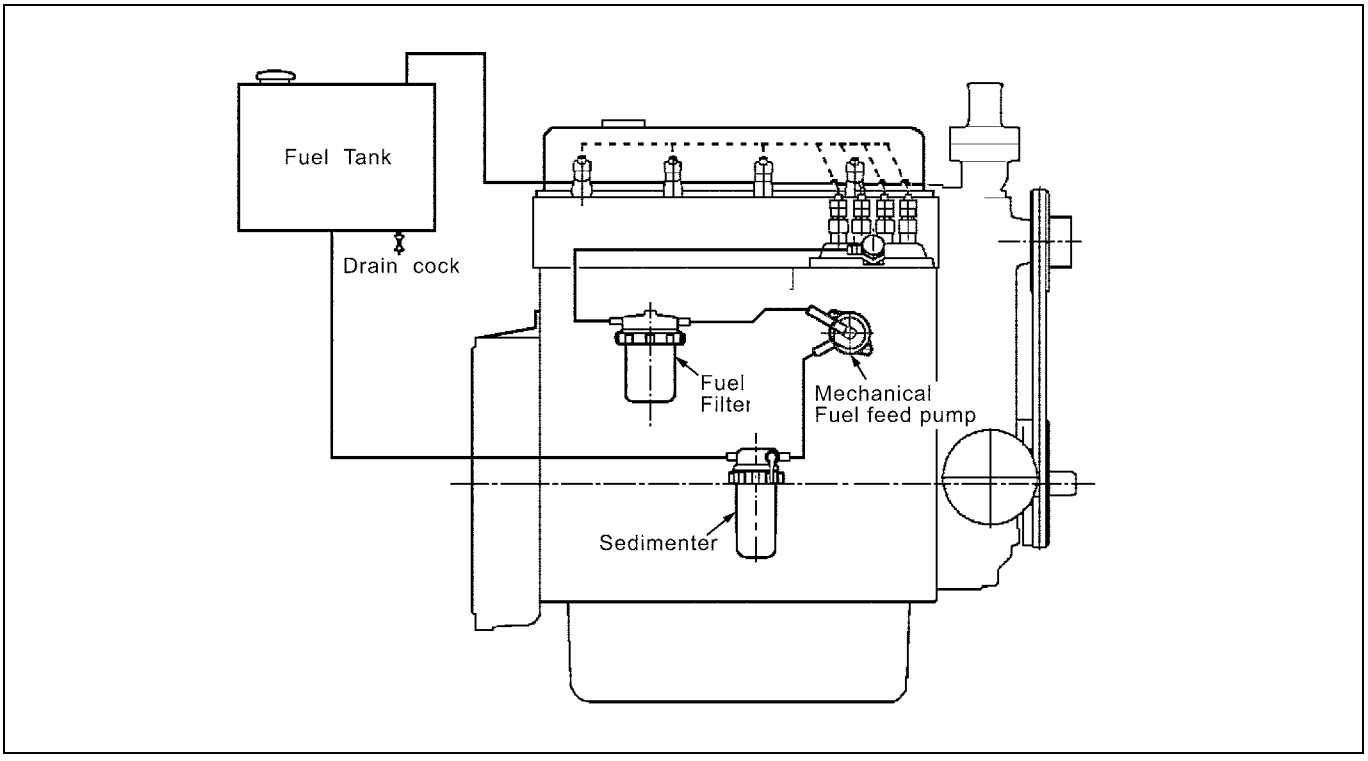



Fig. 4-15 Fuel pipinng

**B When the fuel tank is mounted below or same level the injection pump**

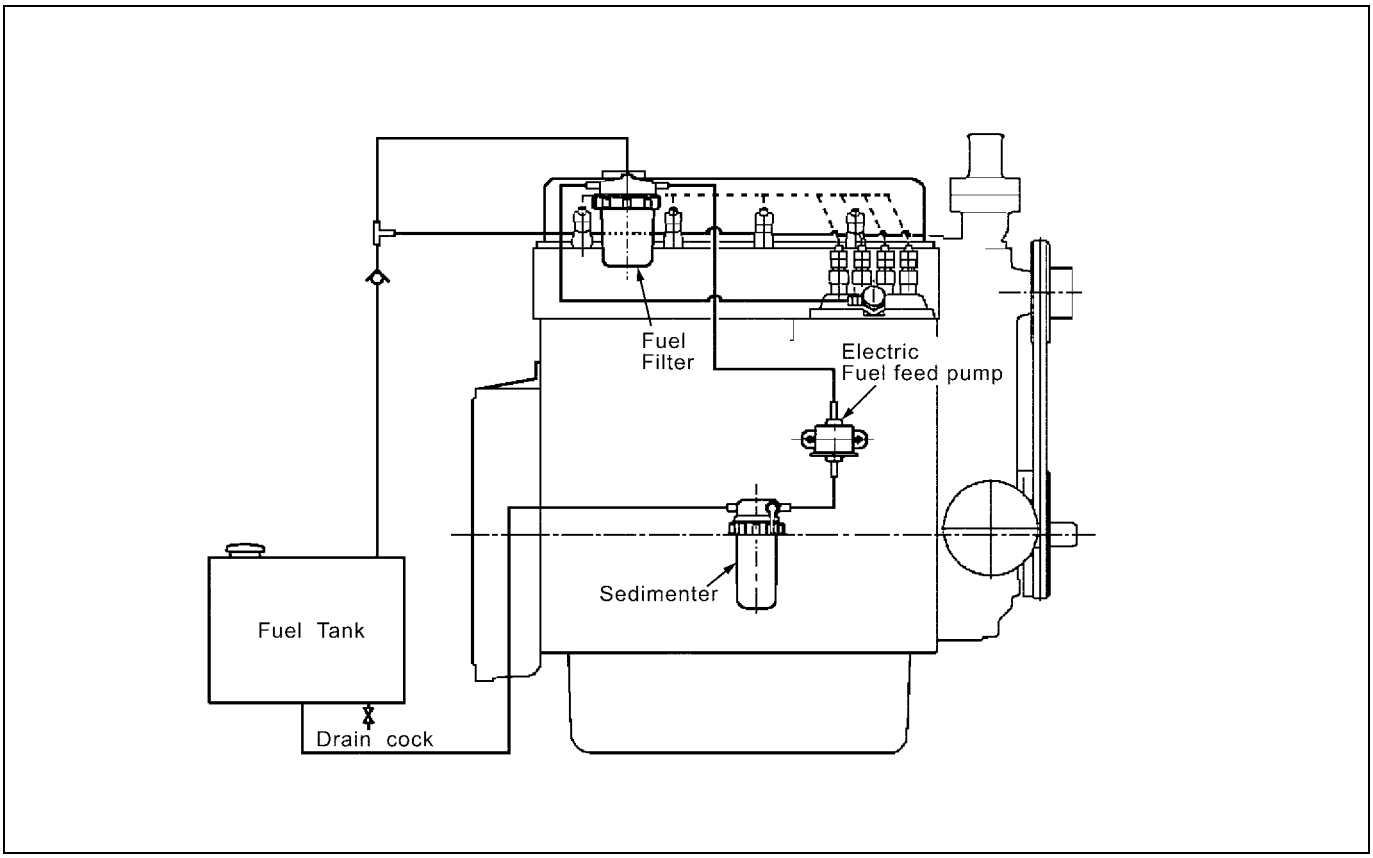



Fig. 4-16 Fuel piping

If the fuel tank is installed at a lower level than the injection pump or at the same level, the electric fuel feed pump should be used to improve air bleeding the fuel in the fuel system, starting failure, the output decrease and the fluctuation of rotation, all of which occur due to such installation positions can be prevented.

KUBOTA recommends the above piping.

It is desirable that the fuel filter is installed at higher position than the injection pump.

