

KMOU Division of Marine System Engineering

Introduction to Internal Combustion Engine



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Lesson content for each week

Ch0_Introduction to the Class

Ch1_Overview of the Internal Combustion Engine

Ch2_Thermodynamics and Compressed Air System

Ch3_Marine Fuels and Internal Fuel Oil System

Ch4_Intake and Exhaust System

Ch5_Turbocharger

Midterm

Ch6_Piston Fittings and Crankshaft

Ch7_Lube Oil System

Ch8_Cooling Water System

Ch9_Introduction to the Main Engine

Ch10_Alternative Fuels and Alternative Fuel Systems

Ch11_Environmental Regulations and Exhaust Gas Aftertreatment Systems

Ch12_Tools, Apprentice Engineer Duties, and Career Direction

Final Exam

4-stroke ICE (G/E)

Inside the G/E cylinder, atomized fuel injected from the fuel injection nozzle and pressurized air supplied by the turbocharger are mixed and exploded, pushing the piston downward to reciprocate and generate rotational power.

The goal of this chapter is to learn about the fuel used on ships and the fuel supply system.



Marine fuels

The fuels typically used on ships are as follows:

HFO : Heavy Fuel Oil

VLSFO : Very Low Sulfur (Sulphur) Fuel Oil

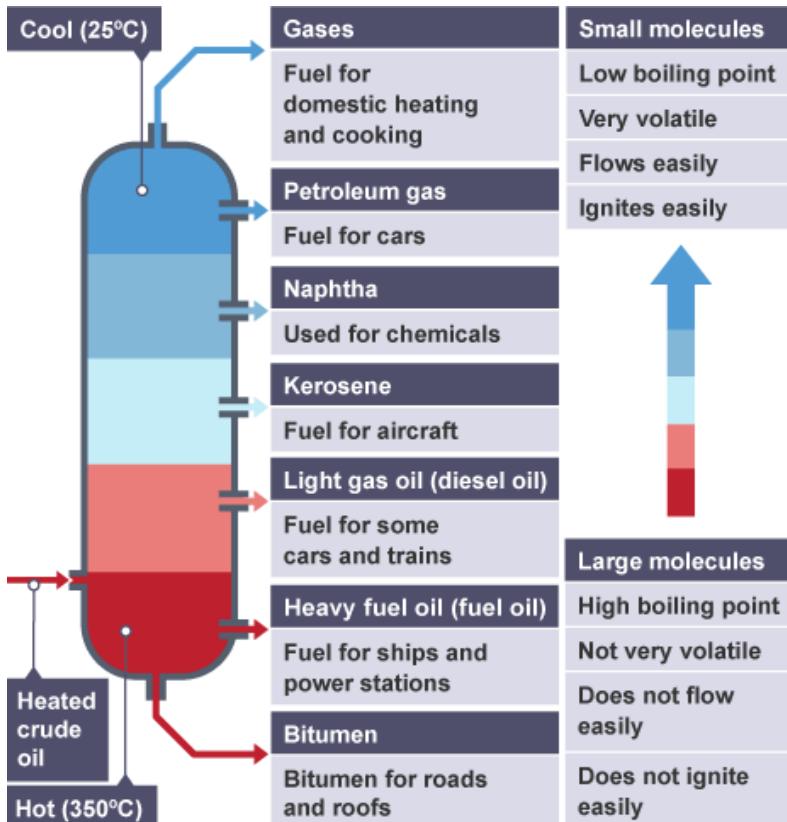
MDO : Marine Diesel Oil

MGO : Marine Gas Oil

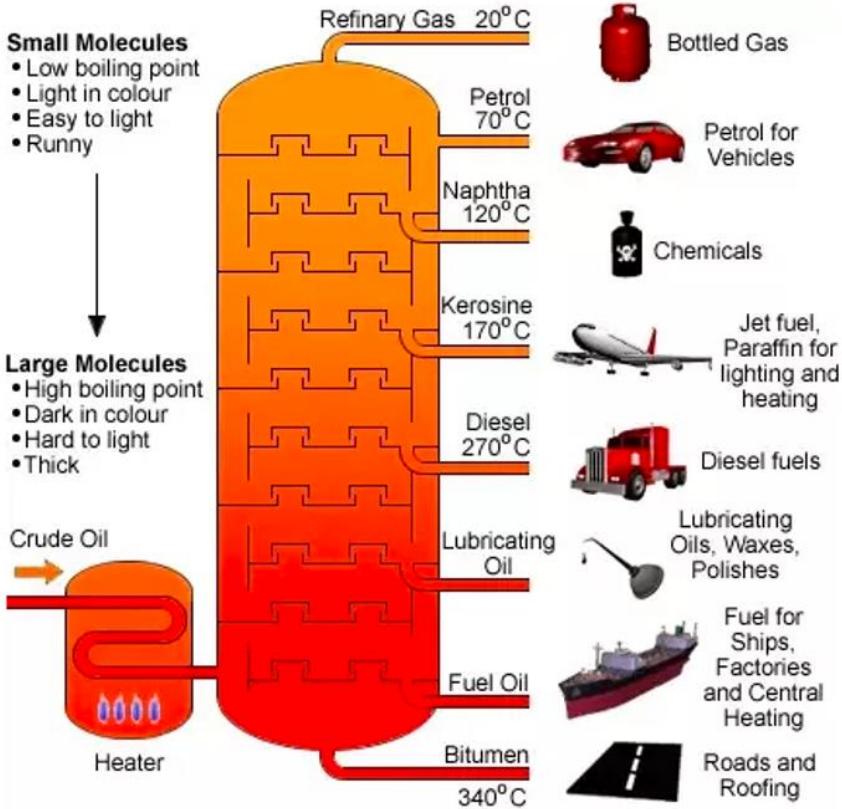
LSMGO : Low Sulfur Marine Gas Oil

Marine fuels

Fractional distillation of crude oil



Fractional distillation of crude oil



Marine fuels

Crude oil



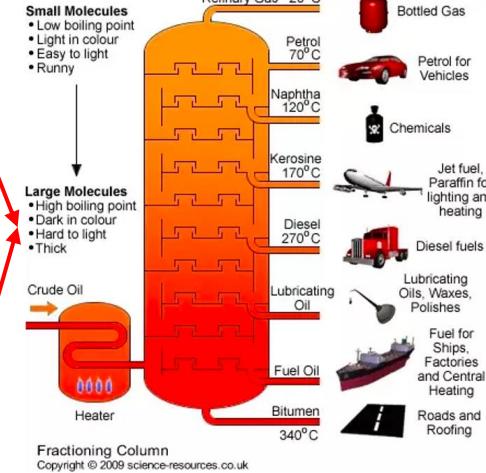
Crude oil tanker



Yeosu complex



Ulsan complex



Marine fuels



HFO (Heavy Fuel Oil):

HFO is a category of fuel oils of a tar-like consistency.

Also known as bunker fuel, or residual fuel oil, HFO is the result or remnant from the distillation and cracking process of petroleum.

For this reason, HFO contains several different compounds that include aromatics, sulfur, and nitrogen, making emissions upon combustion more polluting compared to other fuel oils.

HFO is predominantly used as a fuel source for marine vessel propulsion using marine diesel engines due to its relatively low cost compared to cleaner fuel sources such as distillates.

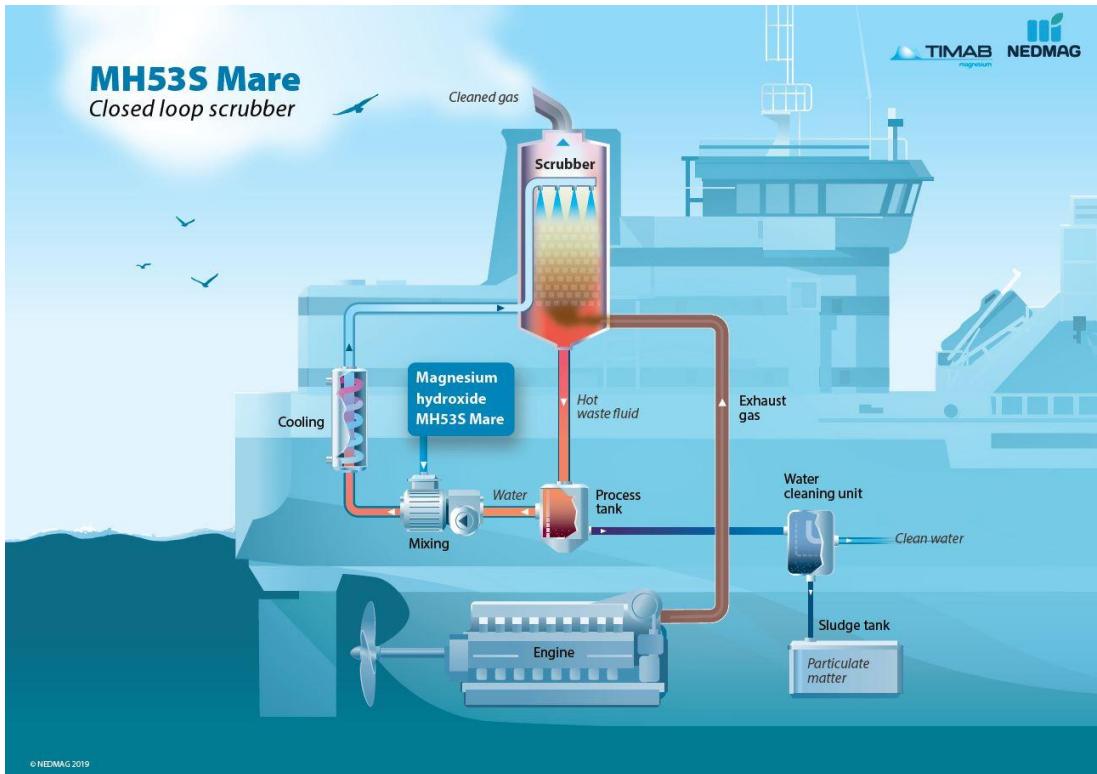
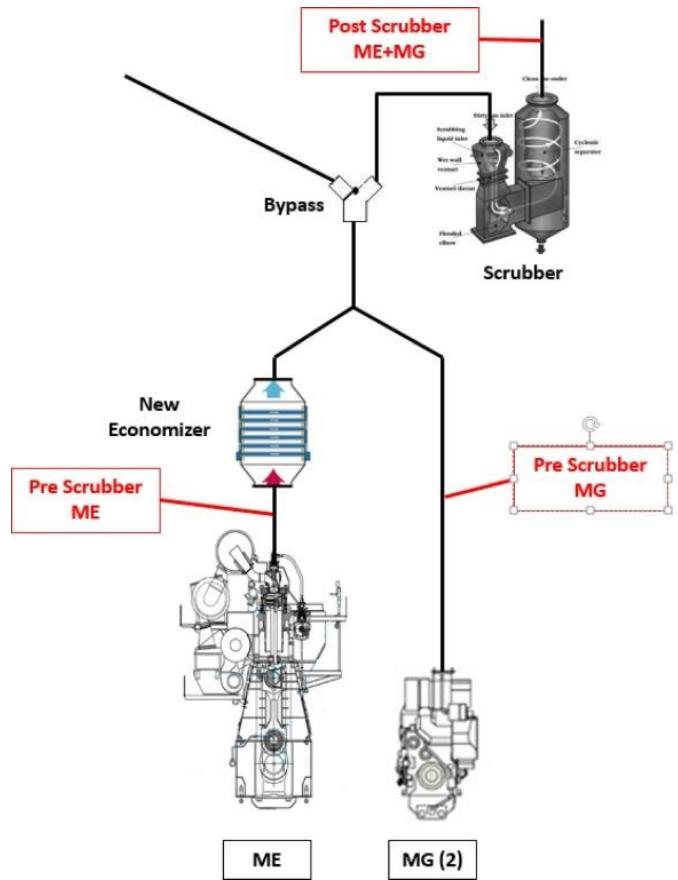
The use and carriage of HFO on-board vessels presents several environmental concerns, namely the risk of oil spill and the continuous emission of toxic compounds and particulates including black carbon, sulfur and para-aminohippuric acid (PAH).

Because HFO has high viscosity and is sticky, it is always heated by boiler steam for use in engines.

HFO designated as high-sulfur fuel oil (HSFO): $0.5\% < \text{sulfur content} \leq 3.5\%$.

Due to environmental regulations, the use of HFO requires the installation of a scrubber device on the exhaust side of the engines (M/E and G/E) to reduce sulfur oxide (SOx) emissions.

Scrubber



Marine fuels

VLSFO (Very Low Sulfur Fuel Oil):

VLSFO is a type of fuel oil with a sulfur content of 0.5% or less by weight.



The creation of VLSFO was primarily driven by the International Maritime Organization's (IMO) regulation, known as IMO 2020, which mandated a hefty reduction in the sulfur content of ship fuels from 3.5% to 0.5% starting January 1, 2020.

This regulation aims to decrease the amount of sulfur oxide emissions from ships.

VLSFO has become the preferred choice for many due to its lower fuel cost compared to MGO and less complex implementation compared to fitting scrubbers.

Ultra Low Sulphur Fuel Oil (ULSFO) are fuels with a sulfur content not exceeding 0.10% S.

Marine fuels

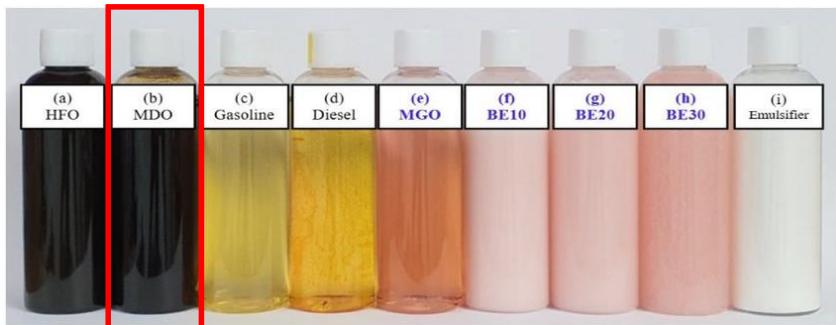
MDO (Marine Diesel Oil):

MDO is a type of fuel oil and is a blend of gasoil and HFO.

MDO is also called distillate marine diesel.

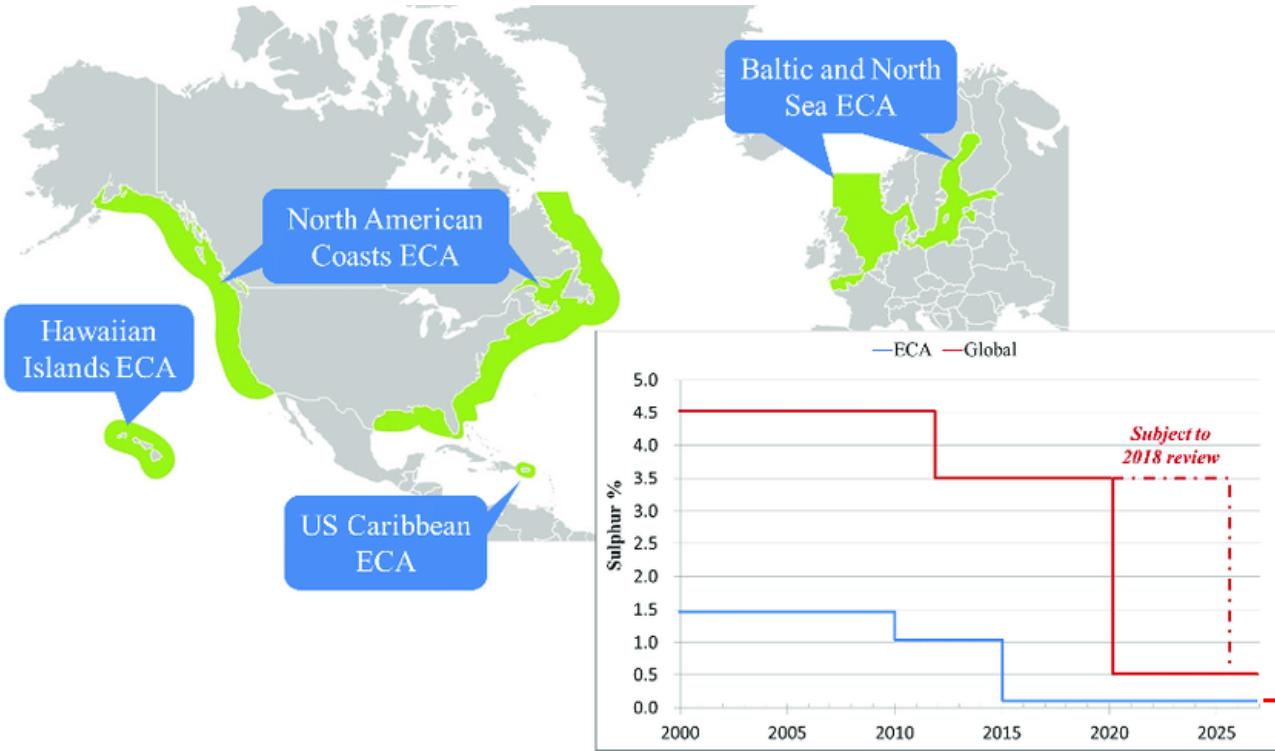
MDO does not need to be preheated before using, while HFO and VLSFO need to be preheated.

MGO is increasingly being used instead of MDO for use in areas (SECA: Sulfur Emission Control Area) subject to sulfur content regulations.



Marine fuels

SECA: Sulfur Emission Control Area



Marine fuels

MGO (Marine Gas Oil):

MGO refers to marine fuels that consist solely of distillates, the components of crude oil that evaporate in fractional distillation and are then condensed from the gas phase into liquid fractions.

Distillates are all those components of crude oil that evaporate in fractional distillation and are then condensed from the gas phase into liquid fractions. MGO usually consists of a blend of various distillates.

MGO is similar to diesel but has a higher density, and unlike HFO, MGO doesn't require heating during storage.