**1) Standard piping for Super Mini and 05 series**

• Upper tank with a Mechanical Fuel Feed Pump

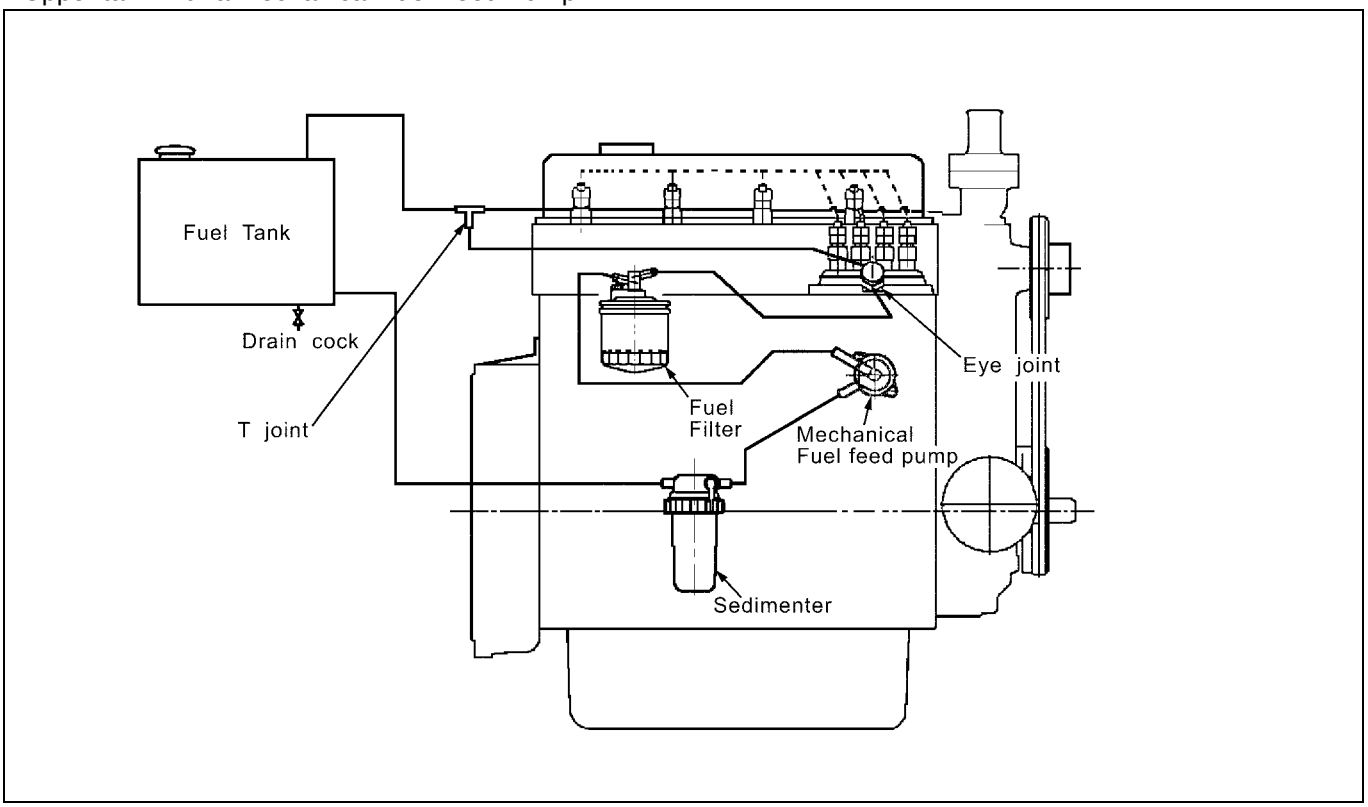



Fig. 4-17

A pre-filter must be installed with suction side of electric fuel pump to protect it.

• Upper tank with an Electric Fuel Feed Pump

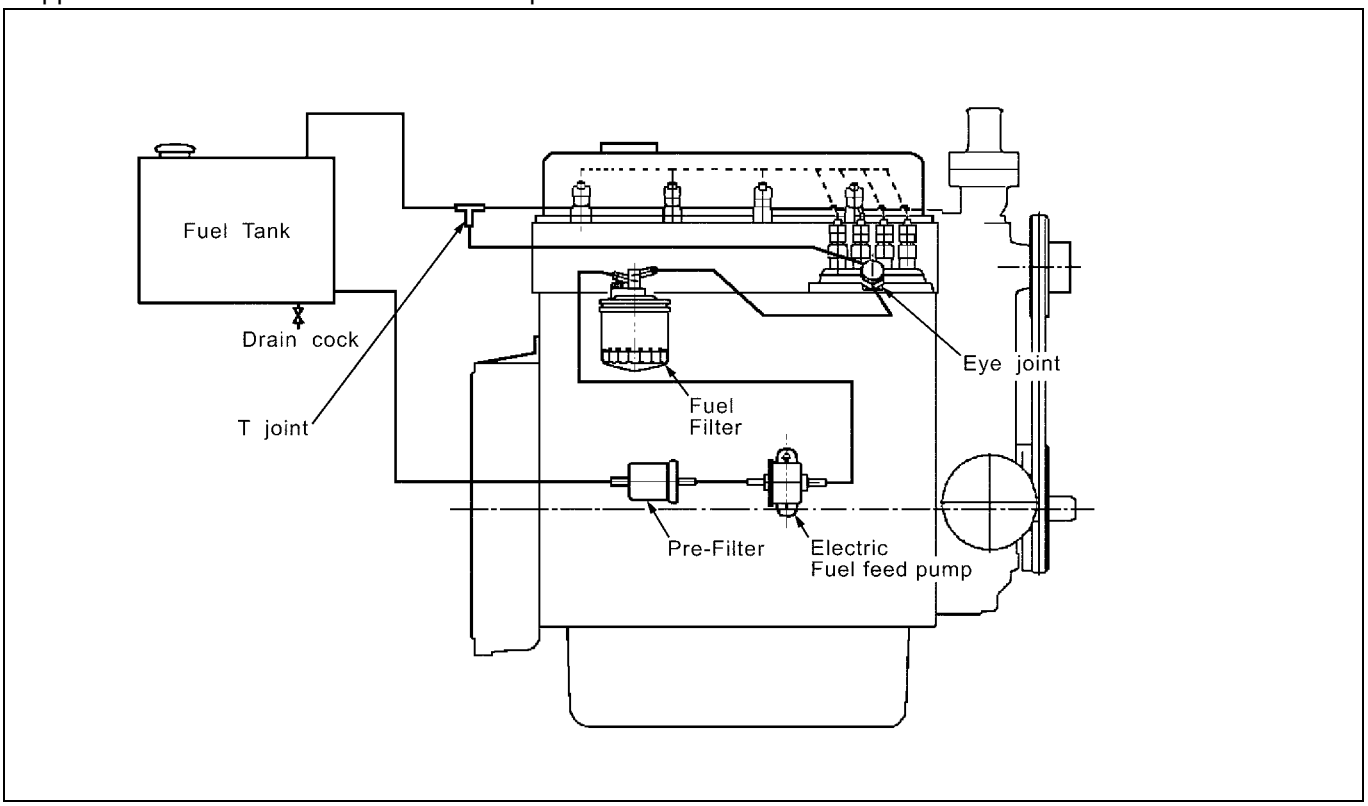



Fig. 4-18

**2) Standard piping for Super Mini and 05 series**

• Lower tank with a Mechanical Fuel Feed Pump

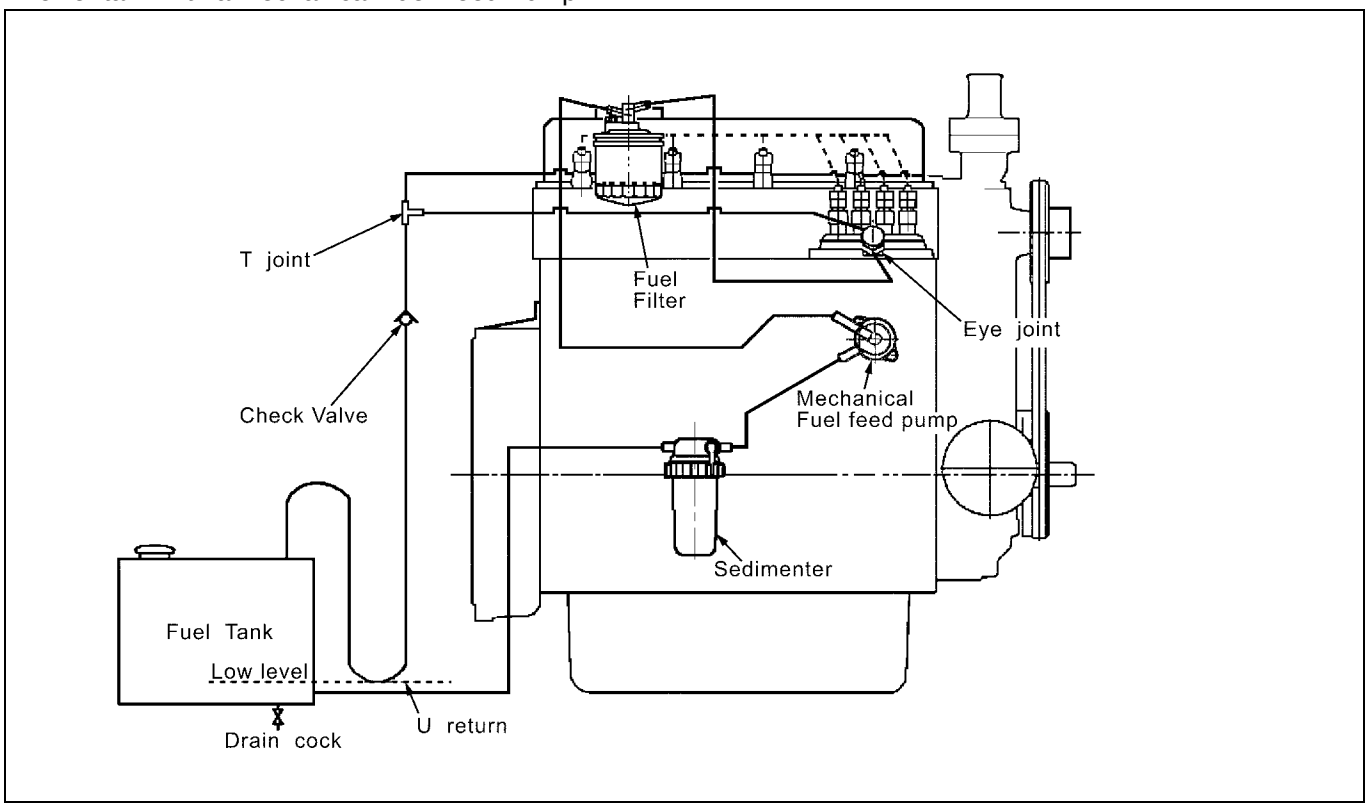



Fig. 4-19

A pre-filter must be installed with suction side of electric fuel pump to protect it.