Marine fuels

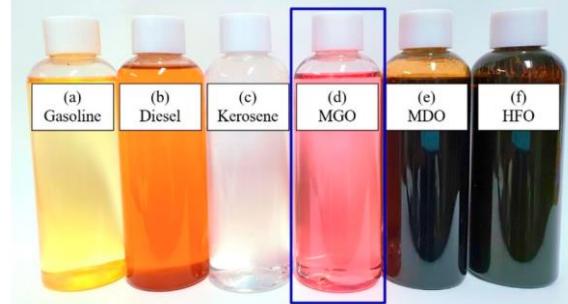
LSMGO (Low Sulfur Marine Gas Oil):

MGO is produced with varying degrees of sulfur content, though the maximum permissible sulfur content of MGO lies below that of HFO.

LSMGO has a sulfur content of less than 0.1%.

This marine fuel can be used in EU ports or Emission Control Areas (ECAs), which among other things impose a sulfur emissions limit corresponding to that of LSMGO.

For this reason, most shipping companies use a LSMGO in these places.



Marine fuels

How is marine fuel loaded onto a ship? (This is called bunkering)

- 1) Bunker Barge (Most ships receive their fuel from bunker barges to load large quantities of fuel onto the ship.)



Bunkering manifold

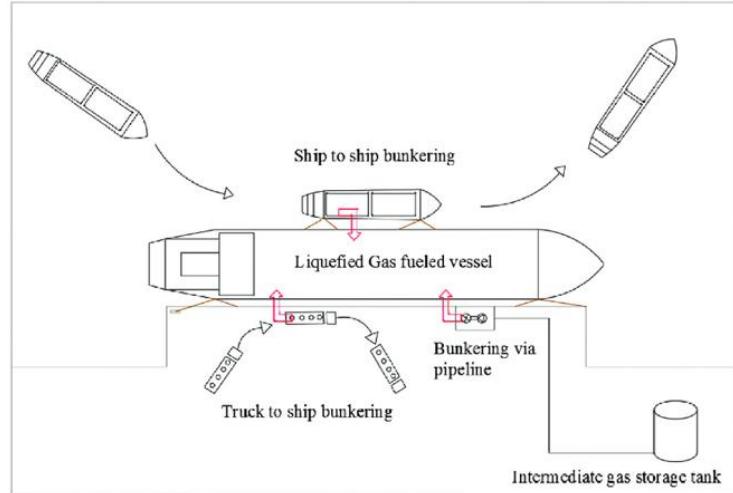
Hose from
bunker barge



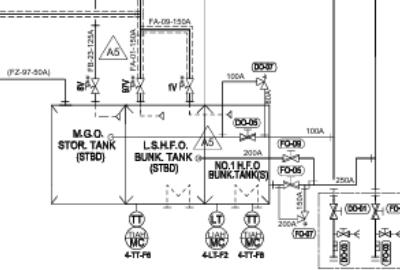
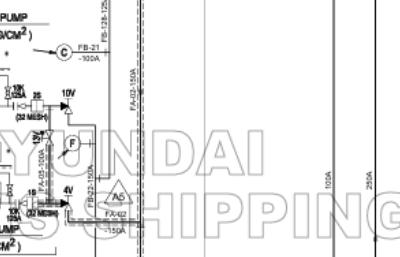
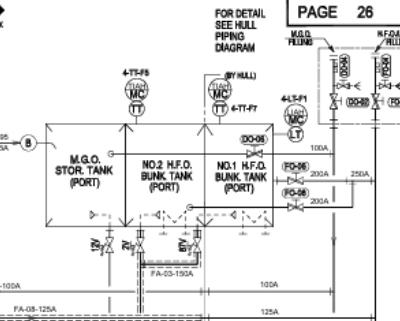
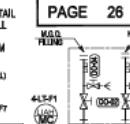
Marine fuels

How is marine fuel loaded onto a ship?

2) Tank Lorry (Tank lorries can be used when supplying MGO to ships in small quantities. However, in most cases, all fuel is supplied by bunker barges. Tank Lorries are mostly used to supply lubricants.)

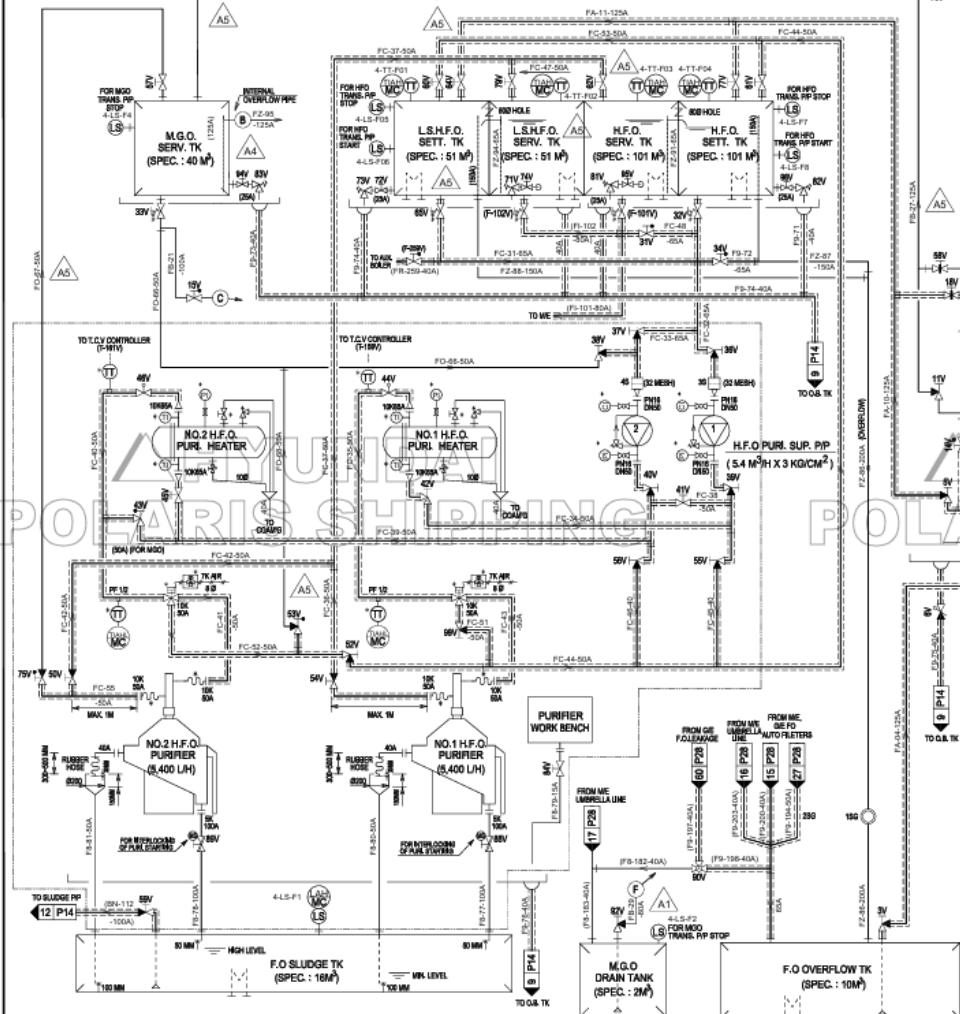


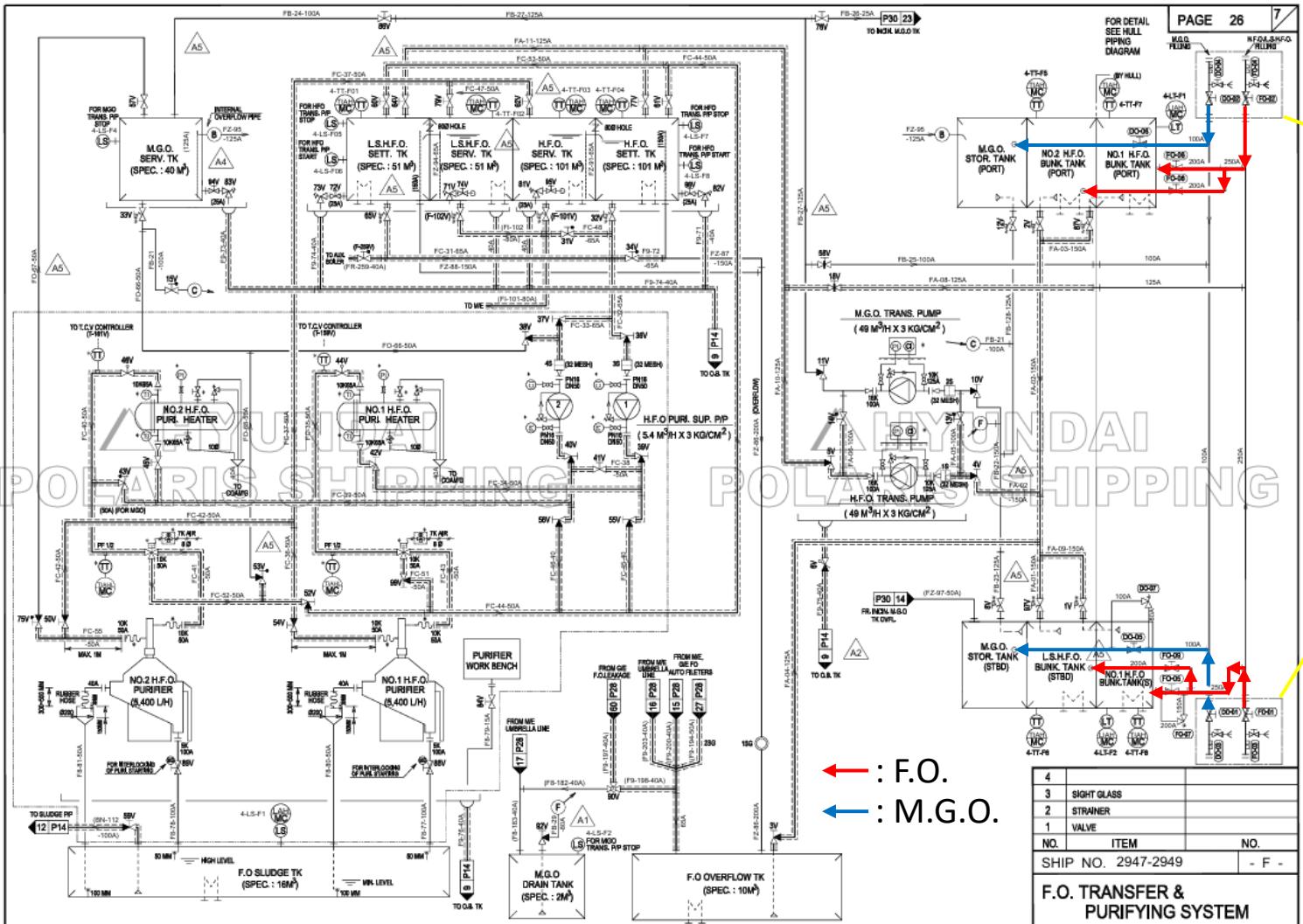
FOR DETAIL
SEE HULL
PIPING
DIAGRAM



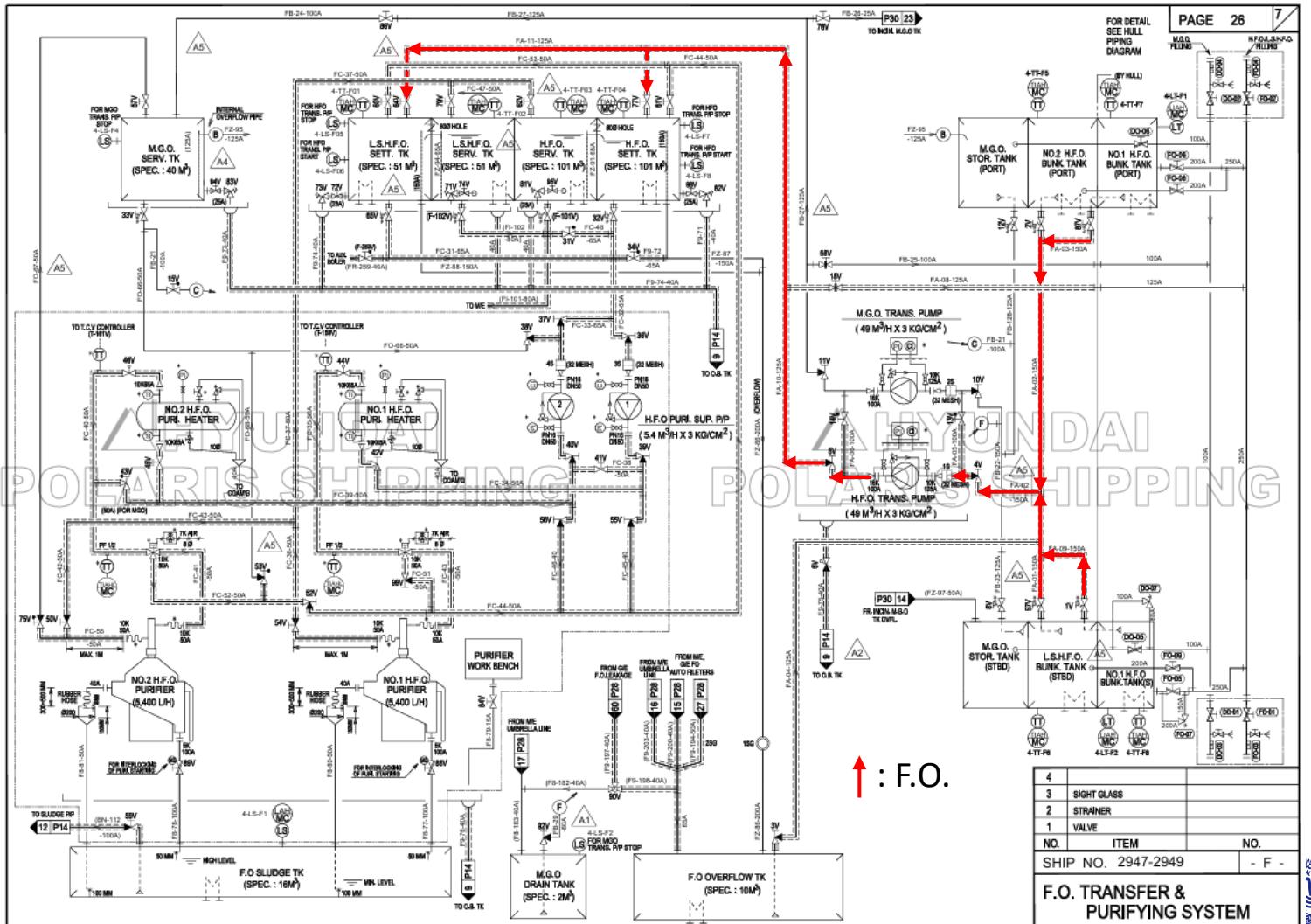
NO.	ITEM	NO.
4		
3	SIGHT GLASS	
2	STRAINER	
1	VALVE	
NO.	ITEM	NO.
SHIP NO.	2947-2949	- F -
F.O. TRANSFER & PURIFYING SYSTEM		

POLARIS SHIPPING POLARIS SHIPPING





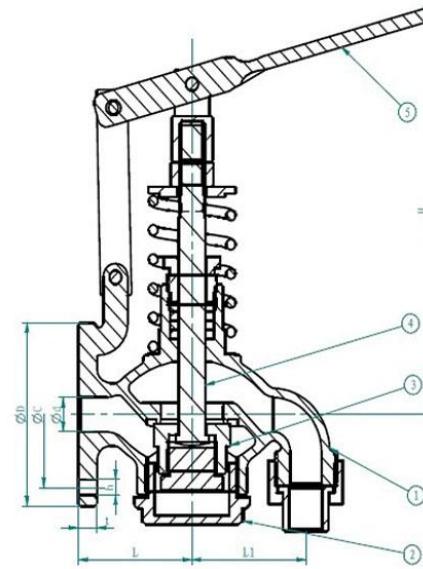
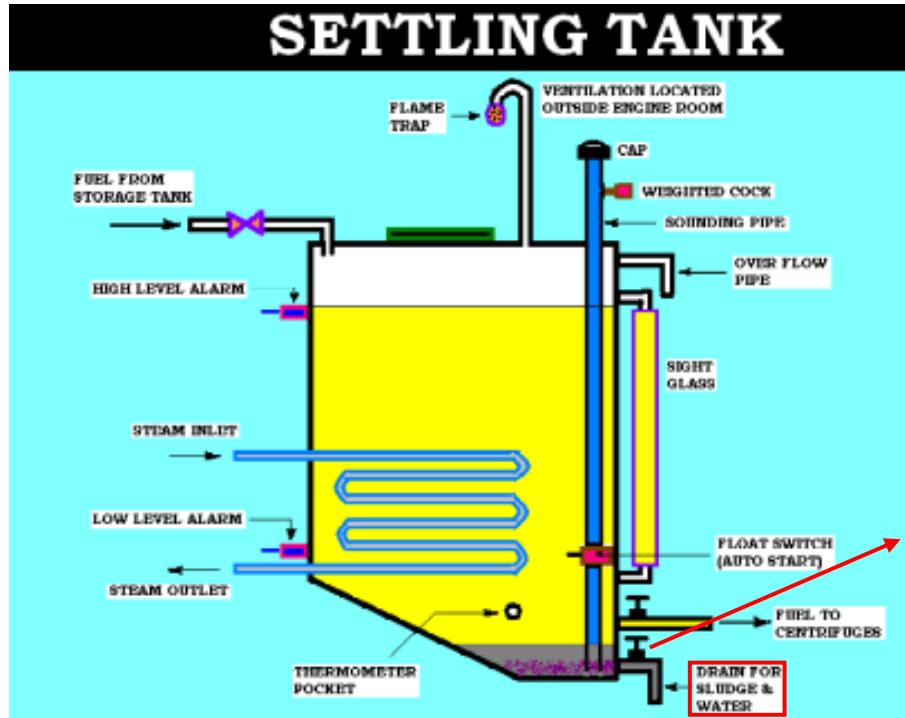
Fuel supplied from the bunker barge is stored in oil storage tanks (H.F.O. tank or M.G.O tank) from the bunker manifold.

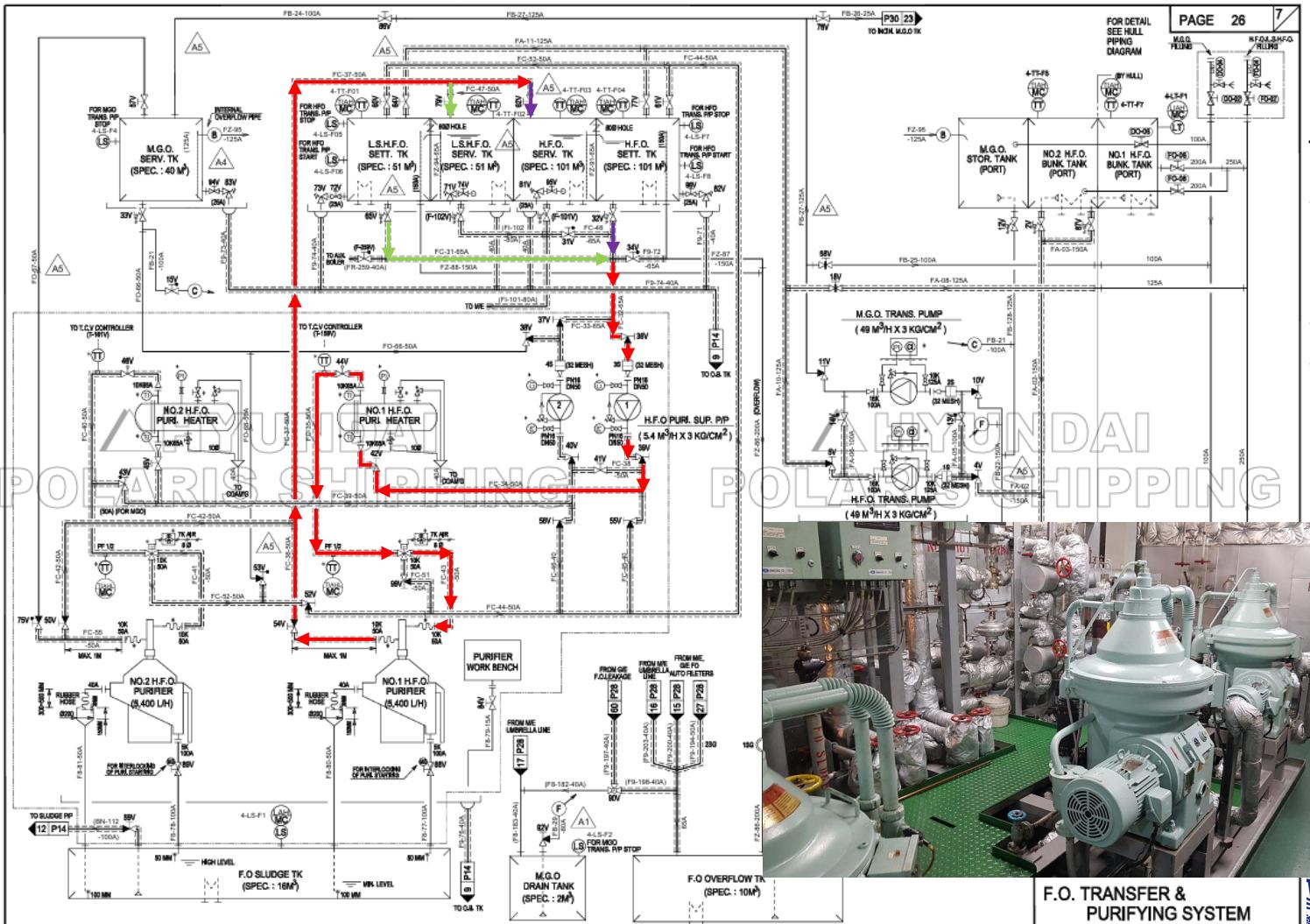


The oil in the H.F.O. tank is sent to the H.F.O. settling tank by the H.F.O. transfer pump.

Drain for F.O. tanks

Since sludge and water accumulate at the bottom of every FO tank, apprentice engineers usually drain it twice a day.



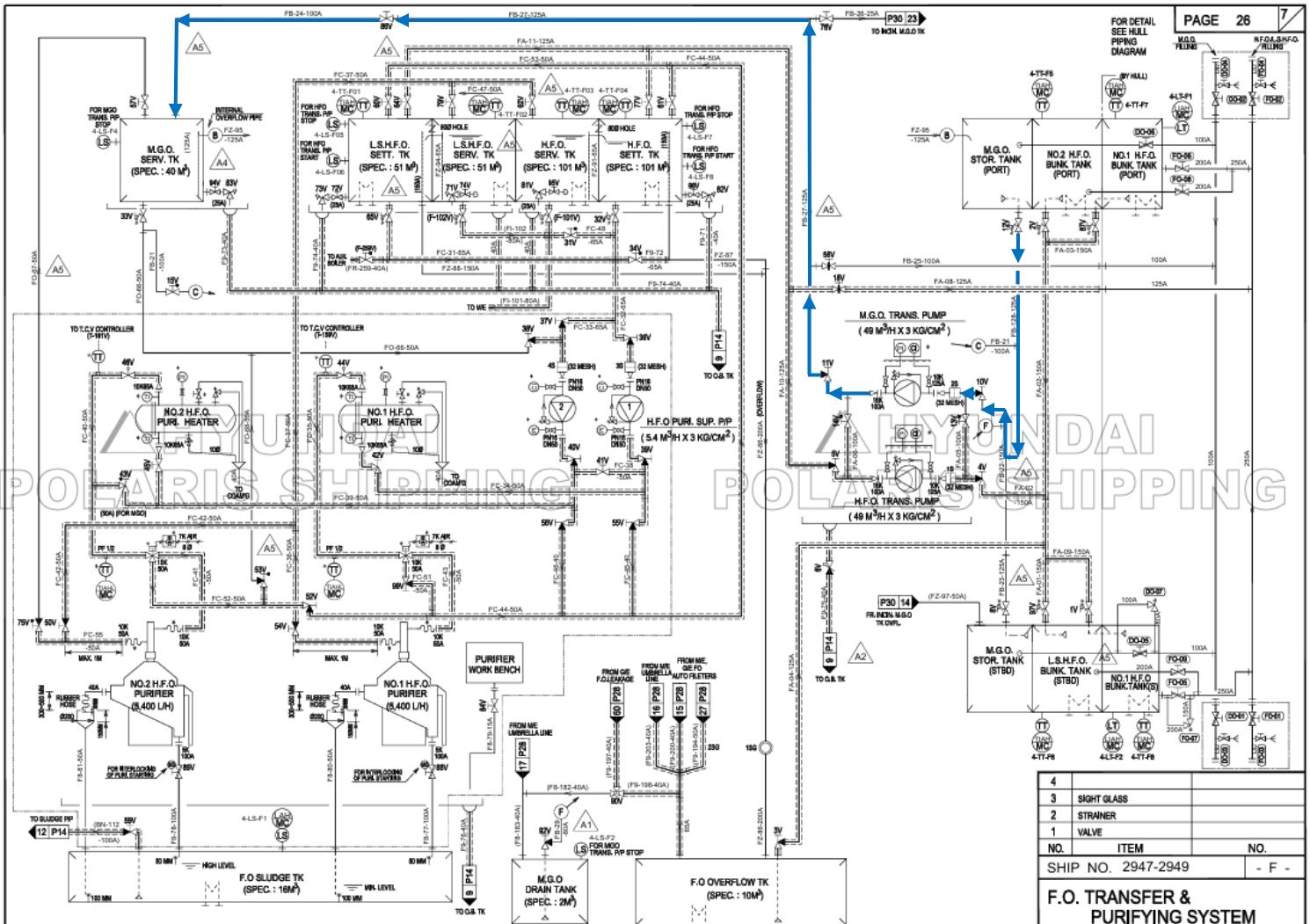


The oil in the H.F.O. sett. tank is purified by the H.F.O. purifier and then sent to the H.F.O. serv. tank.



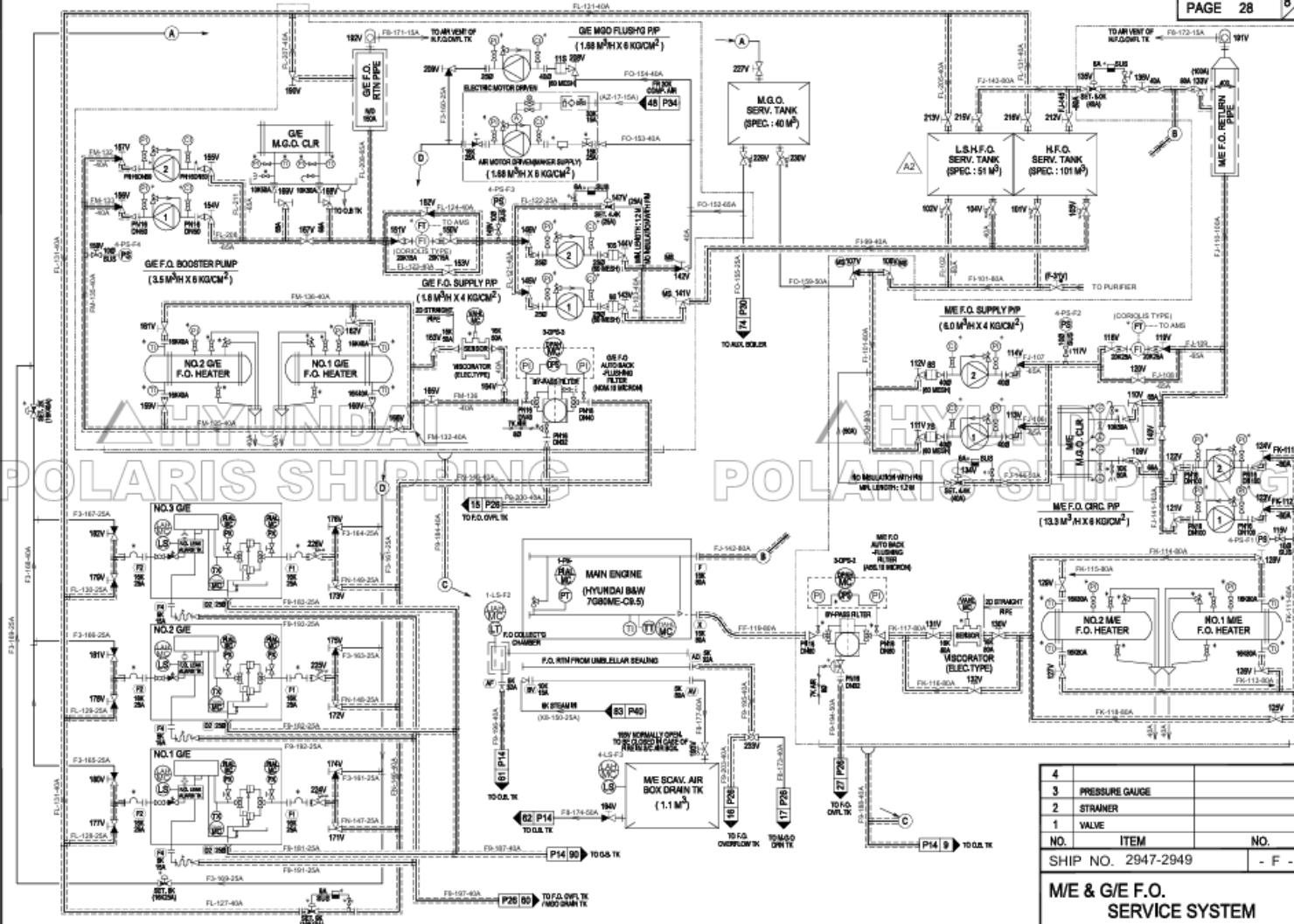
— : H.F.O.
— : L.S.H.F.O.
— : Common

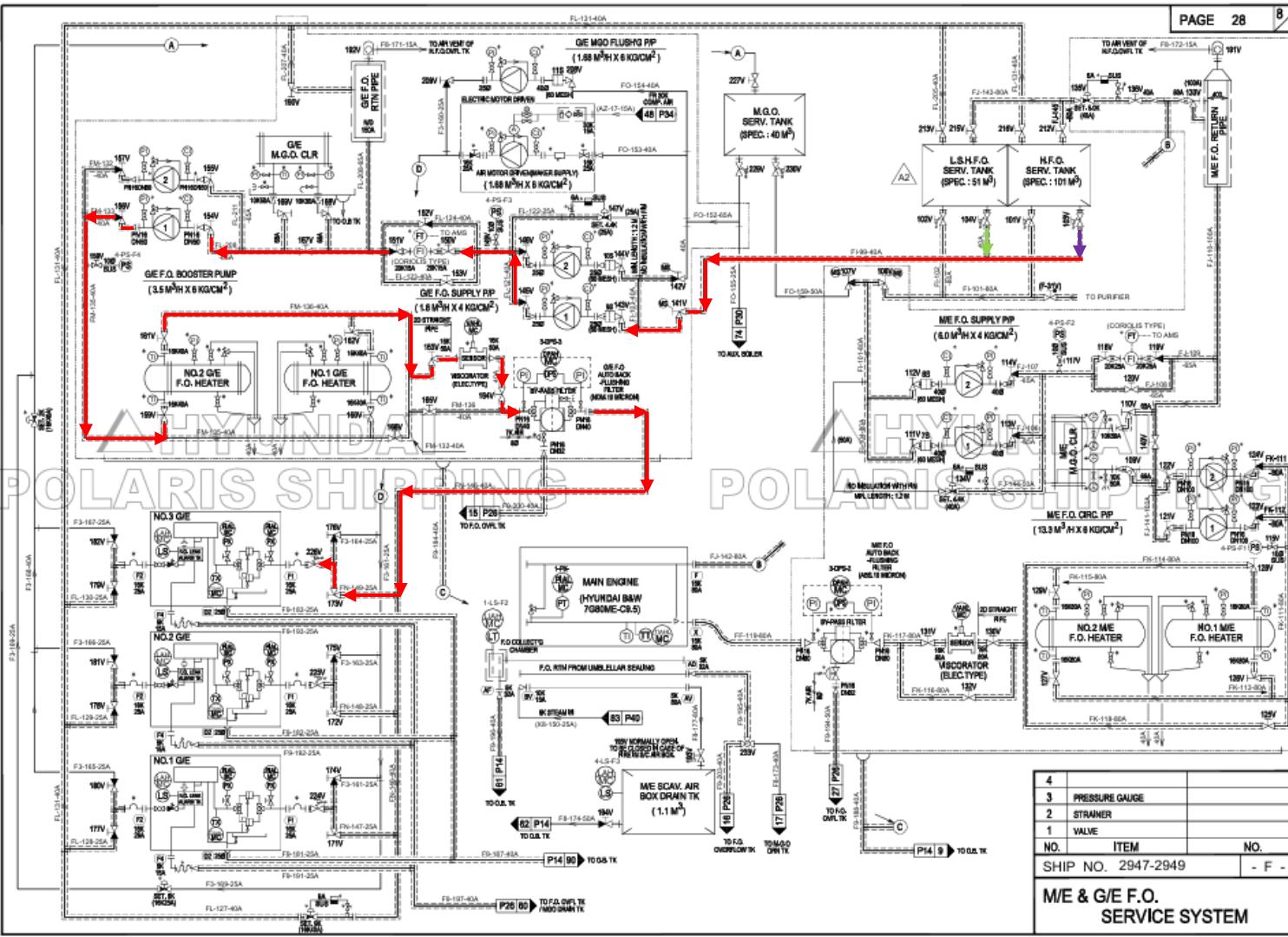
F.O. TRANSFER &
PURIFYING SYSTEM



Since MGO does not need to be purified, it is sent from the M.G.O. stor. tank to the M.G.O. serv. tank by the M.G.O. trans. pump.

4		
3	SIGHT GLASS	
2	STRAINER	
1	VALVE	
NO.	ITEM	NO.
SHIP NO.	2947-2949	- F -
F.O. TRANSFER & PURIFYING SYSTEM		

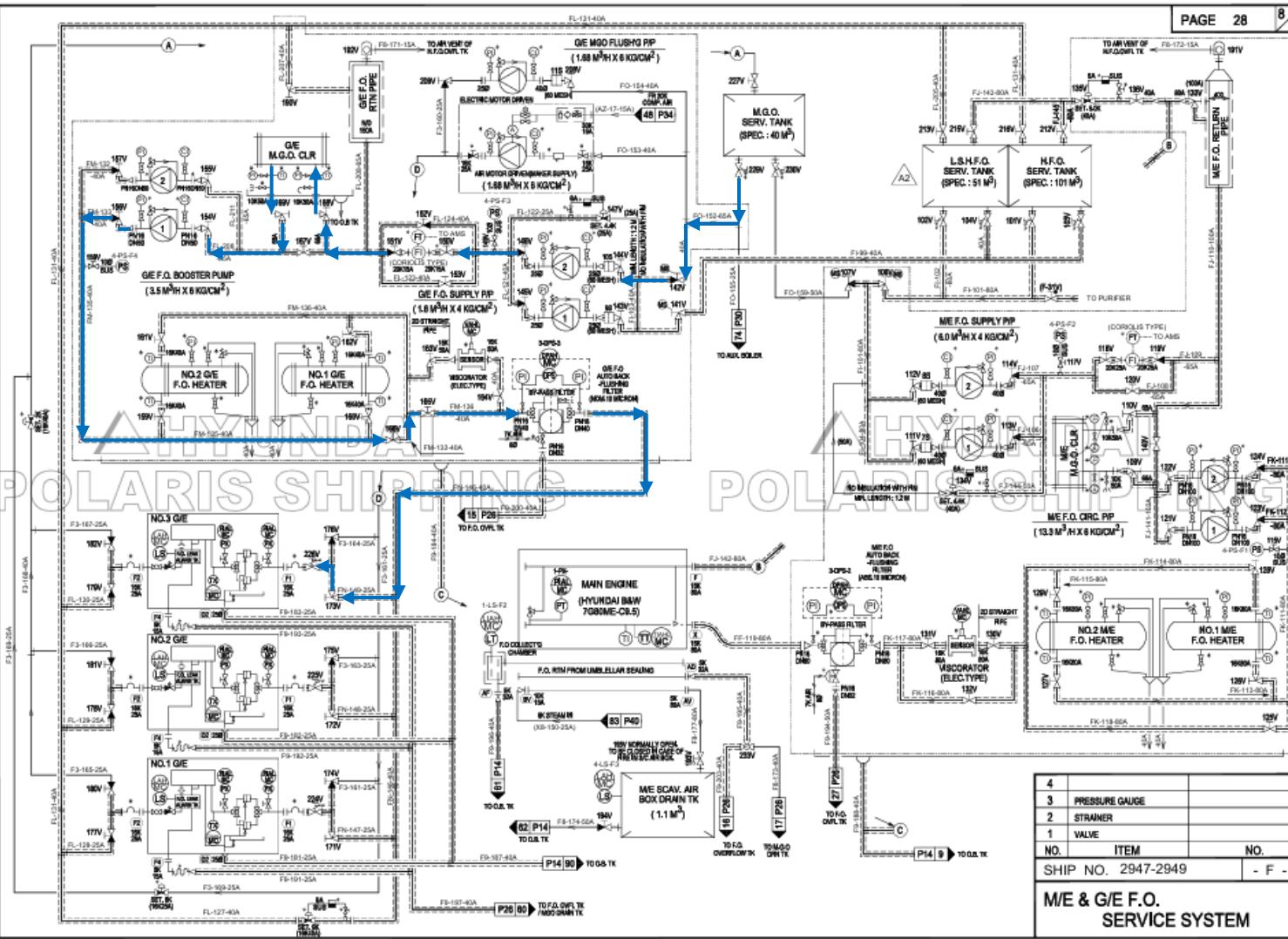




HFO or LSHFO reaches the G/E inlet from the

- 1) service tank through the
- 2) G/E F.O. supply pump,
- 3) Flowmeter,
- 4) G/E F.O. booster pump,
- 5) G/E F.O. heater,
- 6) Viscorator,
- 7) G/E F.O. auto back-flushing filter.