• Lower tank with an Electric Fuel Feed Pump

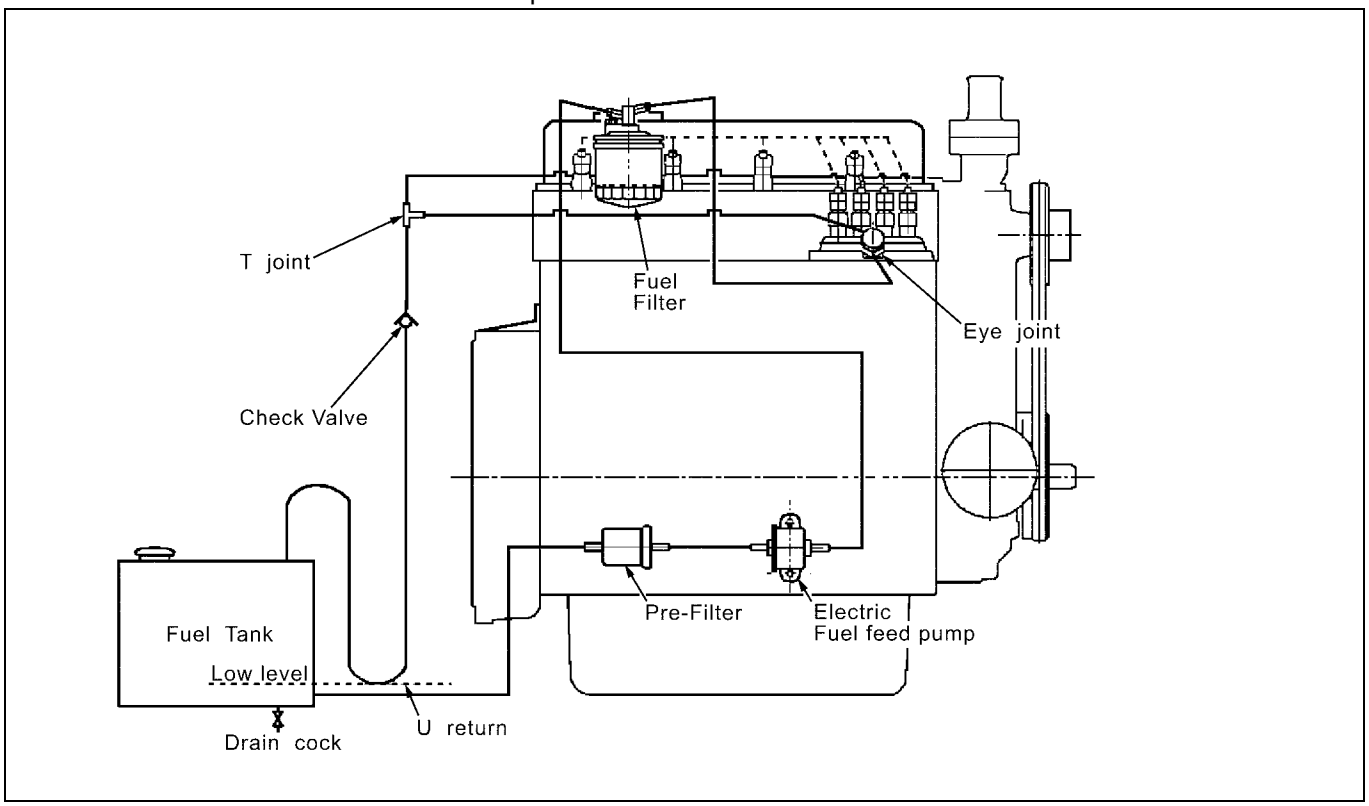



Fig. 4-20

**3) Standard piping for 03-M series**

• Upper tank with a Mechanical Fuel Feed Pump

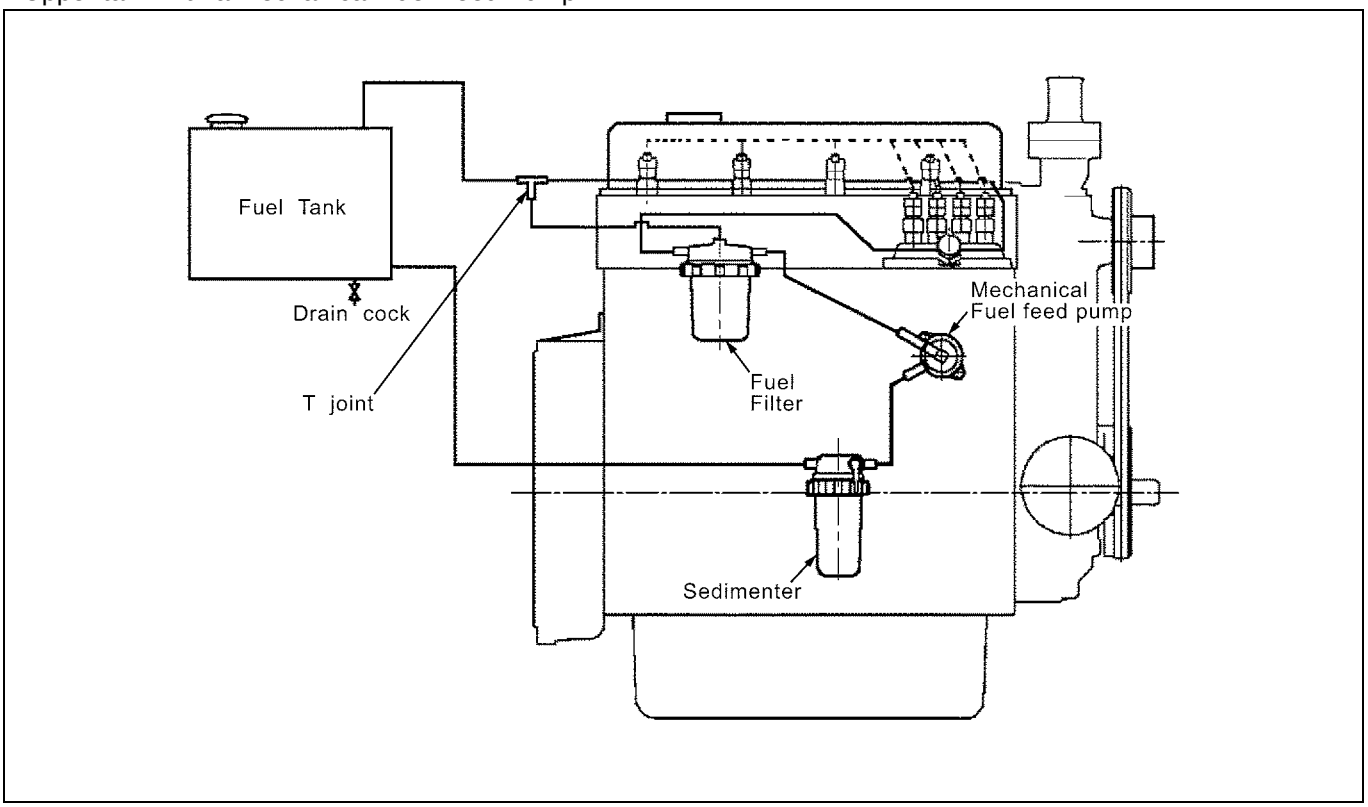



Fig. 4-21

A pre-filter must be installed with suction side of electric fuel pump to protect it.