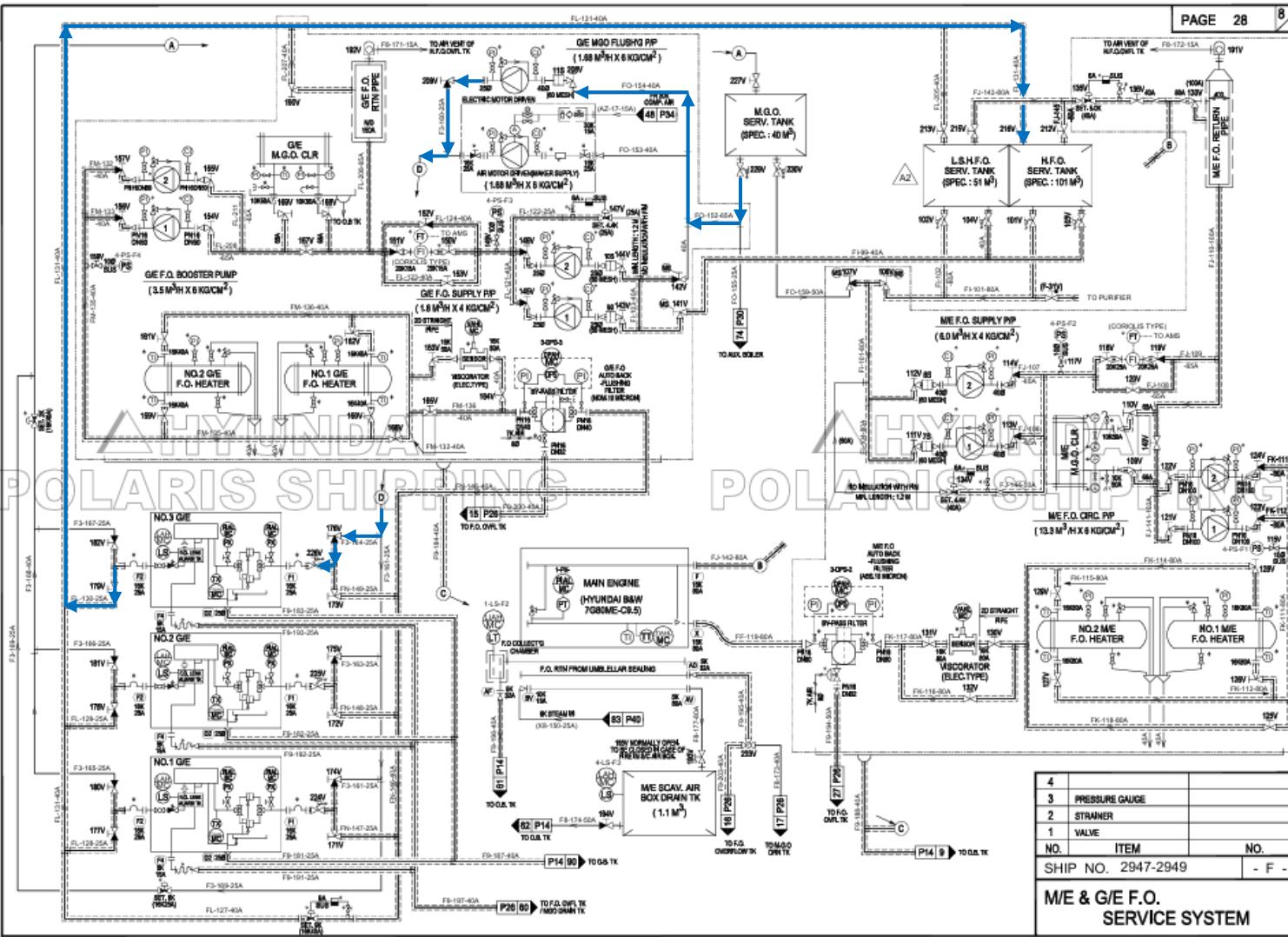
→ : H.F.O.
→ : L.S.H.F.O.
→ : Common



MGO reaches the G/E inlet from the
 1) service tank
 through the
 2) G/E F.O. supply pump,
 3) Flowmeter,
 4) G/E M.G.O. cooler,
 5) G/E F.O. booster pump.

(G/E F.O. auto back-flushing filter is turned off or bypassed.)

→ : M.G.O.



When using a G/E M.G.O. flushing pump, the purpose is to flush only the specific G/E with M.G.O. for reasons such as long-term maintenance, while other G/E's are operated with H.F.O.

→ : M.G.O.

NO.	ITEM	NO.
4	PRESSURE GAUGE	
3	STRAINER	
2	VALVE	
1		
NO.	ITEM	NO.
SHIP NO.	2947-2949	- F -
M/E & G/E F.O. SERVICE SYSTEM		

Internal Fuel Oil System for G/E (MAN B&W)

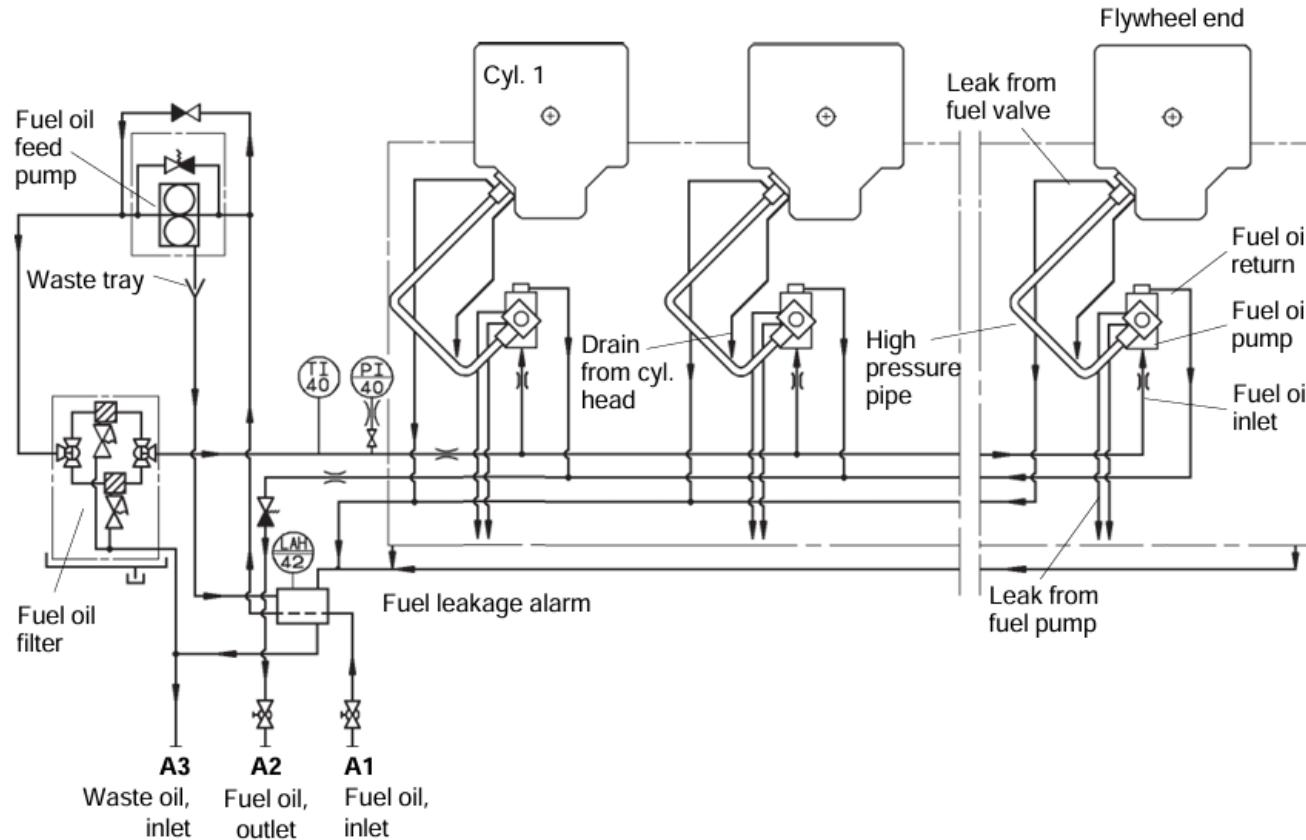
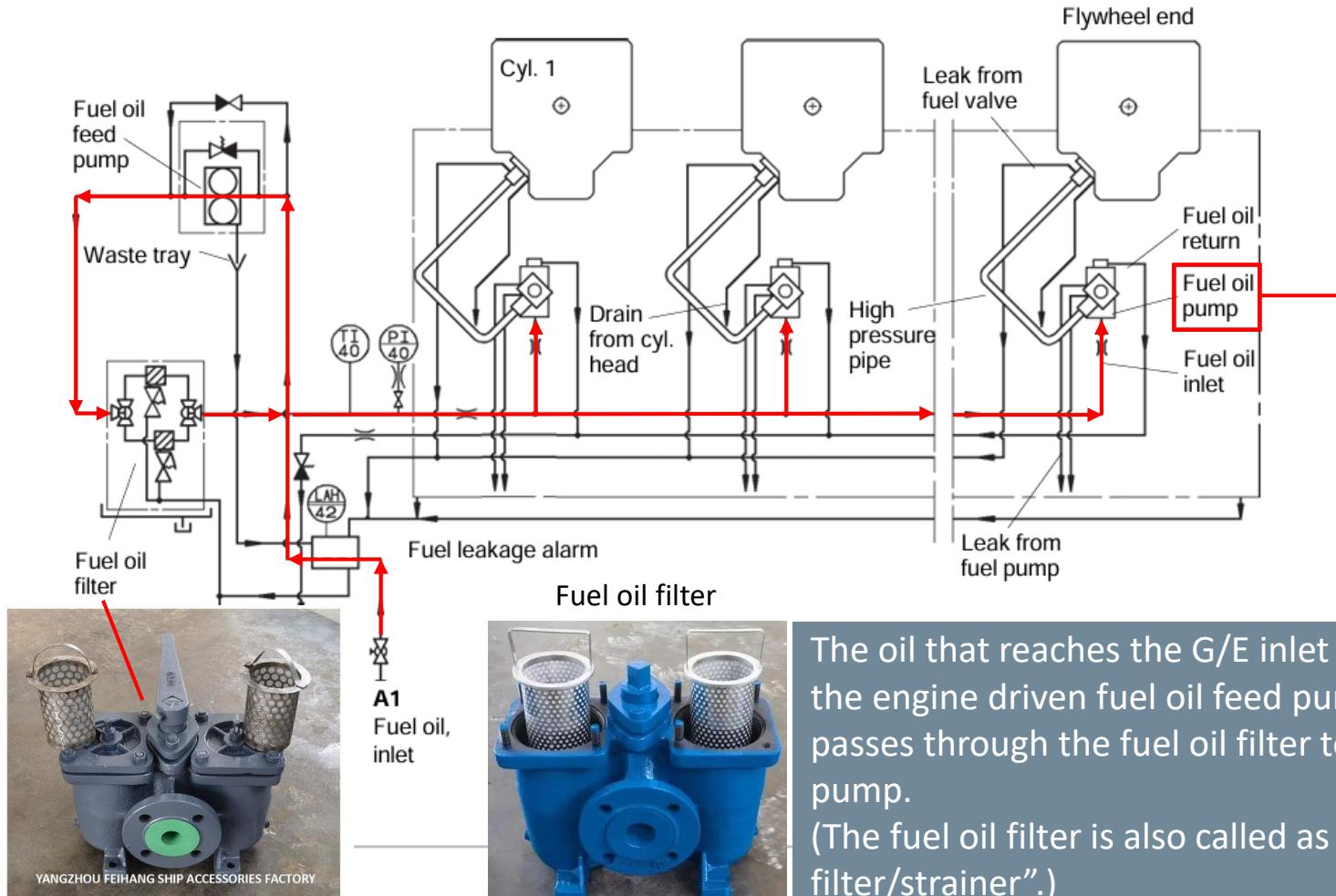


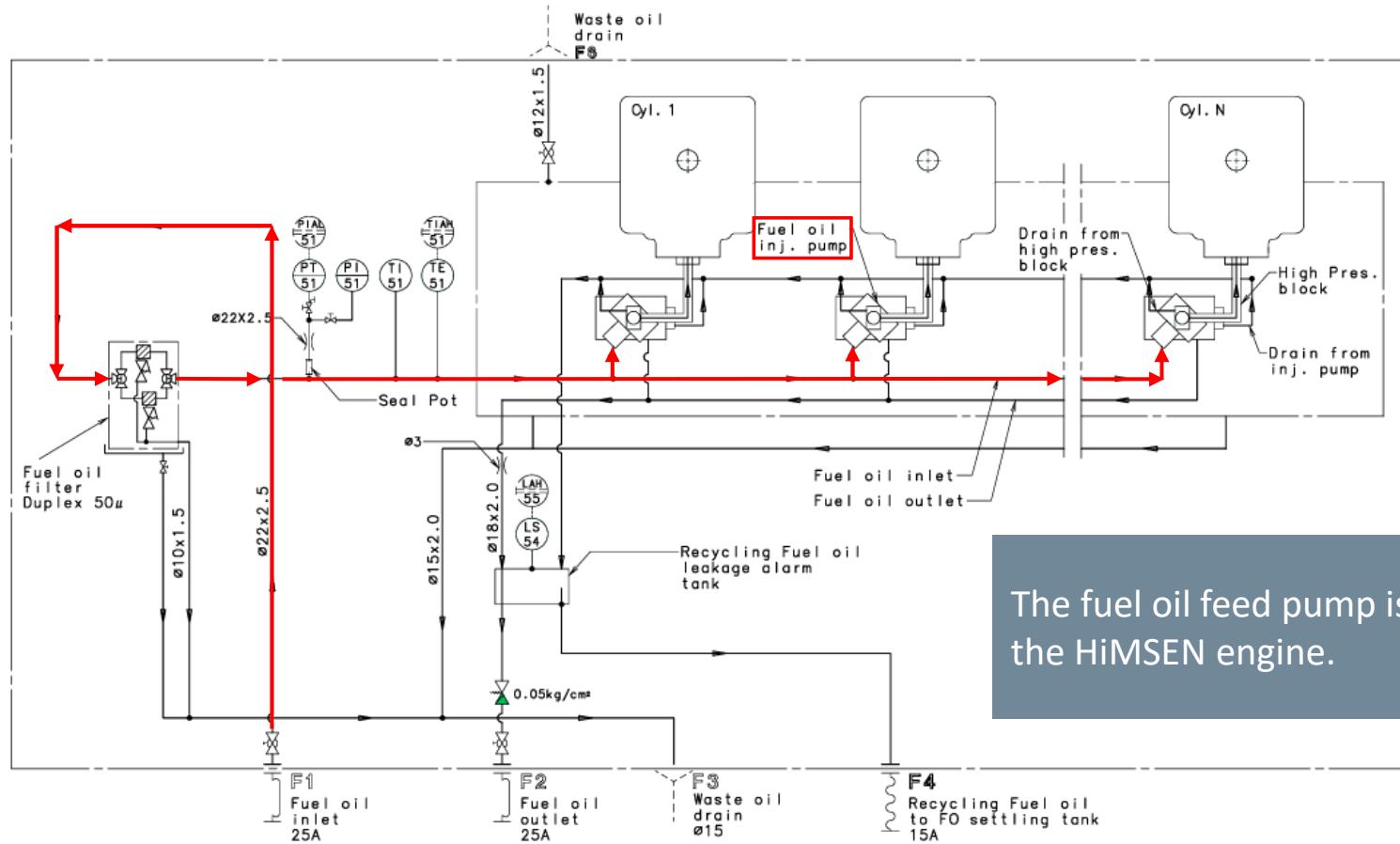
Fig. 1. Diagram for Fuel Oil System

Internal Fuel Oil System for G/E (MAN B&W)



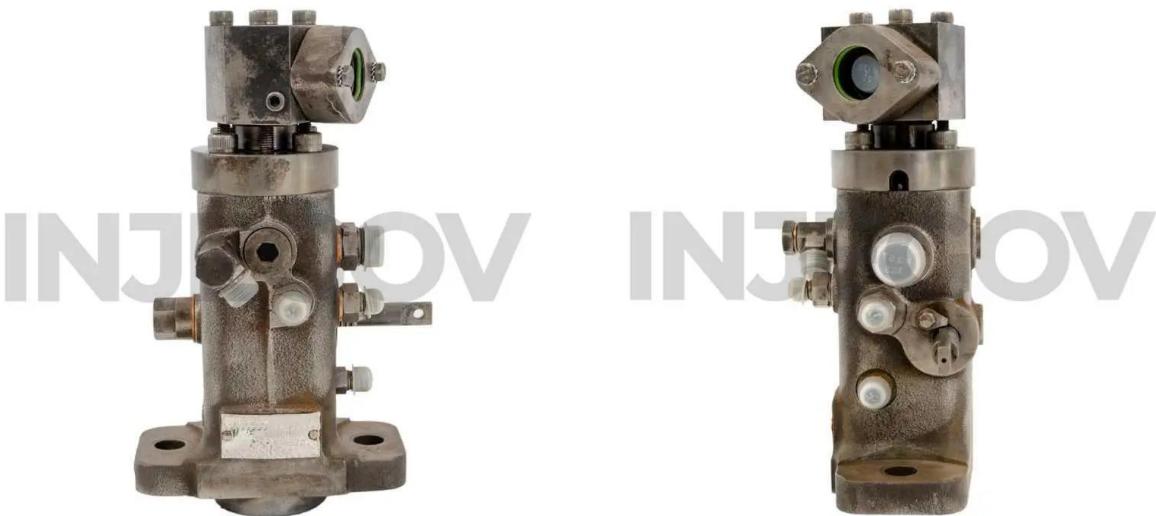
The oil that reaches the G/E inlet is pressurized by the engine driven fuel oil feed pump and then passes through the fuel oil filter to reach the fuel oil pump.
(The fuel oil filter is also called as “duplex filter/strainer”.)