• Upper tank with an Electric Fuel Feed Pump

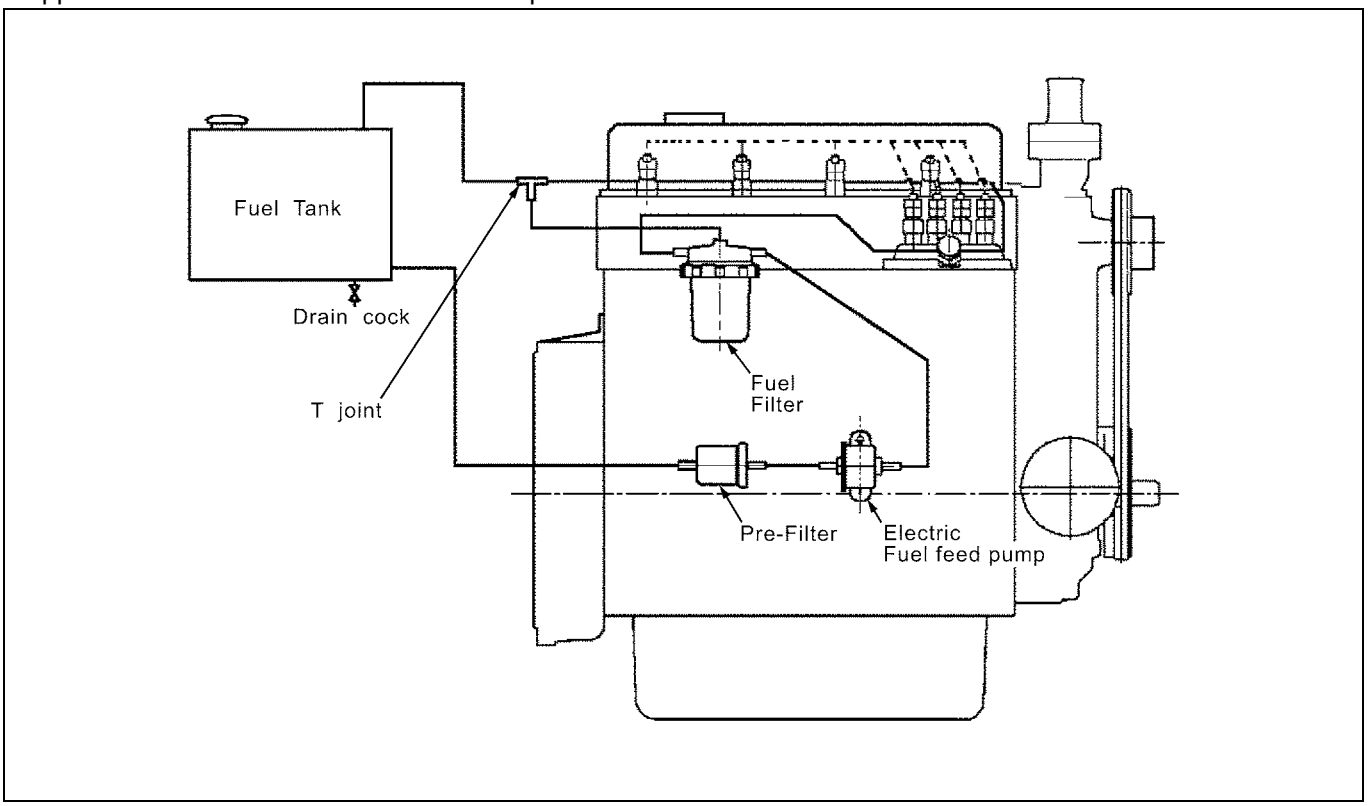



Fig. 4-22

**4) Standard piping for 03-M series**

• Lower tank with a Mechanical Fuel Feed Pump

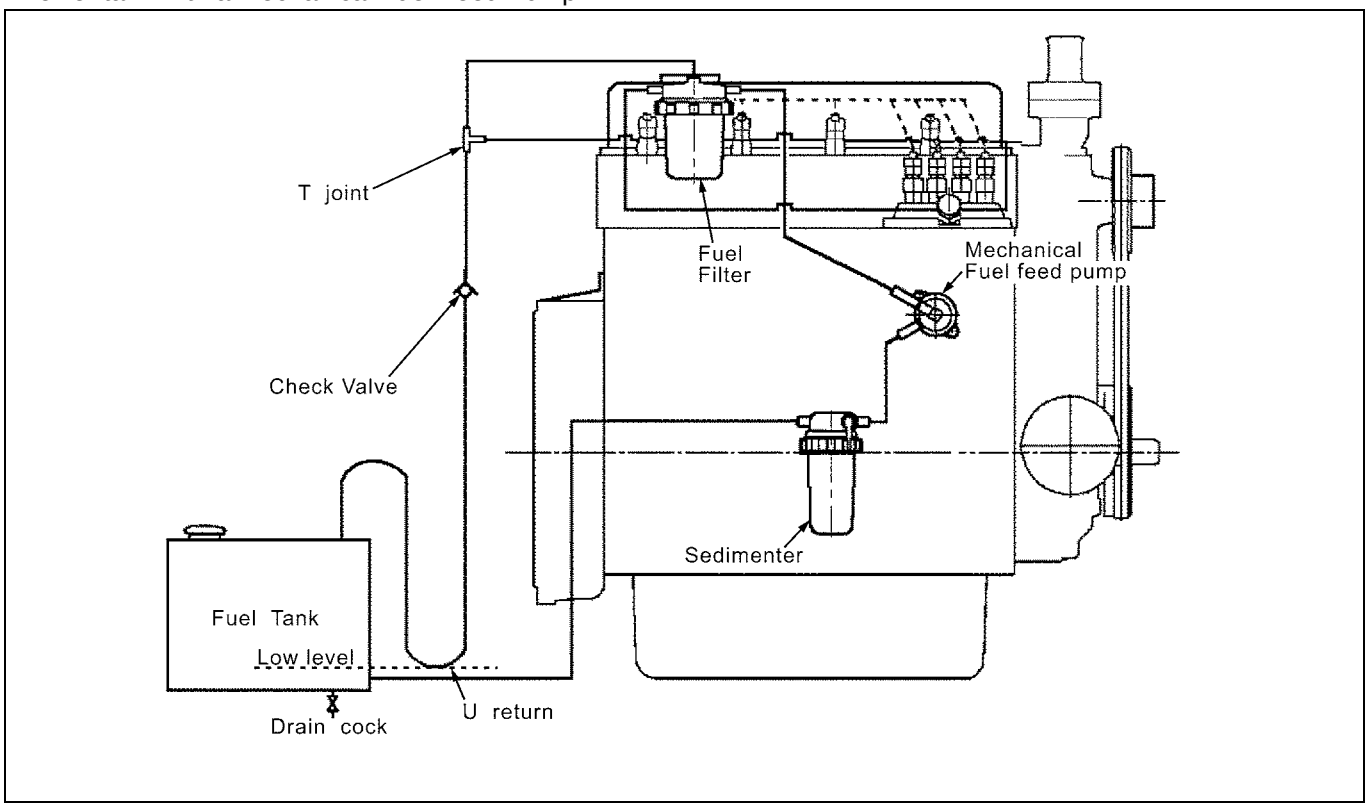



Fig. 4-23

A pre-filter must be installed with suction side of electric fuel pump to protect it.

• Lower tank with an Electric Fuel Feed Pump

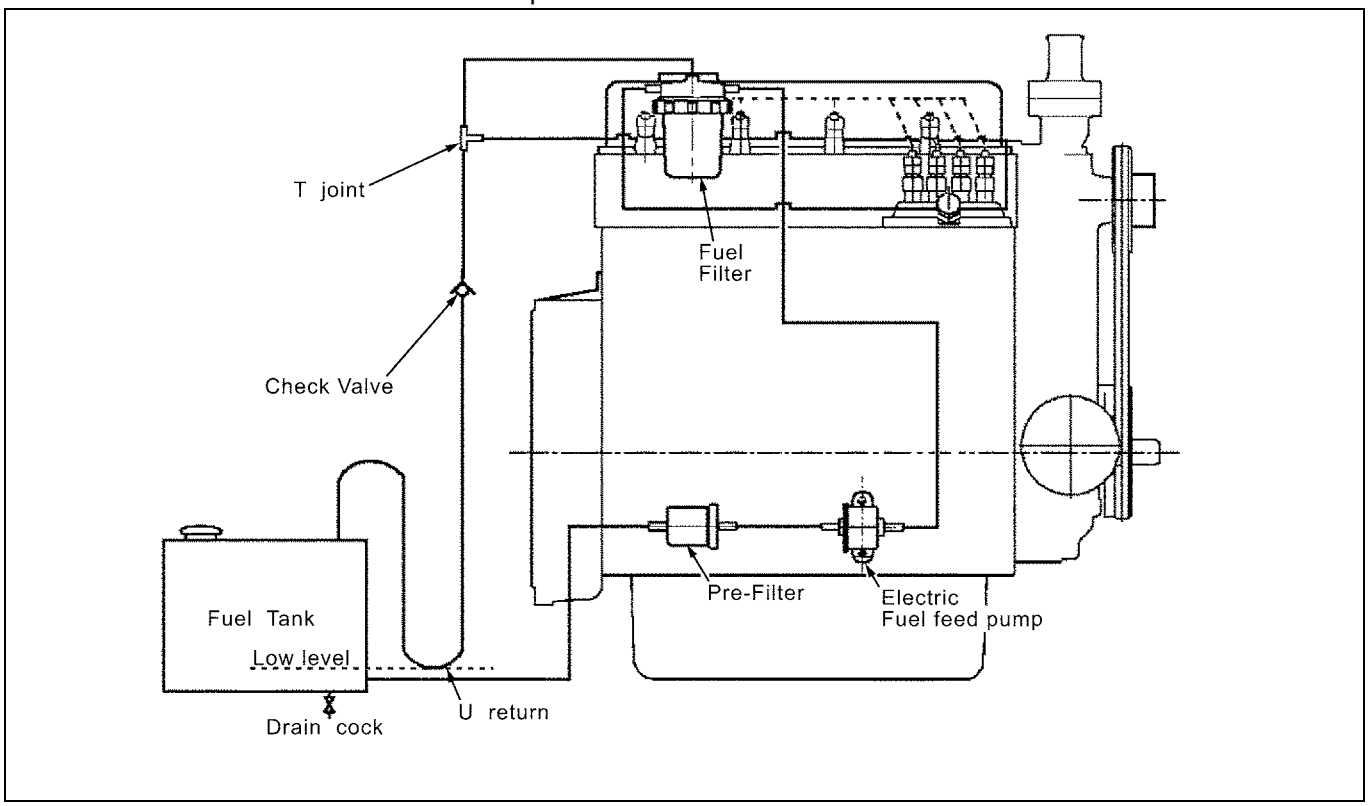



Fig. 4-24

**5) Standard piping for 07 series**

• Upper tank with a Mechanical Fuel Feed Pump

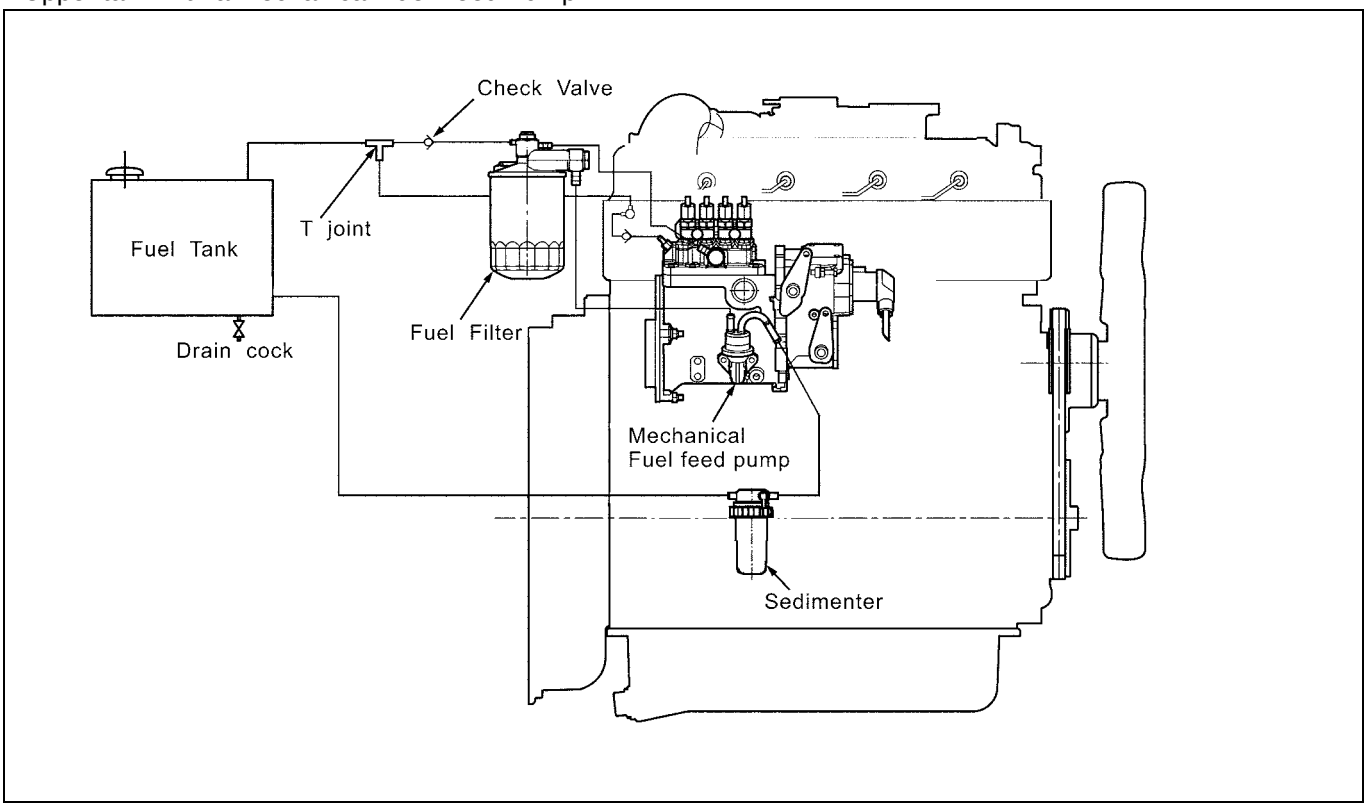



Fig. 4-25

A pre-filter must be installed with suction side of electric fuel pump to protect it.