Diagram for the internal fuel oil system for G/E (HiMSEN)



Fuel injection pump (MAN B&W)

The photos below are actual photos of the fuel injection pump taken from various angles.



Fuel injection pump (MAN B&W)

YouTube videos can be useful for understanding the structure of fuel injection pumps.

Various videos are available on YouTube, so please search for them.

Fuel injection pump (MAN B&W)



EngineFixed-All Marine & Auto Engine

Fuel injection pump (MAN B&W)



Fuel injection pump (MAN B&W)



Fuel injection pump (HiMSEN)

The fuel injection pump of the HiMSEN engine is much larger (also heavy) and looks slightly different than the fuel injection pump of the MAN B&W, but the operating mechanism is the same.

YouTube can be referenced to understand the fuel injection pump of the HiMSEN engine.



Fuel injection pump (HiMSEN)



2. Press the Roller of Tappet assembly

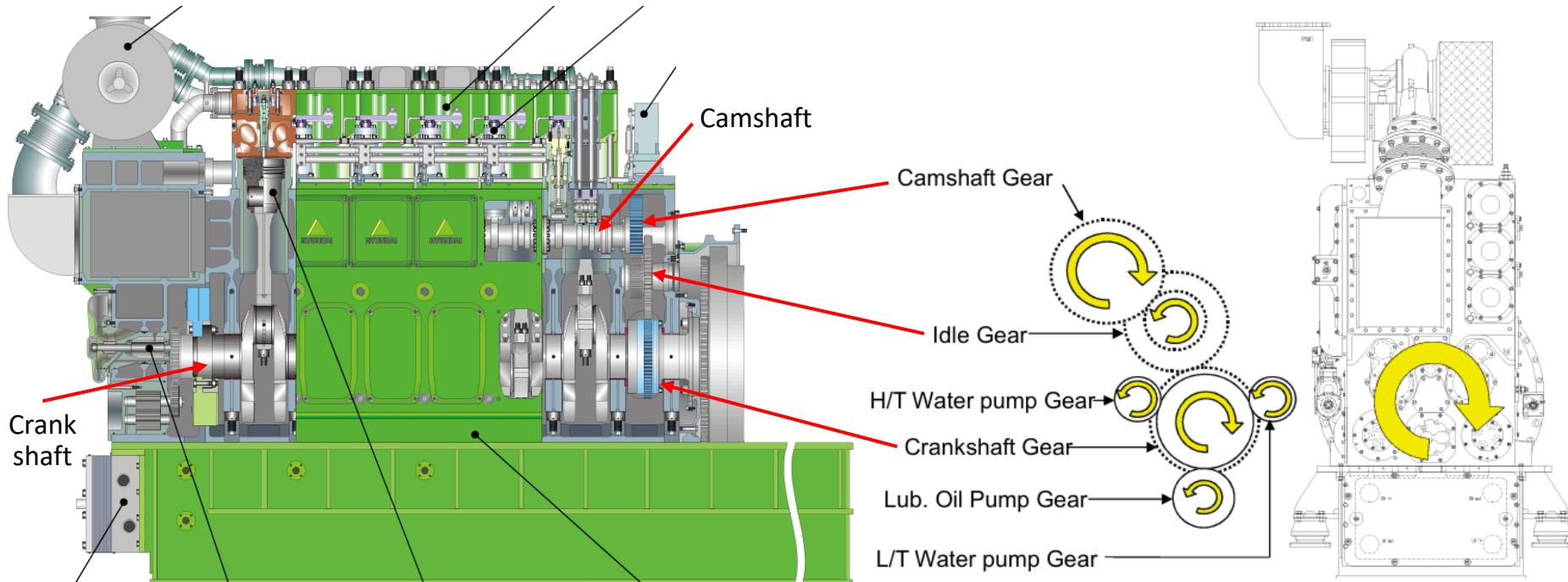
Fuel injection pump (HiMSEN)



HiMSEN 7H21/32

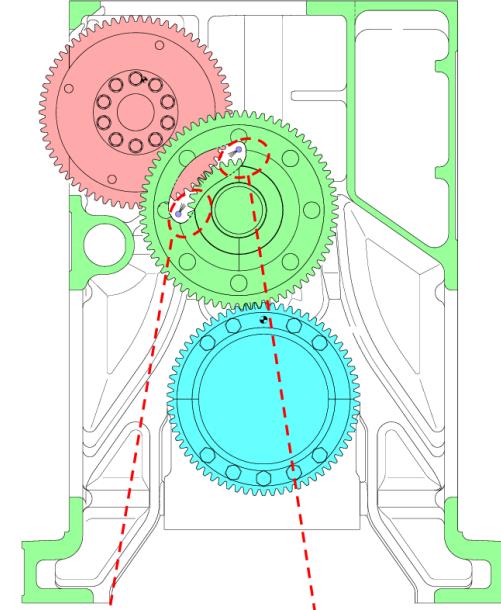
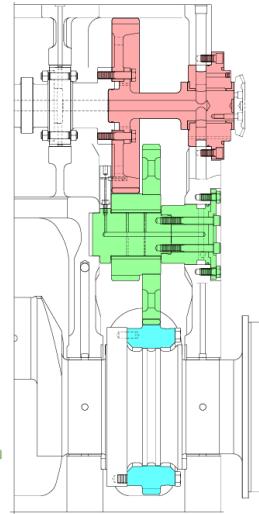
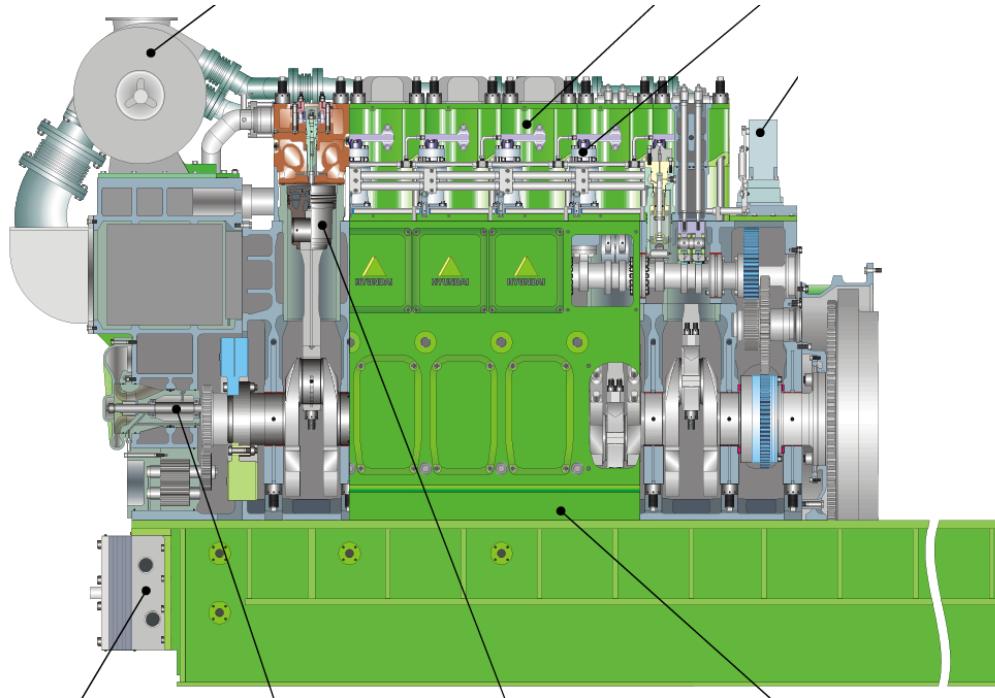
Fuel injection pump (HiMSEN)

The fuel injection pump is installed above the camshaft, and it is activated by the cam on the camshaft.



Fuel injection pump (HiMSEN)

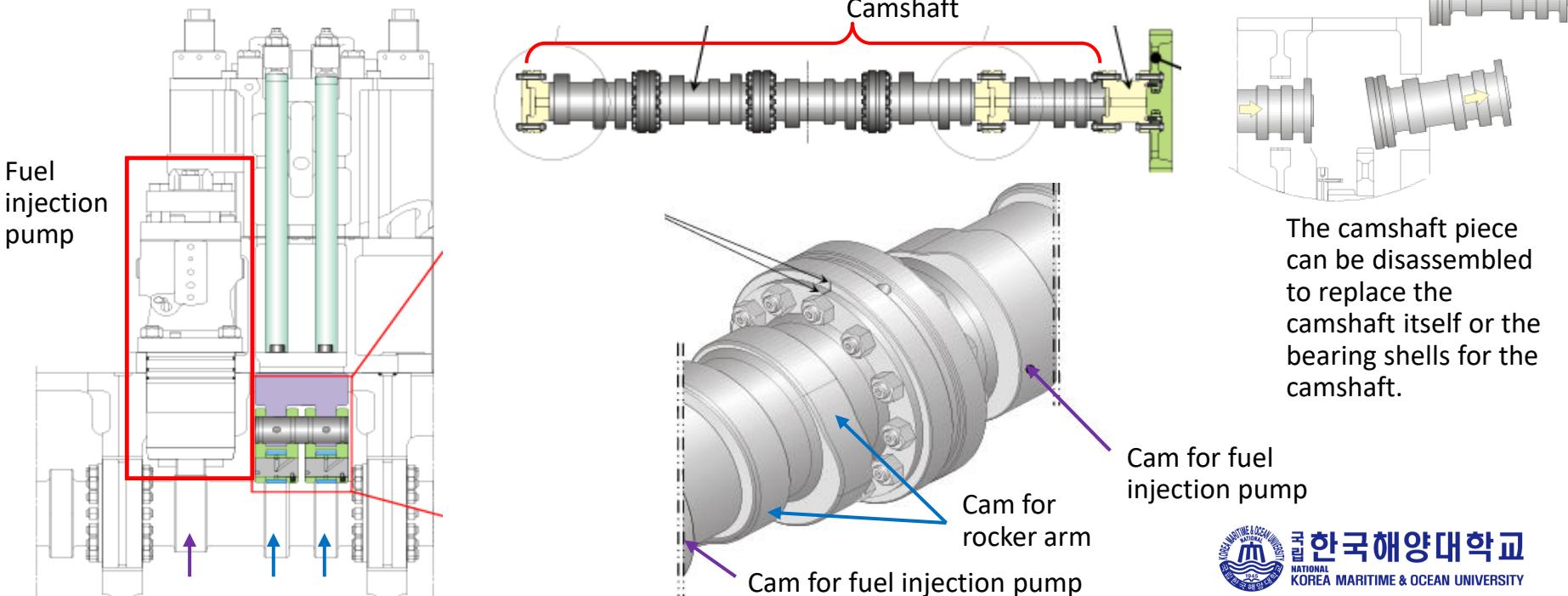
The fuel injection pump is installed above the camshaft, and it is activated by the cam on the camshaft.



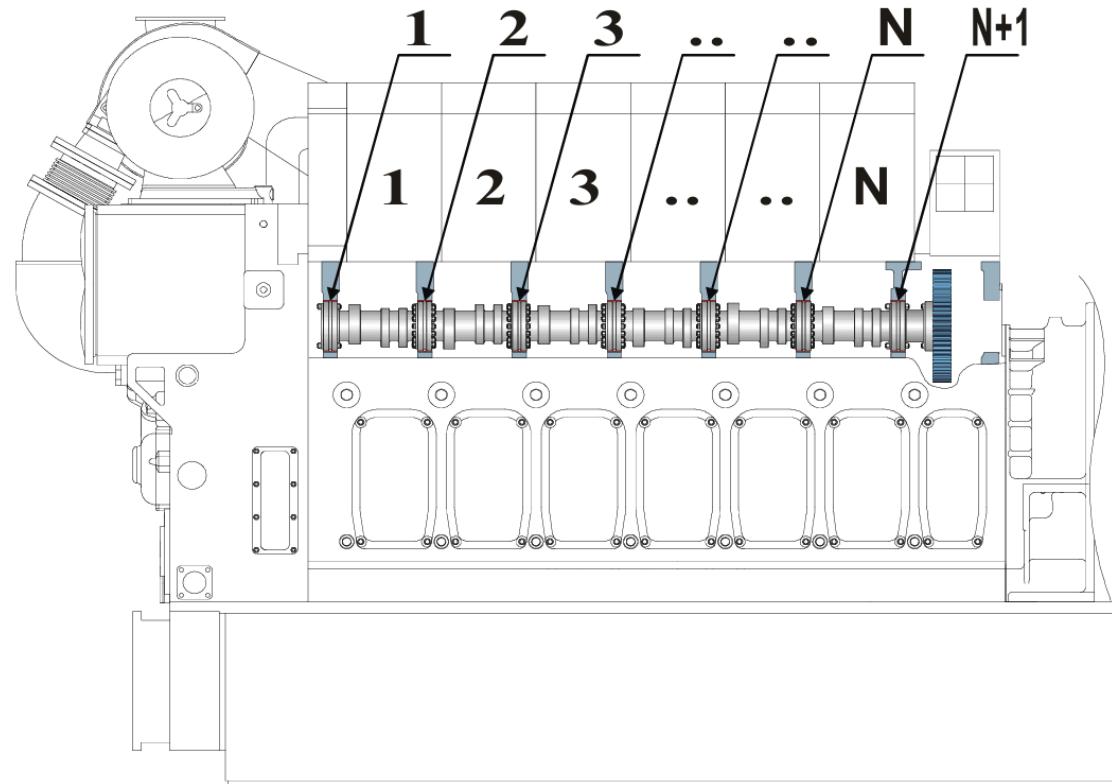
Fuel injection pump (HiMSEN)

The fuel injection pump is installed above the camshaft,

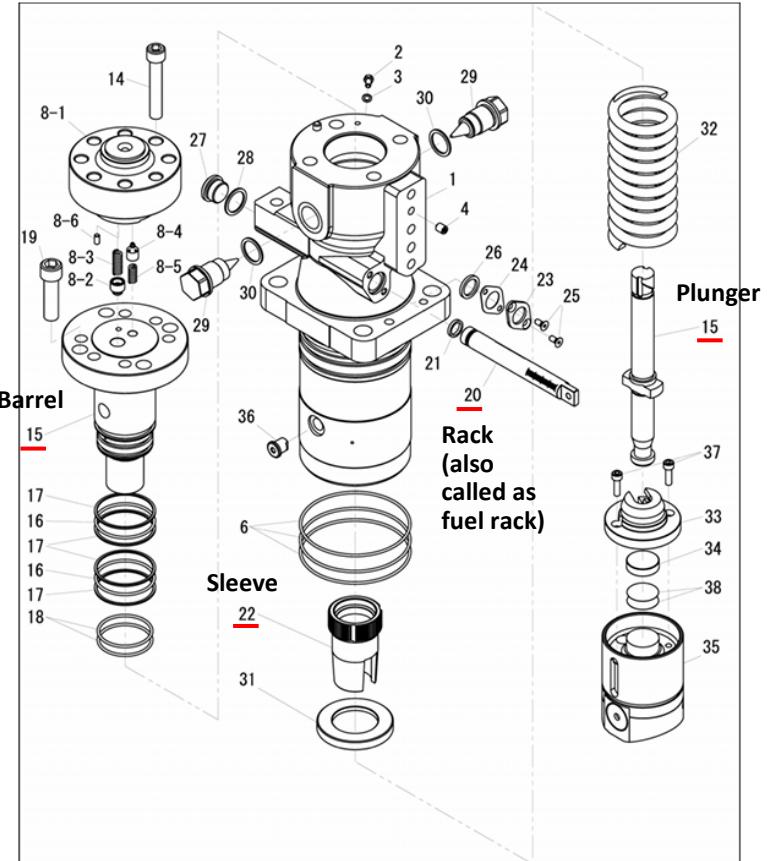
and it is activated by the cam on the camshaft.