• Upper tank with an Electric Fuel Feed Pump

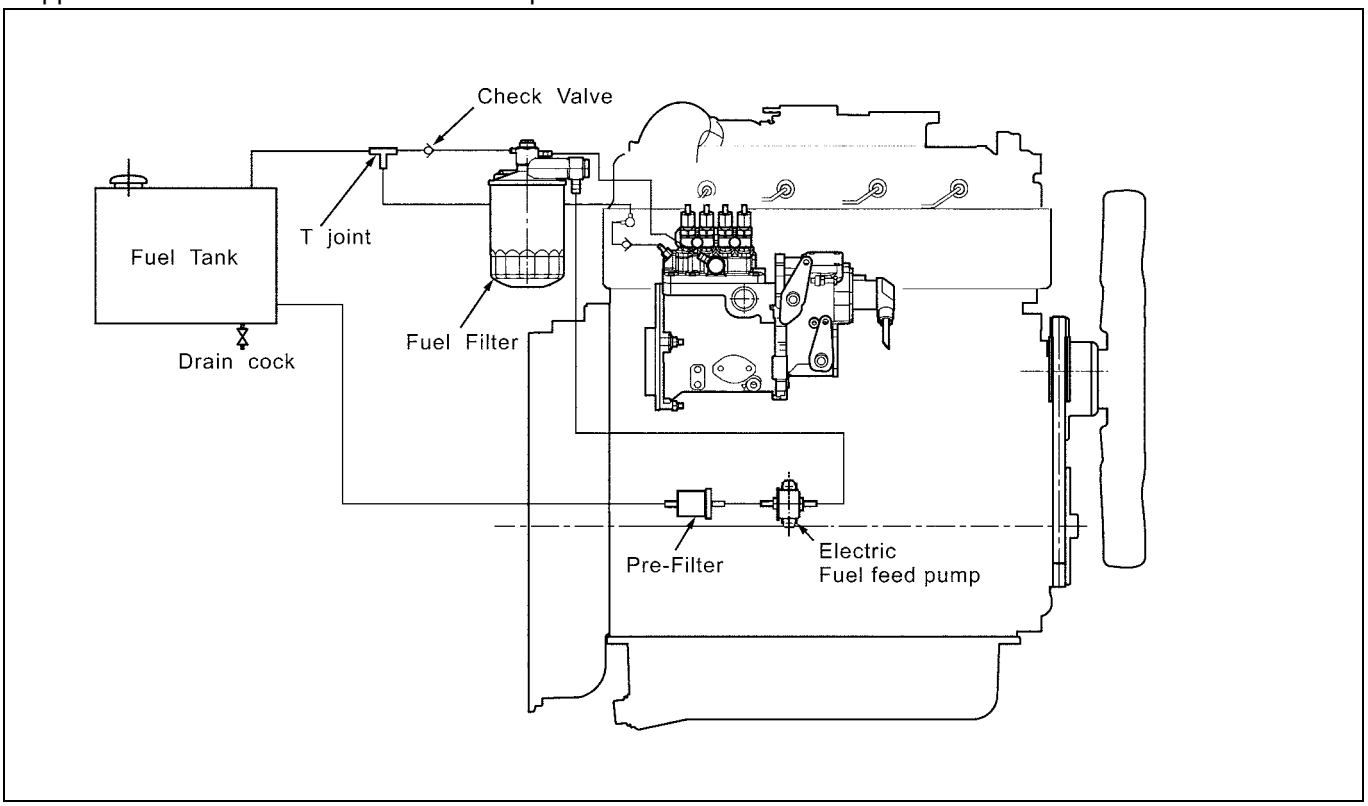



Fig. 4-26

**6) Standard piping for 07 series**

• Lower tank with a Mechanical Fuel Feed Pump

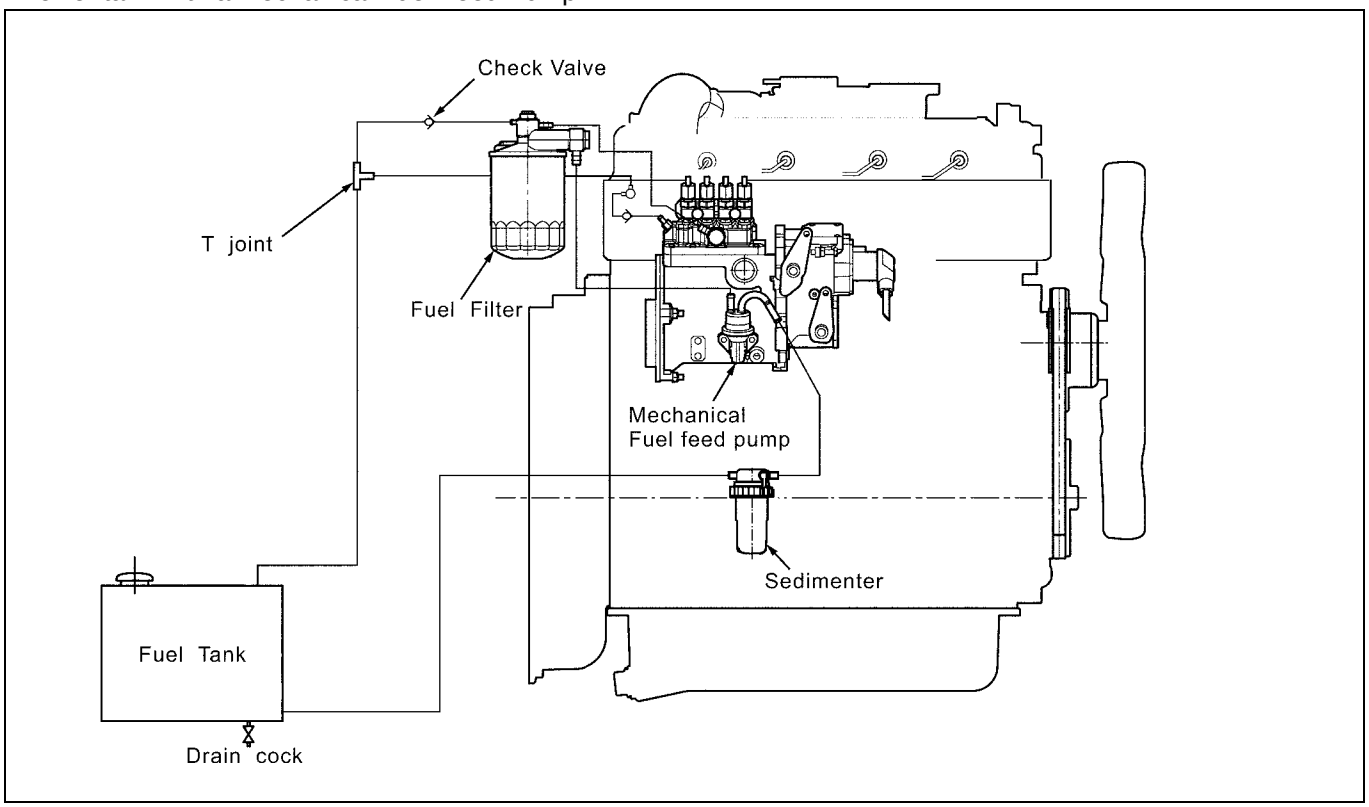



Fig. 4-27

A pre-filter must be installed with suction side of electric fuel pump to protect it.