Camshaft (HiMSEN)

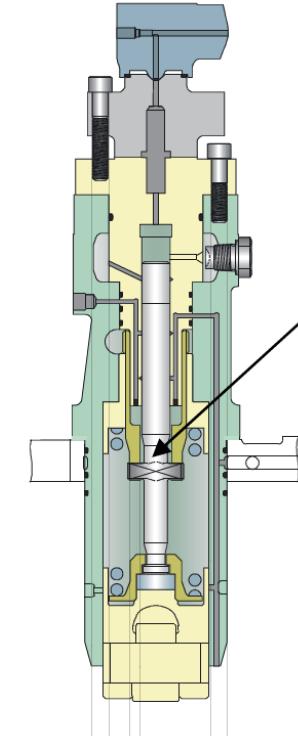


Fuel injection pump (HiMSEN)



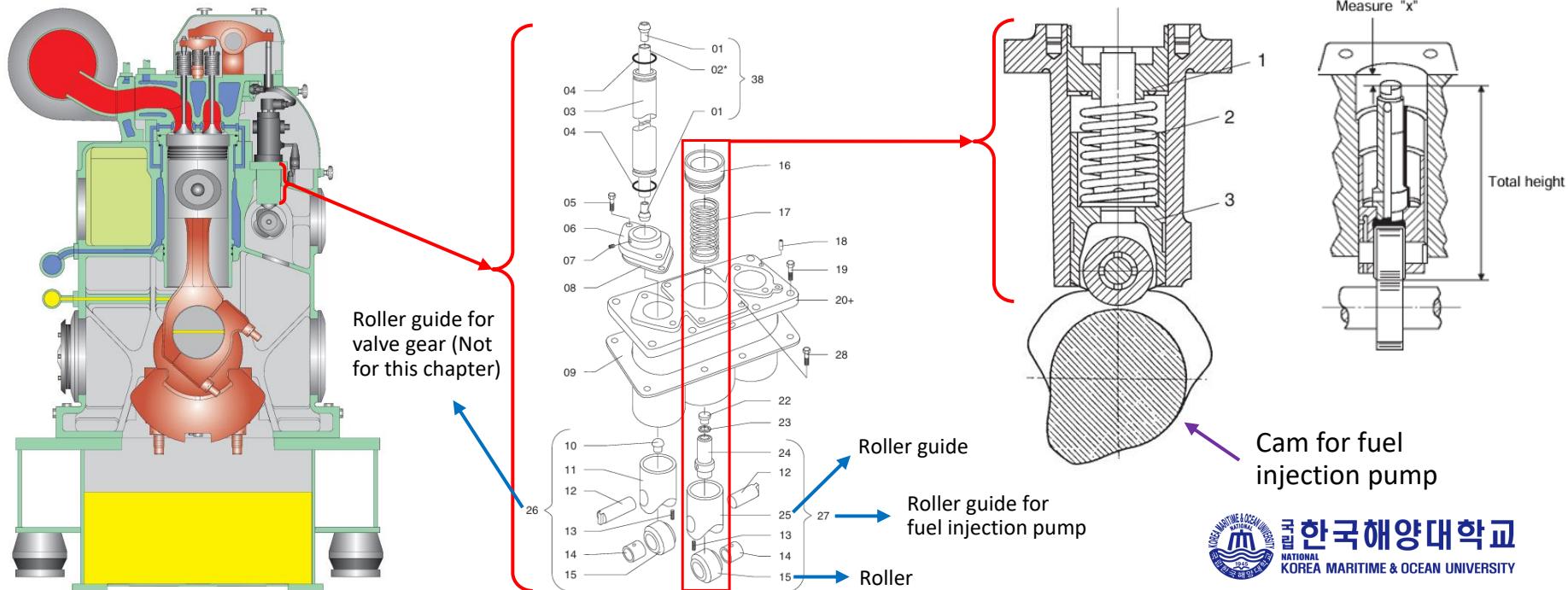
Part List

Pos. No.	Item No.	Description	Q'ty / Cyl.	Weight (kg)	Remarks / See Note
1	101	Pump housing	1set		
2	102	Bolt	1		
3	103	Gasket	1		
4	104	Socket head bolt	1		
6	106	O-ring	3		
8	108	Delivery valve ass'y	1set		
8-1	181	Delivery valve case	1		
8-2	182	Delivery valve	1		
8-3	183	Spring	1		
8-4	184	Return valve	1		
8-5	185	Spring	1		
8-6	186	Pin	1		
14	114	Socket head bolt	6		
15	115	Plunger ass'y	1set		
16	116	O-ring	2		
17	117	Back up ring	4		
18	118	O-ring	2		
19	119	Socket head bolt	4		
20	120	Control rack	1		
21	121	Seal ring	1		
22	122	Control sleeve	1		
23	123	Pointer	1		
24	124	Shim	1		
25	125	Bolt	2		
26	126	Seal ring	1		
27	127	Plug	1		
28	128	Gasket	1		
29	129	Deflector	2		
30	130	Gasket	2		
31	131	Spring seat	1		
32	132	Spring	1		
33	133	Spring seat	1		
34	134	Plate	1		
35	135	Tappet ass'y	1		
36	136	Pin	1		
37	137	Bolt	2		
38	138	Shim	1		

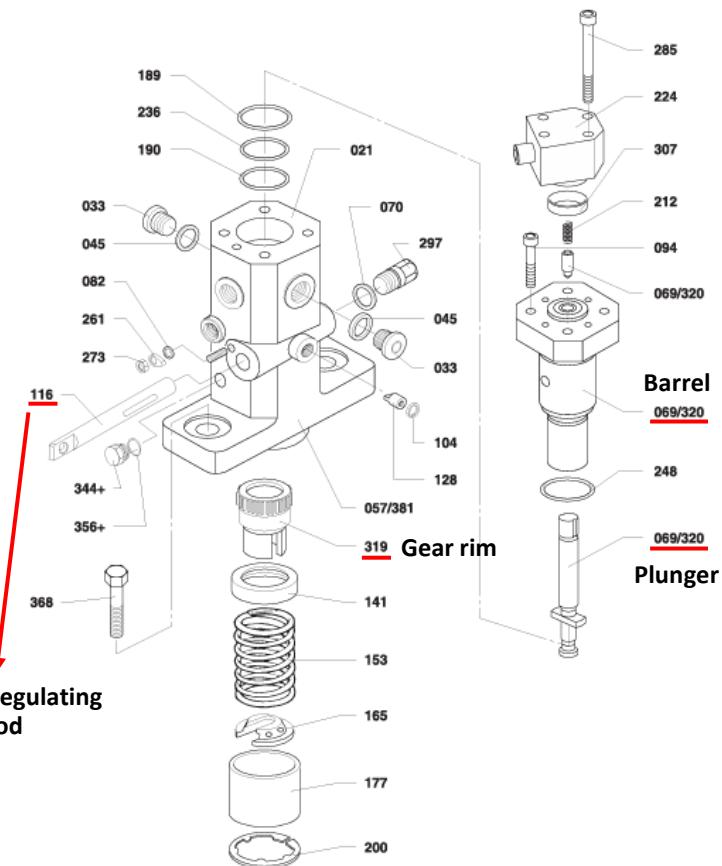


Fuel injection pump (MAN B&W)

The fuel injection pump is installed on the roller guide housing directly above the camshaft, and it is activated by the cam on the camshaft through roller guides fitted in the roller guide housing.



Fuel injection pump (MAN B&W)



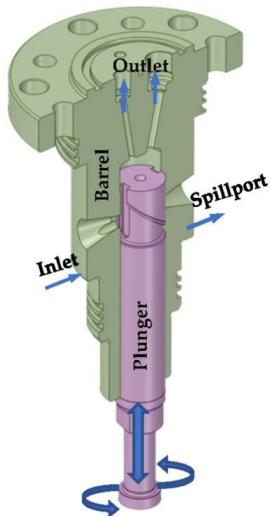
Item No.	Qty.	Designation	Benævnelse
021	1/P	Pump housing	Pumpehus
033	2/P	Screw	Skrue
045	2/P	Packing ring	Pakningsring
057	1/C	Fuel injection pump, complete for L23/30H, 720/750 rpm	Fuel indsprøjtningspumpe, komplet for L23/30H, 720/750 rpm
069	1/P	Plunger and barrel incl. non-return valve for L23/30H, 720/750 rpm	Stempel og cylinder inkl. kontraventil for L23/30H, 720/750 rpm
070	1/P	Joint washer	Pakning
082	2/P	Washer	Skive
094	4/P	Screw	Skrue
104	1/P	Circlip	Låsering
116	1/P	Regulating rod	Reguleringsstang
128	1/P	Guide pin	Styretap
141	1/P	Upper spring plate	Øverste fjederplade
153	1/P	Spring	Fjeder
165	1/P	Lower spring plate	Nederste fjederplade
177	1/P	Thrust cap	Trykhette
189	1/P	O-ring	O-ring
190	1/P	O-ring	O-ring
200	1/P	Circlip	Låsering
212	1/P	Spring	Fjeder
224	1/P	Connecting piece	Forbindelsesstykke
236	1/P	O-ring	O-ring
248	1/P	O-ring	O-ring
261	1/P	Pointer	Viser
273	1/P	Nut	Møtrik
285	4/P	Screw	Skrue
297	1/P	Cap screw	Hætteskrue

Item No.	Qty.	Designation	Benævnelse
307	1/P	Securing ring	Beskyttelsesring
319	1/P	Gear rim	Tandkrans
320	1/P	Plunger and barrel incl. non-return valve for L23/30H, 900 rpm	Stempel og cylinder inkl. kontraventil for L23/30H, 900 rpm
344+	1/P	Screw	Skrue
356+	1/P	Packing ring	Pakningsring
368	2/P	Screw	Skrue
381	1/C	Fuel injection pump, complete for L23/30H, 900 rpm	Fuel indsprøjtningspumpe, komplet for L23/30H, 900 rpm

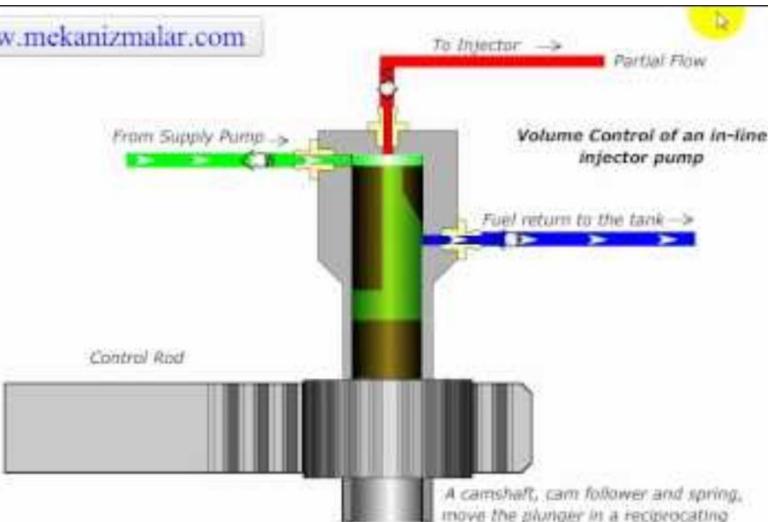
+ Are not included in fuel injection pump, complete
+ Indgår ikke i fuel indsprøjtningspumpe, komplet

Fuel injection pump

The injection amount of the pump is regulated by transversal displacement of a toothed rack in the side of the pump housing. The plunger, which is fixed to the gear rim, rotates as the regulating rod (fuel rack) moves back and forth. As the plunger rotates, the amount of oil flowing out through the spillport changes, and accordingly, the amount of pressurized oil flowing to the outlet (to the high pressure pipe then fuel injection valve) changes.

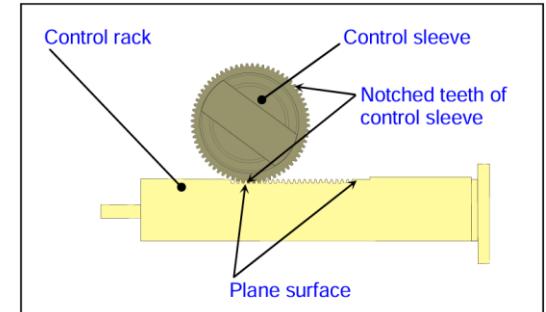
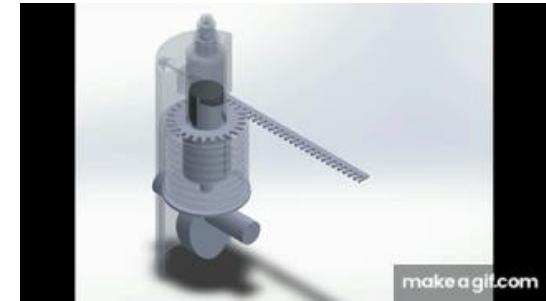
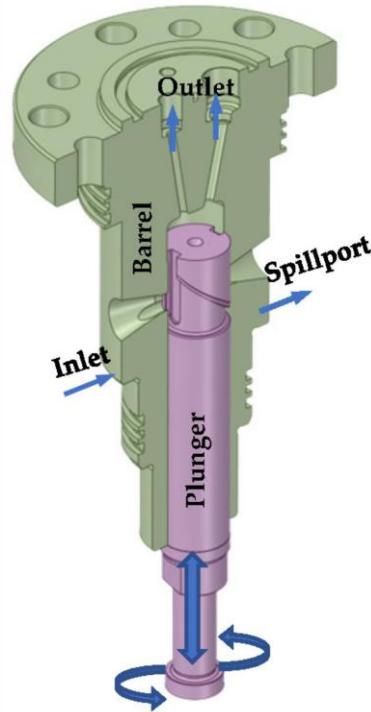
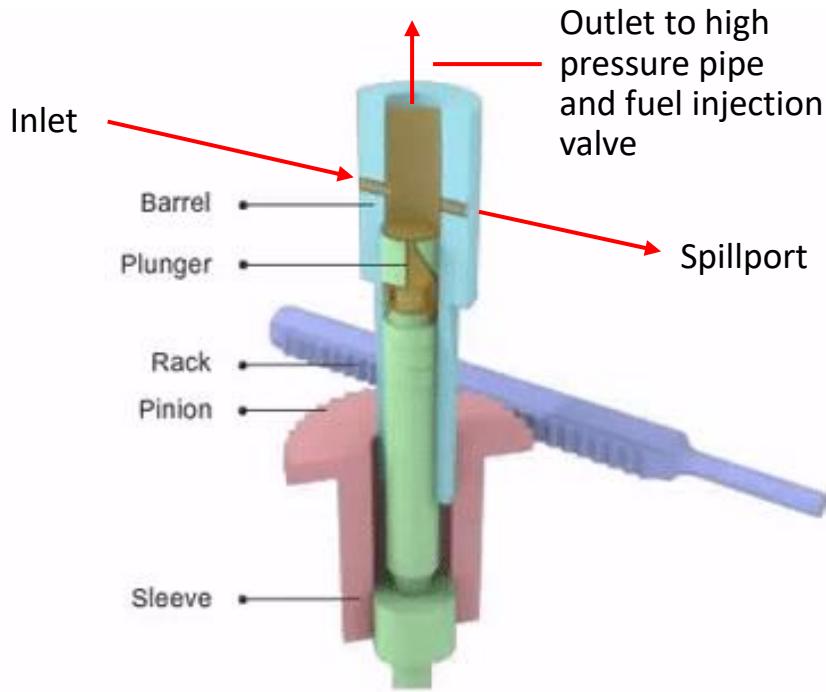


www.mekanizmalar.com



Fuel injection pump

The plunger performs reciprocating motion by the cam on the camshaft.



Fuel injection pump



Fuel injection pump (HiMSEN)

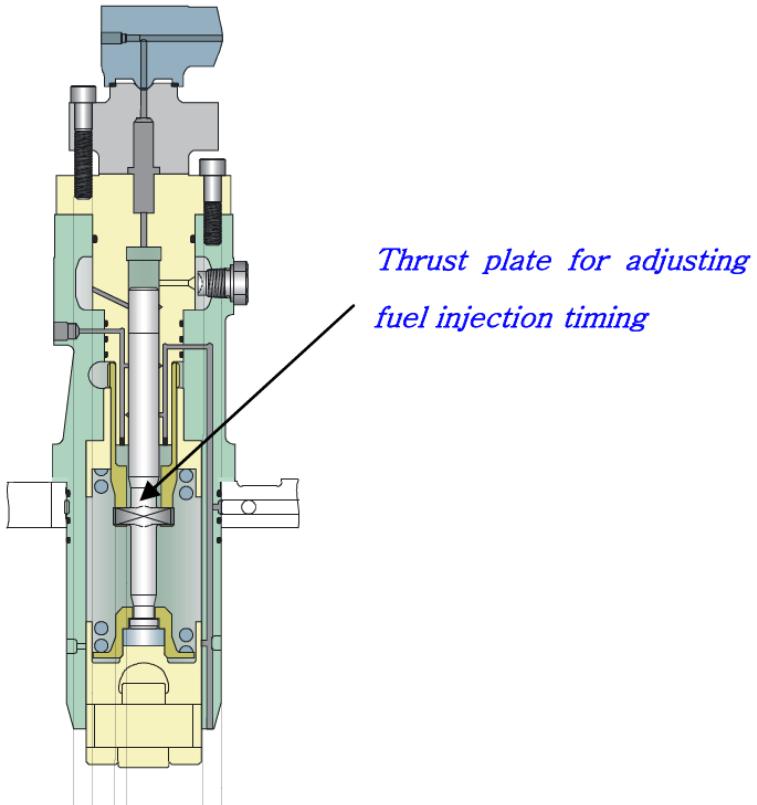


Fig. 1 Thrust plate for adjusting fuel injection timing (연료 분사 시기 조정용 스리스트 플레이트)

Adjustment of fuel injection timing

Fuel injection timing influences the maximum cylinder pressure which is set properly by engine maker and normally recommended not to be adjusted.

However, if new fuel injection pump has been installed or if the deviation of each cylinder pressure is out of tolerance, the injection timing should be checked and adjusted, which can be adjusted by the thickness of thrust plate as shown in fig 1.