• Lower tank with an Electric Fuel Feed Pump

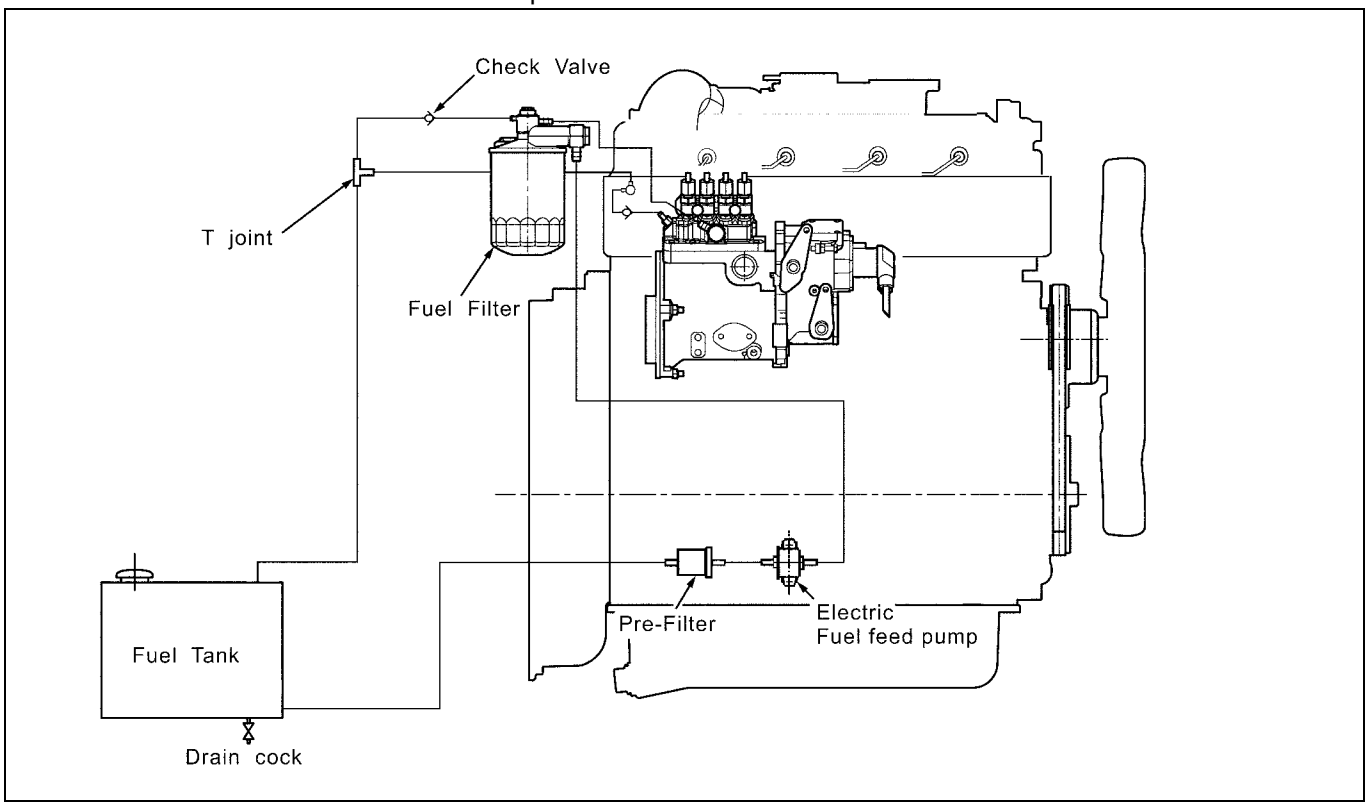



Fig. 4-28

**7) Standard piping for V3 series**

• Upper tank with a Mechanical Fuel Feed Pump

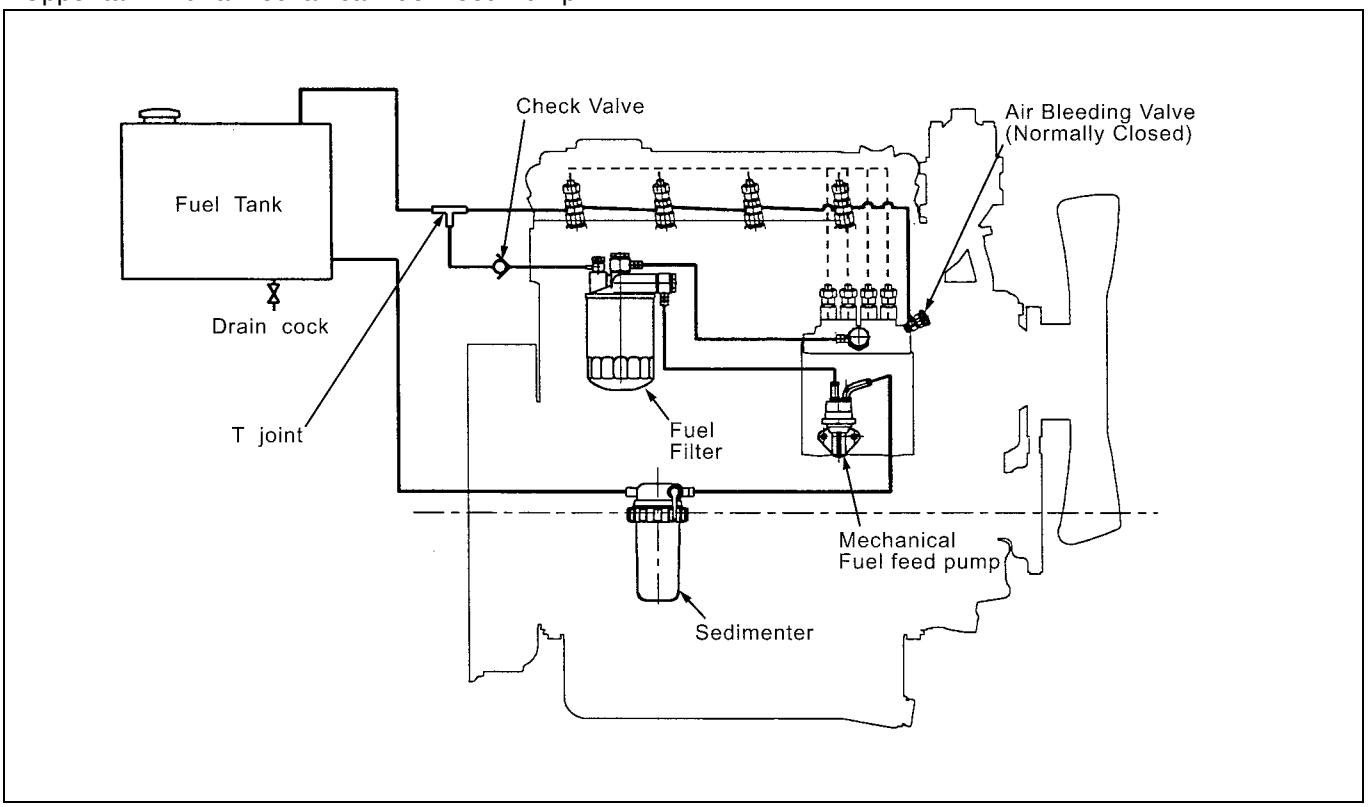



Fig. 4-29

A pre-filter must be installed with suction side of electric fuel pump to protect it.

• Upper tank with an Electric Fuel Feed Pump

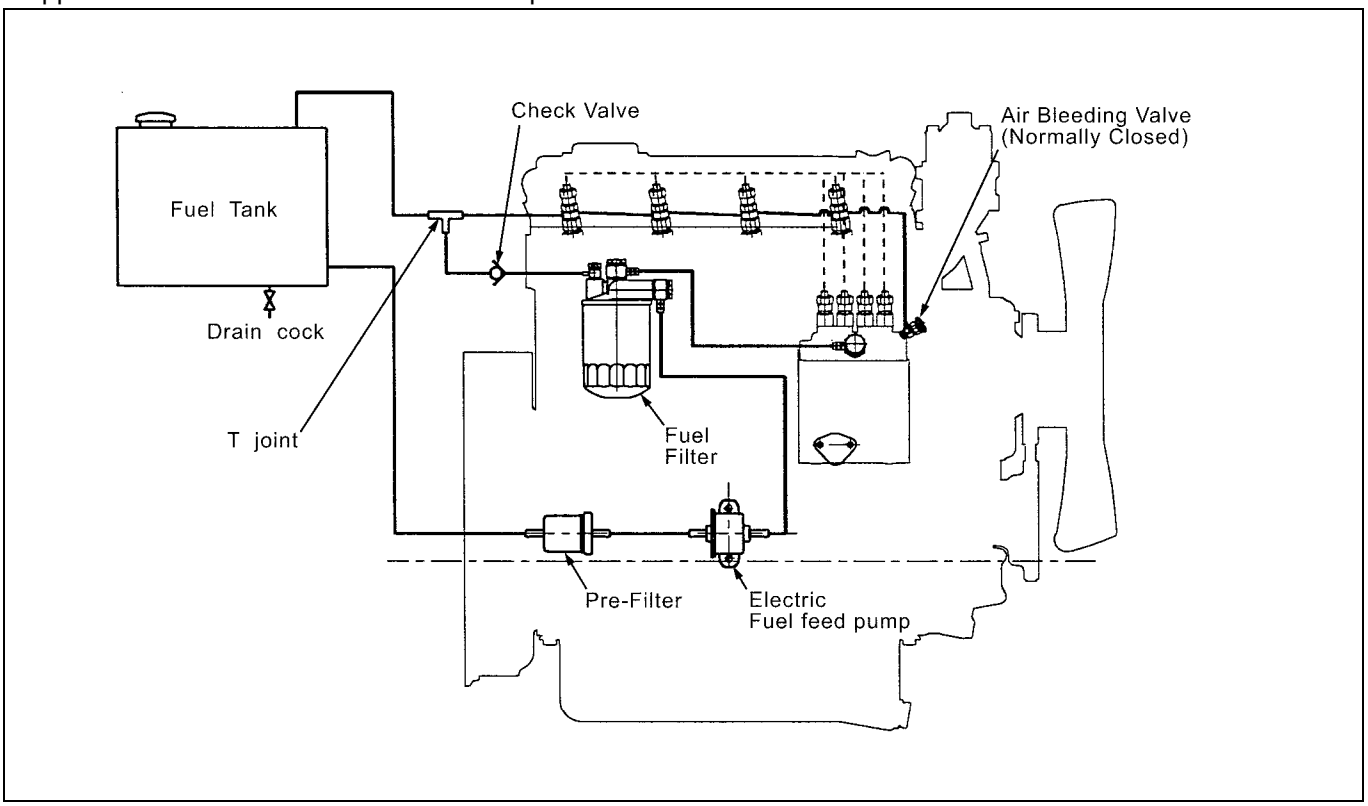



Fig. 4-30

**8) Standard piping for V3 series**

• Lower tank with a Mechanical Fuel Feed Pump

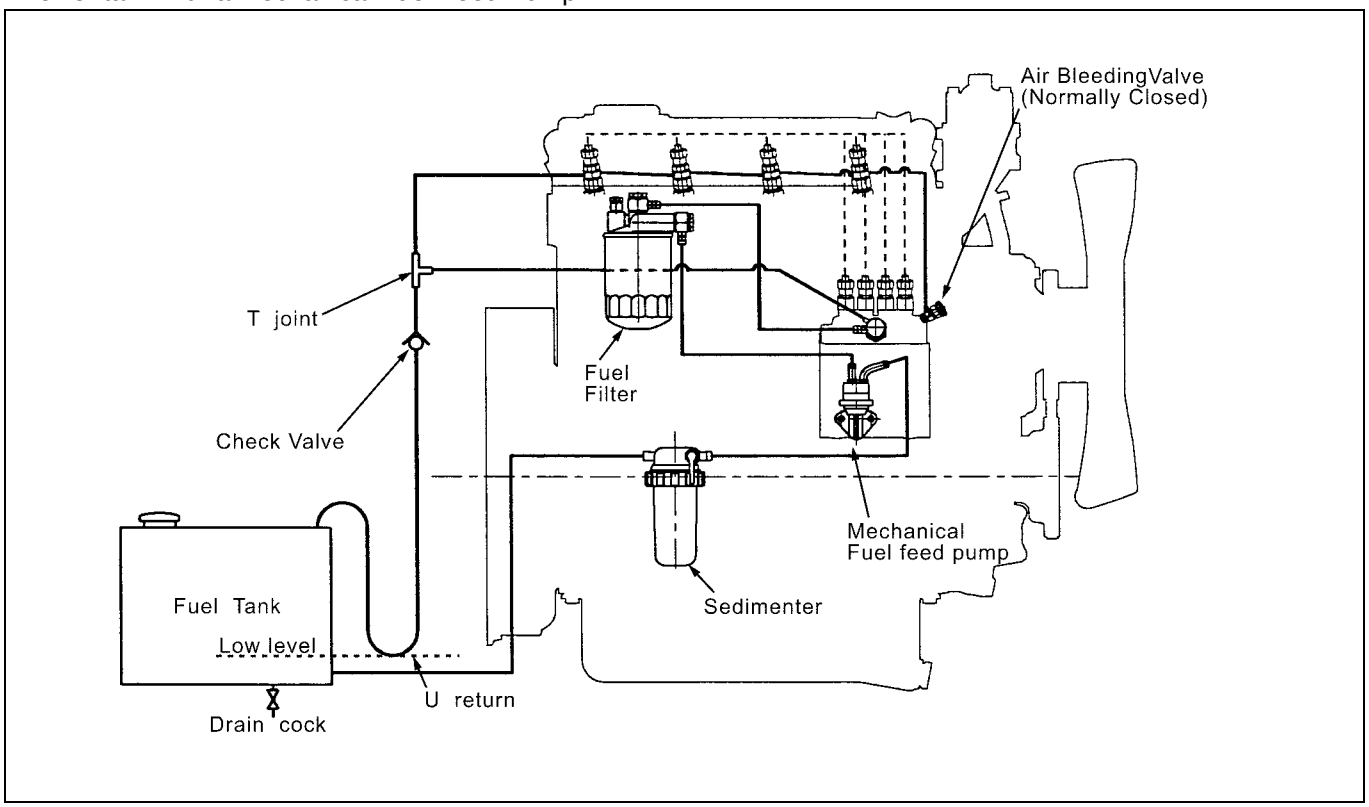



Fig. 4-31

A pre-filter must be installed with suction side of electric fuel pump to protect it.

• Lower tank with an Electric Fuel Feed Pump

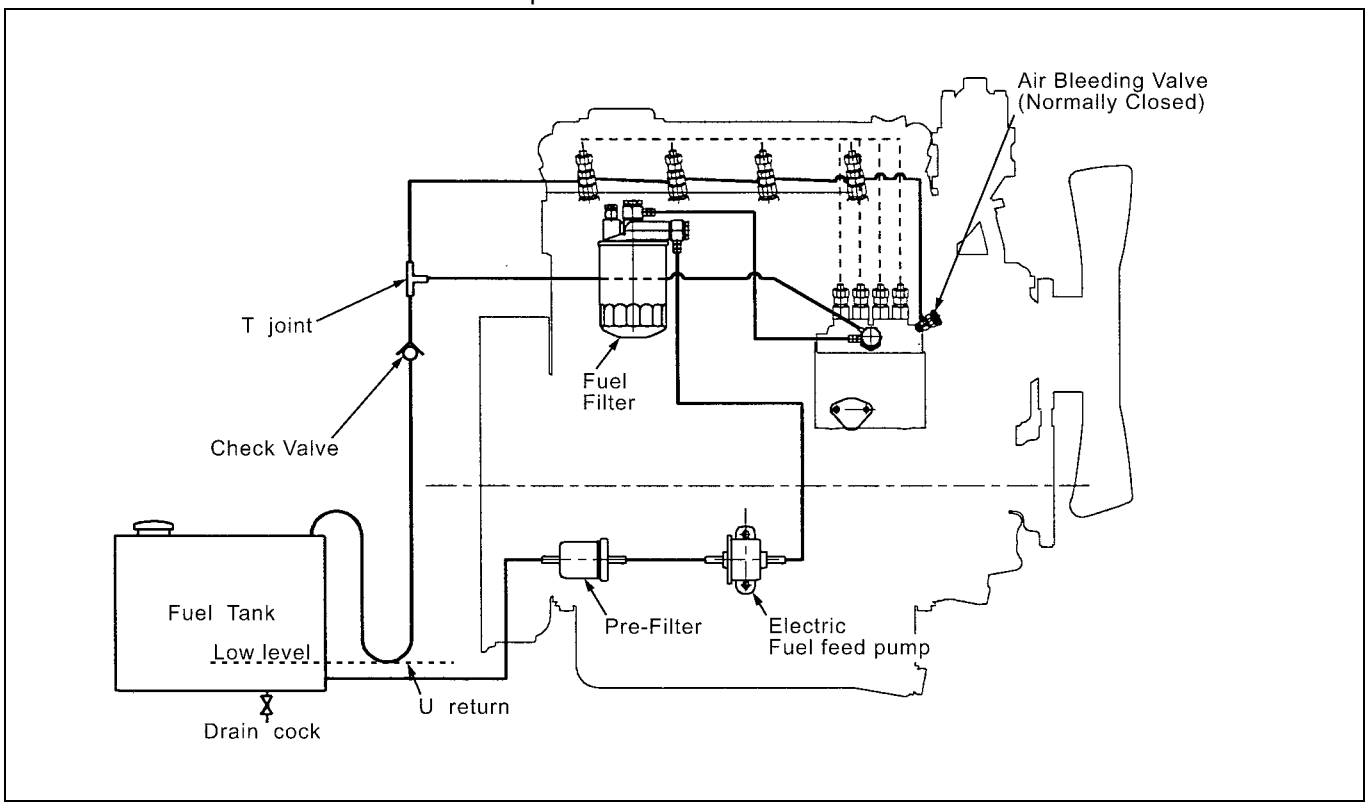



Fig. 4-32

# 9. FUEL

**Fuel standards, grades and recommendations**

Diesel fuels specified to EN590 or ASTM D975 are recommended.

- Since KUBOTA diesel engines of utilize EPA Tier 4 and Interim Tier 4 standards, the use of ultra low sulfur fuel is mandatory for these engines, when operated in US EPA regulated areas. Therefore, please use No.2-D S15 diesel fuel as an alternative to No.2-D, and use No.1-D S15 diesel fuel as an alternative to No.1-D for ambient temperatures below -10 °C (14 °F).
- No.2-D is a distillate fuel of lower voltility for engines in industrial and heavy mobile service. (SAE J313 JUN87)

**Major fuel standards of the world**

1) SAE: Society of Automotive Engineers
2) EN: European Norm
3) ASTEM : American Society of Testing and Materials
4) US EPA : United States Environmental Protection Agency
5) No.1-D or No.2-D, S15: Ultra Low Sulfur Diesel (ULSD) 15 ppm or 0.0015 wt.%

**Note :**
**Don't use kerosen in KUBOTA diesel engines.**

**(1) Requirements for diesel fuel**

The following properties are required of diesel fuel.

1) Good ignitability
2) Appropriate viscosity
3) Low sulfur content
4) Low pour point
5) Good volatility
6) Low residual carbon
7) Free of water and foreign matter

These are described in detail below :

1) Good ignitability
   Fuel with good ignitability burns quickly as it is atomized into the combustion chamber, allowing easy starting and smooth running with a minimum of smoke and noise.
   Therefore, fuel with good ignitability must be used. Ignitability is indicated by the cetane number.

**Recommended fuel cetane rating**

Cetane Rating : The minimum recommended Fuel Cetane Rating is 45. A cetane rating greater than 50 is preferred, especially for ambient temperatures below -20 °C (-4 °F) or elevations above 1500 m (5000 ft).

2) Appropriate viscosity
   Combustion is the engine begins with atomization of fuel, which requires a low viscosity.
   However, penetration of injection is required of the atomized fuel to distribute the atomized particles throughout the combustion chamber, this requires certain amount of viscosity.
   Since fuel is also used to lubricate the plunger and nozzle sliding in the fuel injection subsystem, fuel must have a viscosity sufficient enough to prevent wear and seizure of parts.
   It must not be too viscous, because volatility of the atomized fuel will be reduced and distribution throughout the combustion chamber will be uneven.

3) Low sulfur content
   The sulfur content of fuel must be as low as possible since it contributes to wear of parts and deterioration of oil.
   When a sulfuric compound is burned, it changes to sulfurous acid gas ($SO_2$) and sulfuric anhydride ($SO_3$).

   A large amount of water is also generated in the form of condensation within the engine crankcase. All of these by-products turn into sulfuric acid, which is strongly corrosive. Corrosion in a diesel engine is the result.