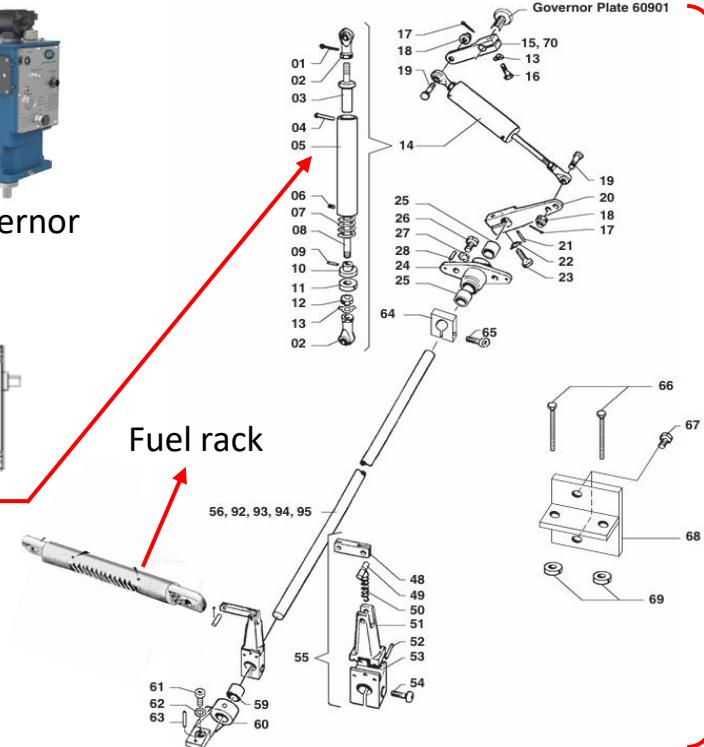
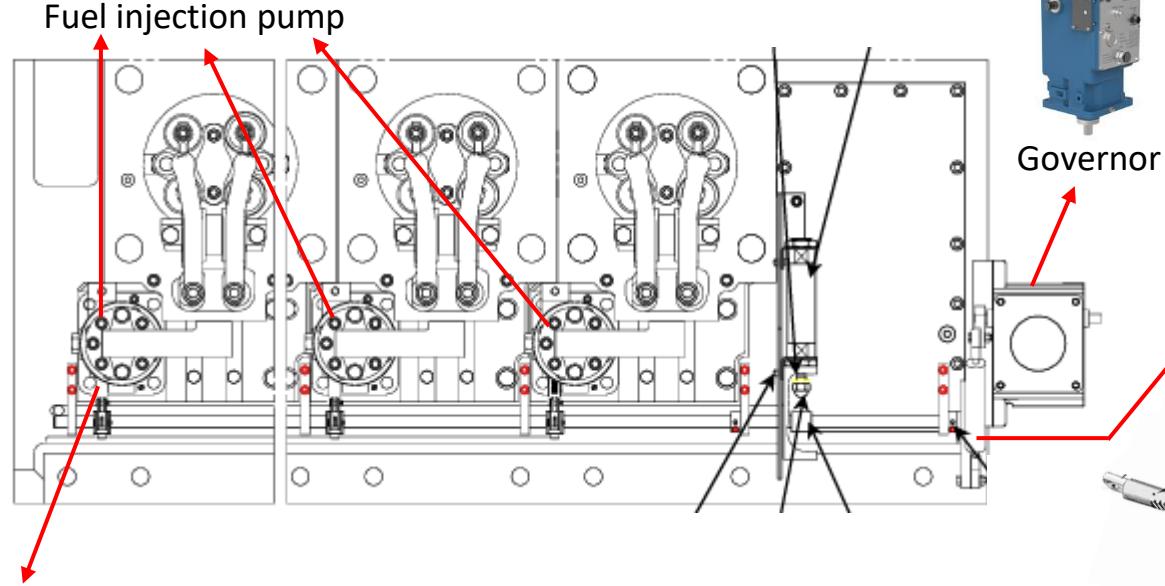
When inserting thrust plate (increasing thickness), the injection timing advanced and maximum cylinder pressure increased.

$$\text{Thrust plate thickness} + 0.1\text{mm} = \text{Cyl. pressure} + 2 \text{ bar}$$

Governor
linkage
assembly

Fuel injection pump (HiMSEN) & Govenor

The fuel racks of all fuel injection pumps are connected to a common regulating shaft and spring-loaded linkages.



Govenor

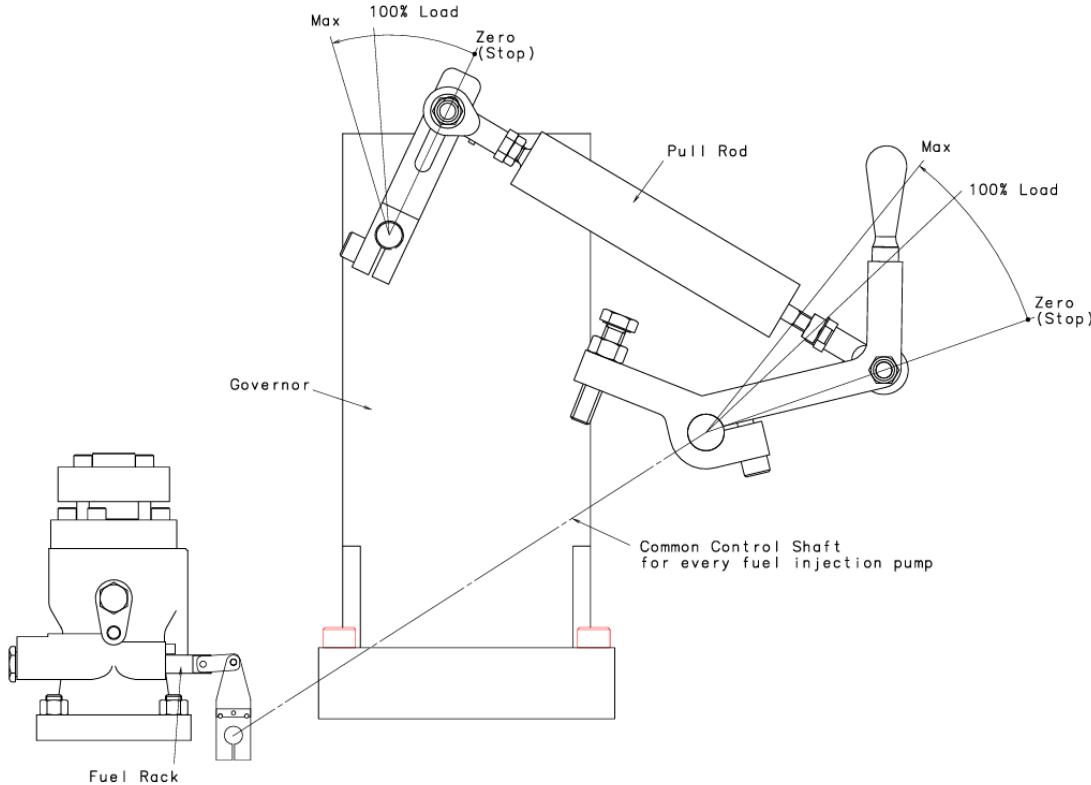


Fig. 3 Fuel control linkage (연료 제어 링크장치)

Fuel injection pump (HiMSEN) & Govenor

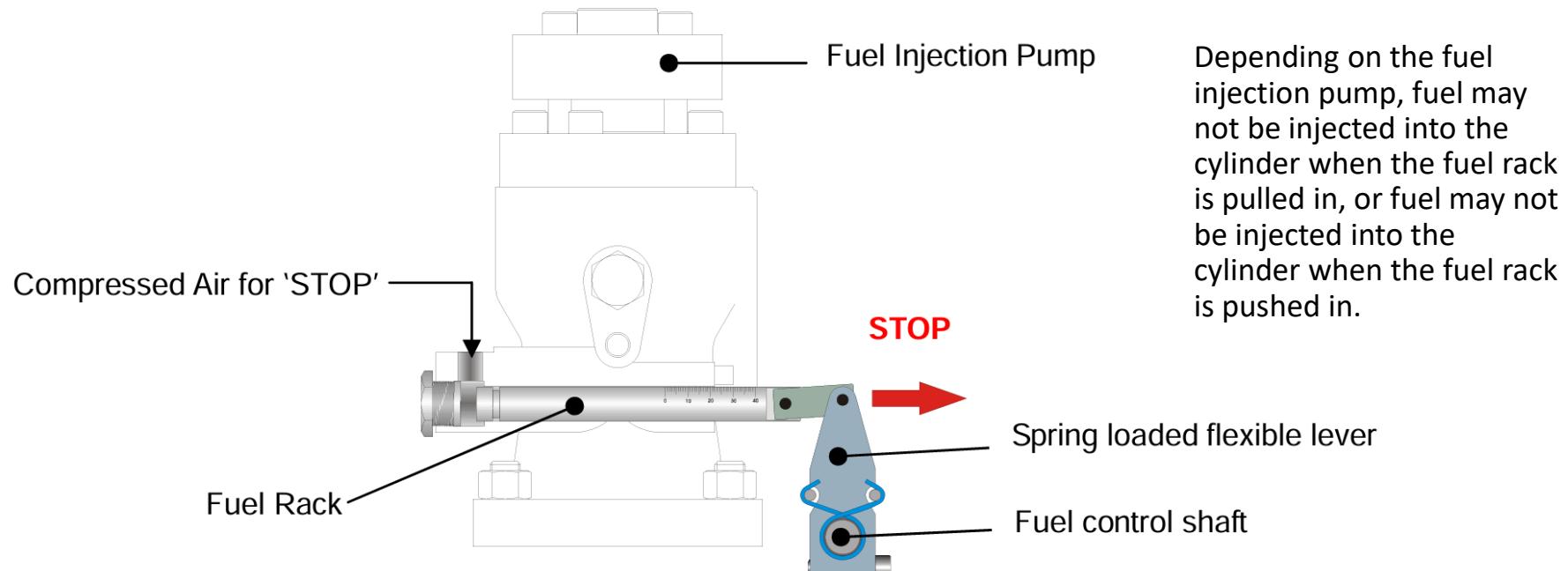
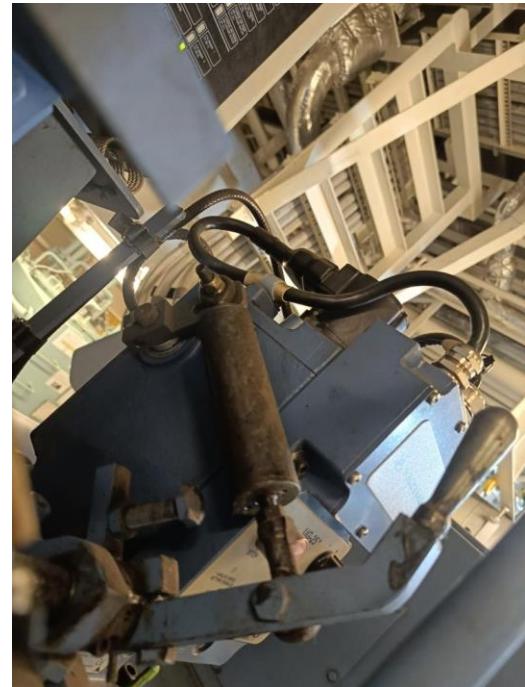
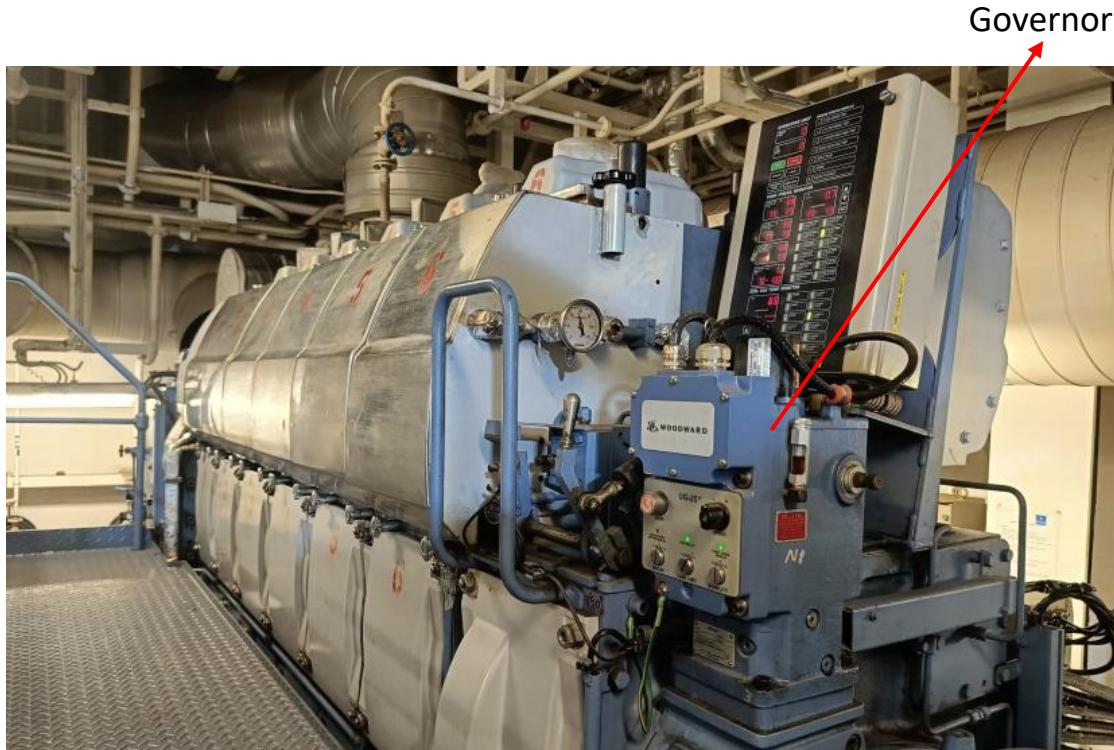
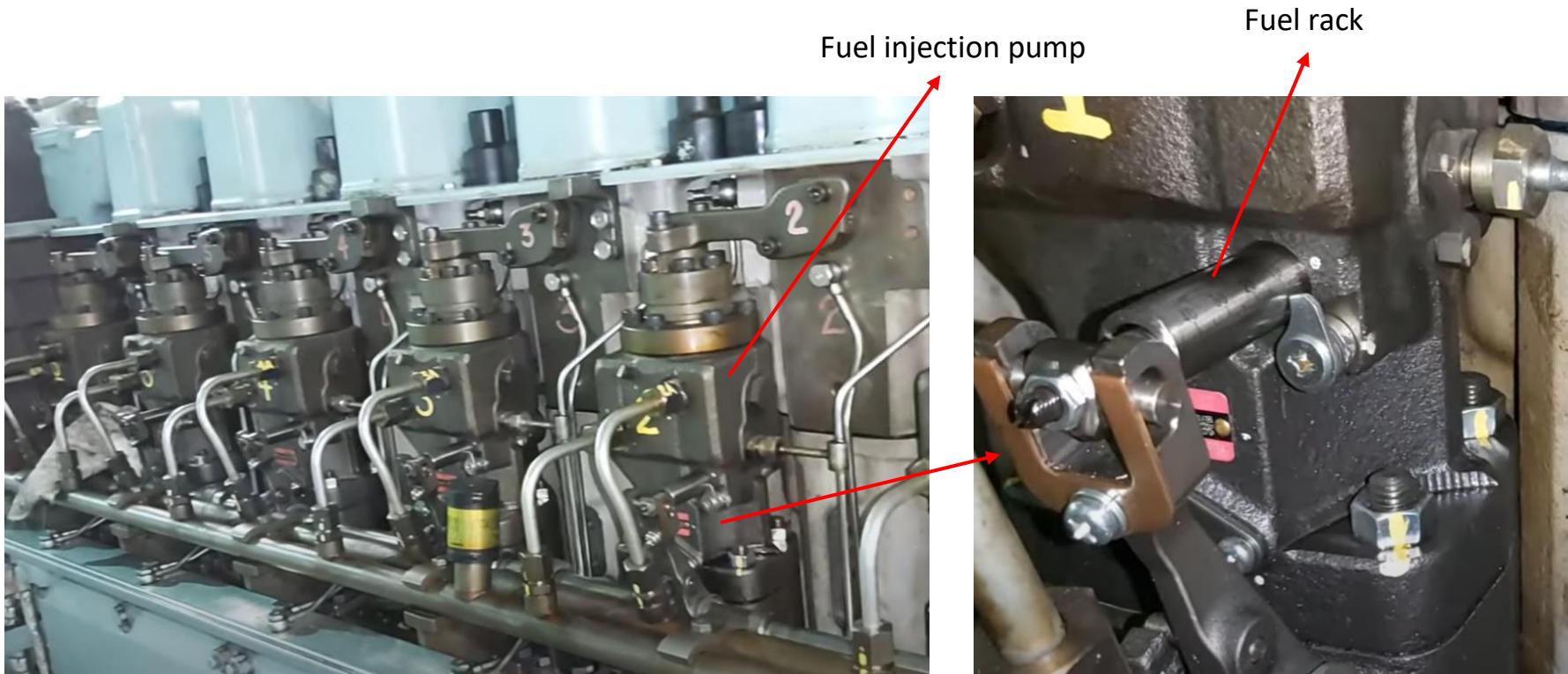


Fig. 2 Engine stop by fuel rack (연료 랙에 의한 엔진 정지)