**Fuel sulfur content and notes on use**

Diesel Fuel Specification Type and Sulfur Content % (ppm) used, must be compliant with all applicable emission regulations for the area in which the engine is operated.

- Use of diesel fuel with sulfur content less than 0.10 % (1000 ppm) is strongly recommended.
- If high-sulfur (sulfur content 0.50 % (5000 ppm) to 1.0 % (10000 ppm)) is used as a diesel fuel, change the engine oil and filter at shorter intervals. (approximately half)
- DO NOT USE Fuels that have sulfur content greater than 1.0 % (10000 ppm).

**Note :**

- **No.1-D or No.2-D, S15 : Ultra Low Sulfur Diesel (ULSD) 15 ppm or 0.0015 wt.%**
- **Use of high sulfur fuel in an external EGR system prohibited.**

4) Low pour point
Fuel must have a low pour point to run smoothly from the fuel tank to the filter and through the fuel pipe of the fuel pump in cold weather.
A low pour point and a good ignitability have contradicting effects since low pour point fuel generally has low cetane number.

5) Good volatility
Fuel is atomized, vaporized and mixed with air before ignition at the combustion of diesel engine. Fuel must have a good volatility to become vaporized and burn quickly.
Any unvaporized oil will cause soot and smoke, and eventually contaminate the oil. Fuel with good volatility burns more completely, minimizing fuel combustion, lowering the exhaust gas temperature and does not generate black smoke.

6) Low residual carbon
Residual carbon is the carbonic residue that is generated during vaporization and decomposition of oil.
Although residual carbon and carbon accumulation in the engine have no direct relationship, they should be minimized.

7) Free of water and foreign matter
The fuel pump in a diesel engine is extremely precise, even the smallest trace of foreign matter can critically affect the fuel injection mechanism. Dust or dirt in the air or a solid matter such as iron rust in the fuel must be eliminated. Water may become mixed with fuel during storage or transportation. Most of it is removed as it settles in storage. Colloidal water floating or dissolved in water (0.1 to 0.5%) can enter the combustion chamber. Diesel fuel containing water loses its ignitability, adversely affecting combustion performance. Water must also be eliminated since it will freeze in cold temperature and block filtration.

**(2) Cetane number**

Cetane numbers indicate the anti-diesel knocking characteristics of fuel. The cetane number is measured in a similar way as an octane number using standard CFR testing engines.

A standard fuel is a mixture of n-cetane and αmethylnaphthalene. The former indicates the lowest knocking point, its cetane number is defined as 100. The latter has the greatest knocking points, its cetane number is defined as 0. Knocking of the standard fuel and the sample fuel is compared on testing engines by changing the mixing ratio of the two components in the standard fuel until both engines show equal knocking characteristics. The percentage of n-cetane at this point in a standard fuel is then taken as the cetane number of the sample fuel. Anti-knocking characteristics of fuel oil can also be indicated by diesel indexes and cetane indexes, which are derived from results of characteristics tests without using testing engines.

The cetane number for KUBOTA diesel engines must not be less than 45.

**(3) Fuel ratings**

Fuel ratings vary in different countries. Fuel must be chosen according to the operating temperature and emission regulations. Fuel feed will be adversely affected if a fuel is used in a temperature below its pour point.

Japan (JIS K2204)

1) Applicable range : This regulation specifies the diesel fuel to be used for diesel engines (mainly for automobiles).

2) Type : Diesel fuel is classified into five types, i.e., Special No.1, No.1, No.2, No.3, and Special No.3, according to each pour point.

3) Requirements

★ General matters

Diesel fuel is mainly composed of refined mineral oil having proper quality as the fuel oil for diesel engines (mainly those for automobiles), and it shall not include water and sediments.

★ Required quality

The property of diesel fuel should be within the range specified in the table below.

| Property Class of fuel | Flash point °C (°F) | Distillation (90% distillation temperature in °C (°F) | Pour point °C (°F) | Mass % of residual carbon in 10% residual oil | Cetane (2) | Kinematic viscosity 30 °C (86 °F) $mm^2/s$ (cSt) (3) |
|---|---|---|---|---|---|---|
| Special No.1 | Over 50 (122) | Below 360 (680) | Below +5 (41) | Below 0.1 | Over 50 | Over 2.7 |
| No.1 | Over 50 (122) | Below 360 (680) | Below -2.5 (27.5) | Below 0.1 | Over 50 | Over 2.7 |
| No.2 | Over 50 (122) | Below 350 (662) | Below -7.5 (18.5) | Below 0.1 | Over 45 | Over 2.5 |
| No.3 | Over 45 (113) | Below 330 (626) (1) | Below -20 (-4) | Below 0.1 | Over 45 | Over 2.0 |
| Special No.3 | Over 45 (113) | Below 330 (626) | Below -30 (-22) | Below 0.1 | Over 45 | Over 1.7 |

**Note :**

**(1) It is below 350 °C (662 °F) in case of Kinematic viscosit 30 °C (86 °F) is below 4.7 $mm^2/c$ (4.4 cSt).**

**(2) It is possible to use cetane number.**

**(3) 1 $mm^2/s$ = 1 cSt**

U.S.A. (SAE J313)

Abstract :

Automotive and railroad diesel fuels, in general, are derived from petroleum refinery products which are commonly referred to as middle distillates. Middle distillates represent products which have a higher boiling range than gasoline and are obtained from fractional distillation of the crude oil or from streams from other refining processes. Finished diesel fuels represent blends of middle distillates. The properties of commercial distillate diesel fuels depend on the refinery practices employed and depend on the refinery practices employed and the nature of the crude oils from which they are derived.

Thus, they may differ both with and within the region in which they are manufactured. Such fuels generally boil over a range between 163 and 371 °C (325 and 700 °F). Their makeup can represent various combinations of volatility, ignition quality, viscosity, sulfur level, gravity, and other characteristics.

Additives may be used to impart special properties to the finished diesel fuel.

| Grade of Diesel fuel oil | Flash point °C (°F) | Distillation Temperatures °C (°F) 90% Point | Viscosity Kinematic cSt or $mm^2/s$ at 40 °C (104 °F ) | Cetane Number |
|---|---|---|---|---|
| No.1-D | 38 (100) | Below 288 (550) | 1.3 to 2.4 | Over 40 |
| No.2-D | 52 (125) | 282 to 338 (540 to 640) | 1.9 to 4.1 | Over 40 |

**(4) Biodiesel fuel (B5/B7)**

Kubota only permits to use the biofuel (BDF) that satisfies the following conditions 1) - 4).

In using the biofuel (BDF), pay enough attention to the storing methods, using methods, and maintenance methods of the engine described in the following clauses of 5) to 14) while understanding the characteristics of the biofuel.

Conditions for the biofuel

1) Only the fuel that contains 5 % (B5) or 7 % (B7), or lower volume mixing ratio of 100 % BDF (B100) in the mineral diesel fuel can be used.
2) The mineral diesel fuel shall be according to the newest edition of EN590 (Europe) or ASTMD975 (USA), while the B100 to be mixed shall be according to the newest edition of EN14214 (Europe) or ASTMD6751 (USA) standards. The final mixture fuel B5/B7 shall, also, be according to the newest edition of E590 (Europe). Raw expressed vegetable oil cannot be used.
3) B100 or the mixed fuel B5/B7 shall be purchased from the reliable manufacturers or dealers (in USA, the one accredited by BQ-9000). (Because on-the-site mixing tends to cause uneven mixing, it is recommendable to purchase the B5/B7 that has been mixed at the manufacturer's factory in advance.)
4) Uses of Kubota Emission Certified Engines are responsible for obtaining any appropriate local, state and national exemptions required for the use of BDF.

Characteristics, storing procedures, and maintenance cautions of the biofuel

5) To prevent accumulation of moisture in the fuel tank, keep the fuel tank full as much as possible. Also, surely tighten the cap of the fuel tank to prevent moisture intrusion.
6) Confirm the engine oil level before starting the engine every day. Also, keep strictly the engine oil change interval because the delay in the engine oil change causes damages to the engine.
7) In the cold weather, take special care because clogging of the fuel lines can cause such problems as starting failures.
8) Be careful that BDF tends to aggravate multiplication of and contamination by microorganisms, which can causes such malfunctions like corrosion of the fuel Bsystem or too early clogging of the fuel filter.
9) Pay careful attention to the following cautions, because the fuel (BDF) during refueling and in the fuel tank tends to deteriorate by oxygen, water, heat, and foreign matters.
   a) Do not store the fuel in the fuel tank or in drums for longer than 3 months.
   b) In the case of the prolonged parking or storage of the vehicle, wash the engine by idling it using the conventional mineral diesel oil for at least 30 minutes.

10) BDF is hygroscopic and, therefore, tends to contain higher moisture content than the conventional diesel fuel. Accordingly, the intervals of the fuel filter cleaning and exchange, the fuel pipe check and exchange, the nozzle check and exchange, and the fuel system maintenance and check shall be shorter than those for the conventional mineral diesel fuel.
    In addition, use of a sedimenter is strongly recommended.
11) When the biodiesel fuel is spilled on a painted surface, immediately wipe it off because it can damage the painting.
12) If the biodiesel fuel of higher concentration than B7 is used, it is possible to deteriorate the output and fuel consumption. Also, the higher concentration biodiesel fuel than B7 can corrode the brass/zinc parts and rubber/resin products of the fuel system. Therefore, never use the higher concentration biodiesel fuel than B7.
13) The adjustment of the tamper parts (fuel confinement) of the engine under the use of the biodiesel fuel is deemed to be an illegal activity to the emission regulation and punished. Never execute such adjustments.
14) The BDF of palm-oil-base has lower low-temperature fluidity than the BDF of soybean/rape seed-oil-base. Therefore, pay special attention to the fact that it can cause the fuel filter clogging during the cold season.