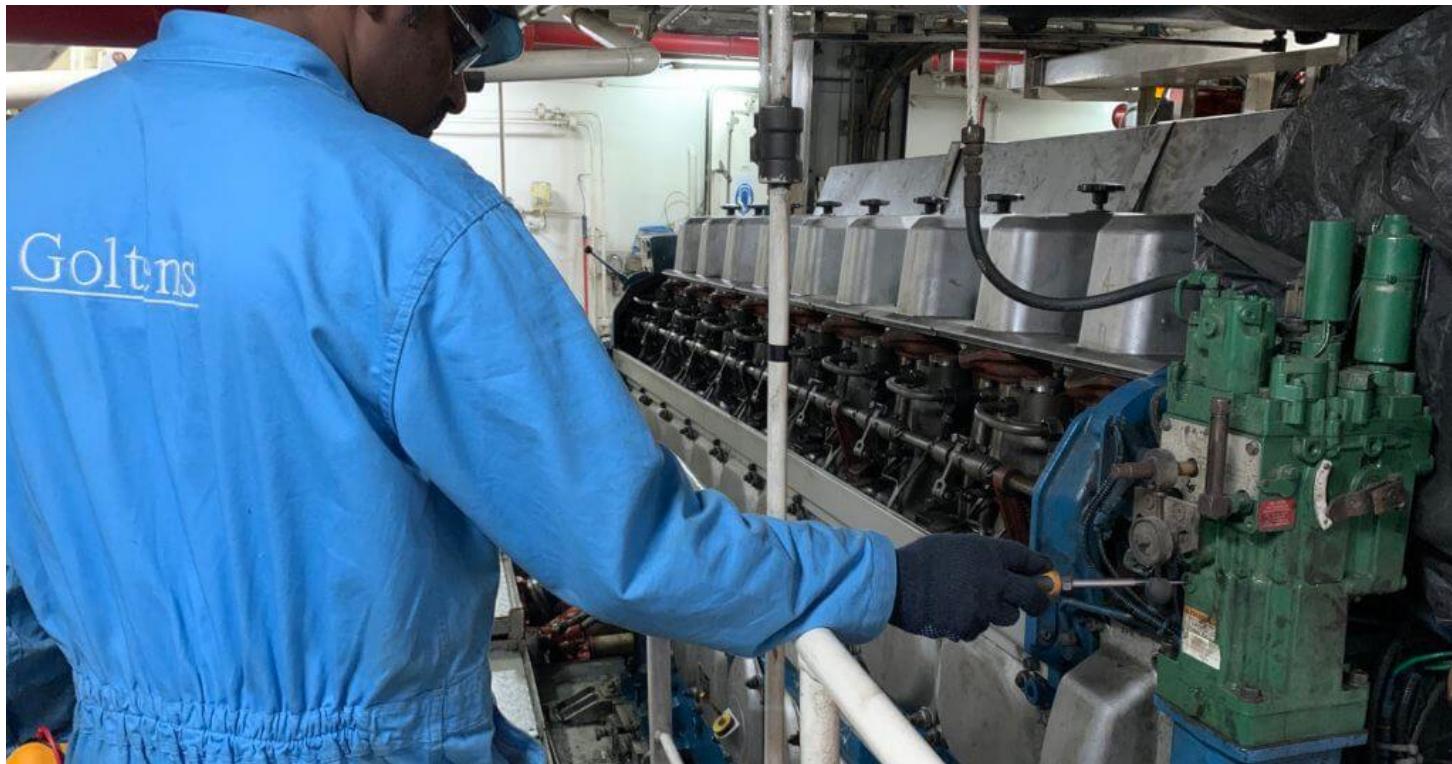
Fuel injection pump & Governor



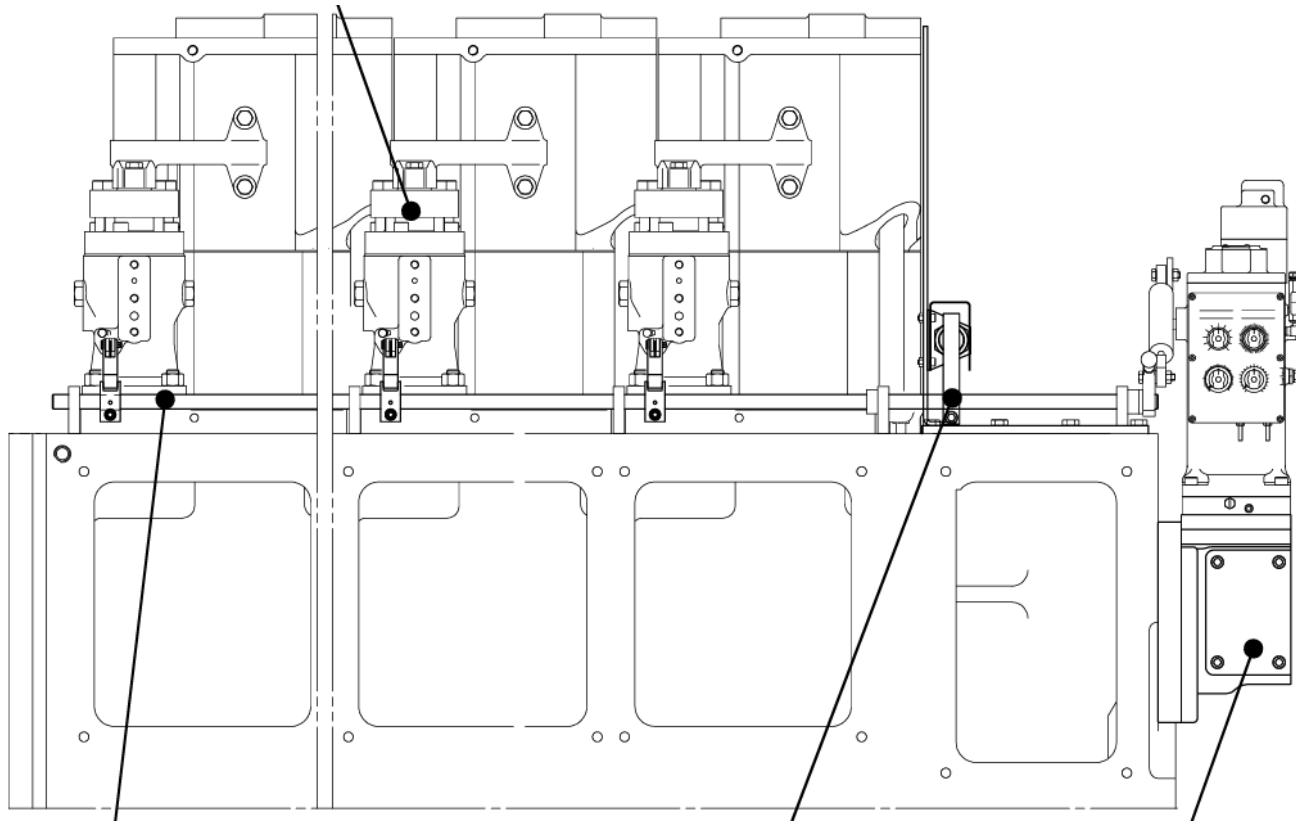
Fuel injection pump & Governor



Fuel injection pump & Govenor



Fuel injection pump & Govenor



Fuel injection pump (HiMSEN) & Govenor



Engine Stop System

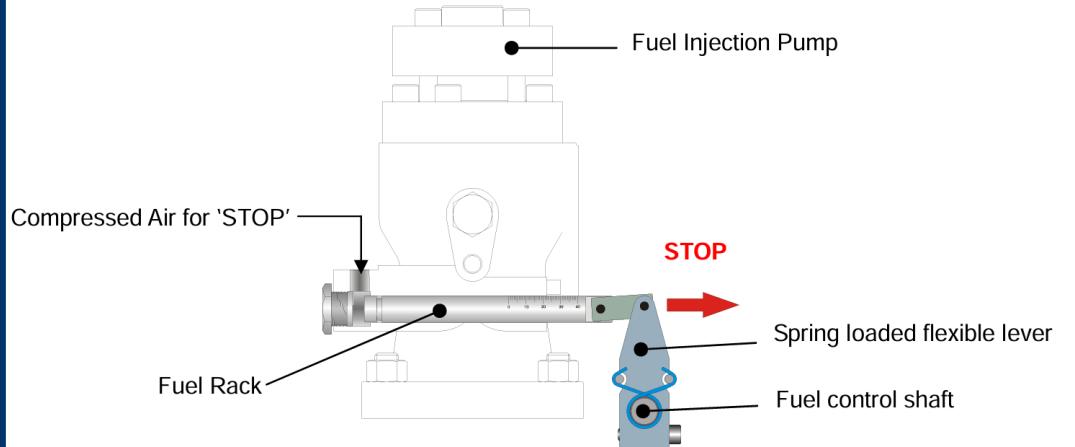


Fig. 2 Engine stop by fuel rack (연료 랙에 의한 엔진 정지)

The engine is stopped when pressing 'STOP' button or 'EMERGENCY STOP' button on control panel intentionally, or by 'AUTO STOP' signal.

Engine automation system generate 'AUTO STOP' signal when abnormal condition of the engine is detected.

However, the engine is stopped fundamentally when the fuel injection into the combustion chamber is stopped. This means that the rack of each fuel injection pump is moved to stop position by stop signal. Every fuel rack is connected to common control shaft mechanically and also connected to common compressed air line pneumatically.

Fuel injection pump (HiMSEN) & Govenor



Engine Stop System

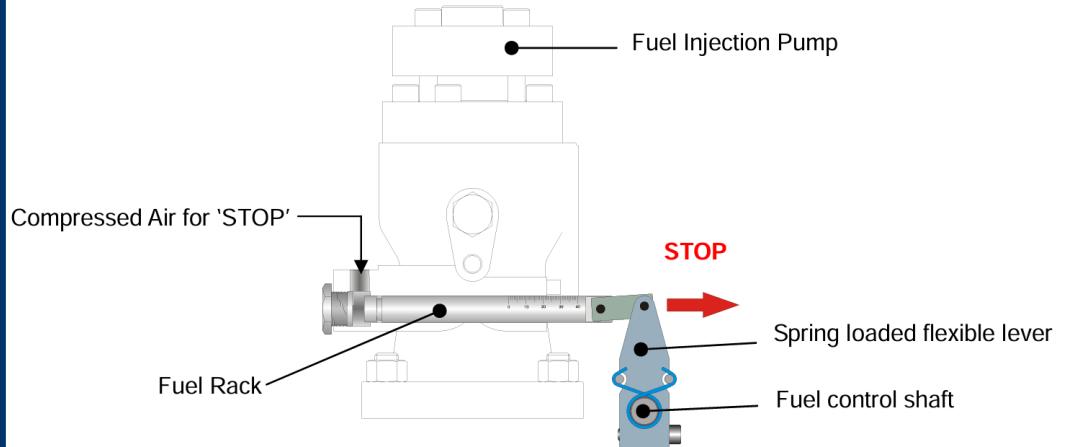


Fig. 2 Engine stop by fuel rack (연료 랙에 의한 엔진 정지)

Therefore, there are two ways of moving fuel racks to stop position (Zero index) as shown in fig 2.

The one is by the mechanical stop, which pull the racks to stop position by the governor or the manual control lever. 'STOP' button activates the governor to be 'STOP' position.

The other is by the pneumatic stop by compressed air, which pushes the rack to stop position regardless of the governor control. 'EMERGENCY STOP' button or 'AUTO STOP' signals activates the stop solenoid valve to supply the compressed air for all fuel injection pumps. This 'EMERGENCY STOP' signal also activates governor's stop simultaneously.

Lambda cylinder

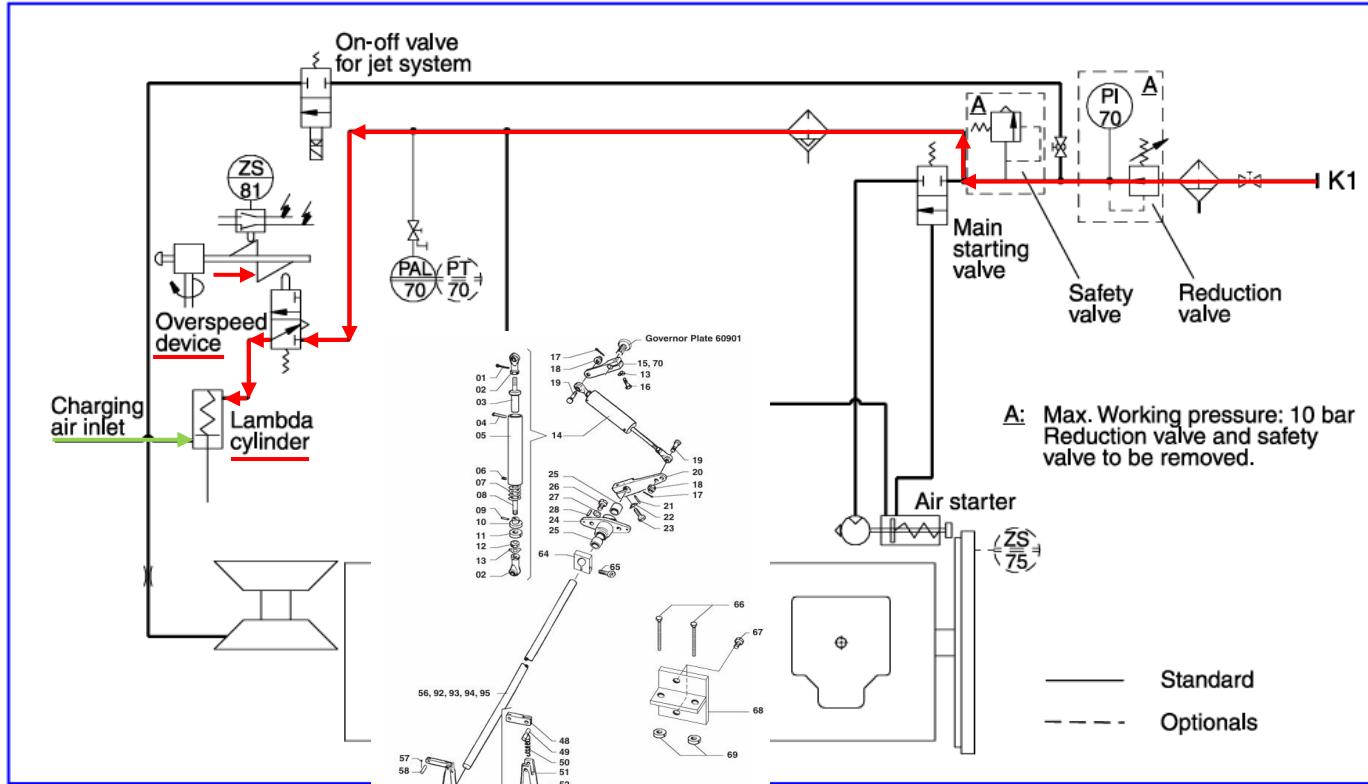


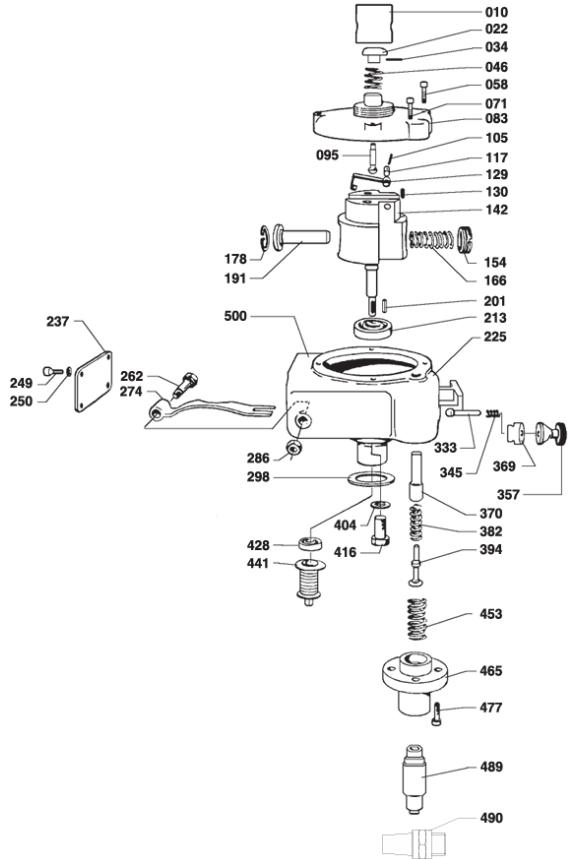
Fig 1 Diagram for compressed air

Lambda cylinder

Lambda cylinder is located near the governor linkage assembly and prevents excessive fuel from being injected into the cylinder during G/E initial start.

When the G/E overspeeds, compressed air is sent to the lambda cylinder, which in turn restricts the fuel rack connected to the linkage assembly, thereby restricting fuel injection into the cylinder and preventing overspeed.

Overspeed device (just for reference)



Item No.	Qty.	Designation	Benævnelse	Item No.	Qty.	Designation	Benævnelse
010	1/E	Socket	Muffe	357	1/E	Button	Knap
022	1/E	Button	Knap	369	1/E	Nipple	Nippel
034	1/E	Spring pin	Fjederstift	370	1/E	Spindle	Spindel
046	1/E	Spring	Fjeder	382	1/E	Spring (left)	Fjeder (venstre)
058	4/E	Screw	Skruer	394	1/E	Spindle	Spindel
071	1/E	Screw	Skruer	404	2/E	Washer	Skive
083	1/E	Cover	Dæksel	416	2/E	Screw	Skruer
095	1/E	Spindle	Spindel	428	1/E	Ball bearing	Kugleleje
105	1/E	Spring pin	Fjederstift	441	1/E	Elastic coupling	Elastisk kobling
117	1/E	Cylindrical pin	Cylindrisk stift	453	1/E	Spring (right)	Fjeder (højre)
129	1/E	Lever	Arm	465	1/E	Valve attachment	Ventilholder
130	1/E	Screw	Skruer	477	4/E	Screw	Skruer
142	1/E	Flyweight housing	Hus for svingvægt	489	1/E	Pneumatic valve	Pneumatisk ventil
154	1/E	Adjusting screw	Justeringsskruer	490	1/E	Silencer	Lyddæmper
166	1/E	Spring	Fjeder	500	1/E	Overspeed device, complete	Overspeed anordning, komplet
178	1/E	Circlip	Sikringsring				
191	1/E	Flyweight	Svingvægt				
201	1/E	Key	Not				
213	1/E	Ball bearing	Kugleleje				
225	1/E	Housing	Hus				
237	1/E	Cover	Dæksel				
249	4/E	Washer	Skive				
250	4/E	Screw	Skruer				
262	1/E	Pin	Stift				
274	1/E	Lever	Arm				
286	1/E	Nut	Møtrik				
298	1/E	Gasket	Pakning				
333	1/E	Spindle	Spindel				
345	1/E	Spring	Fjeder				



Overspeed device (just for reference)

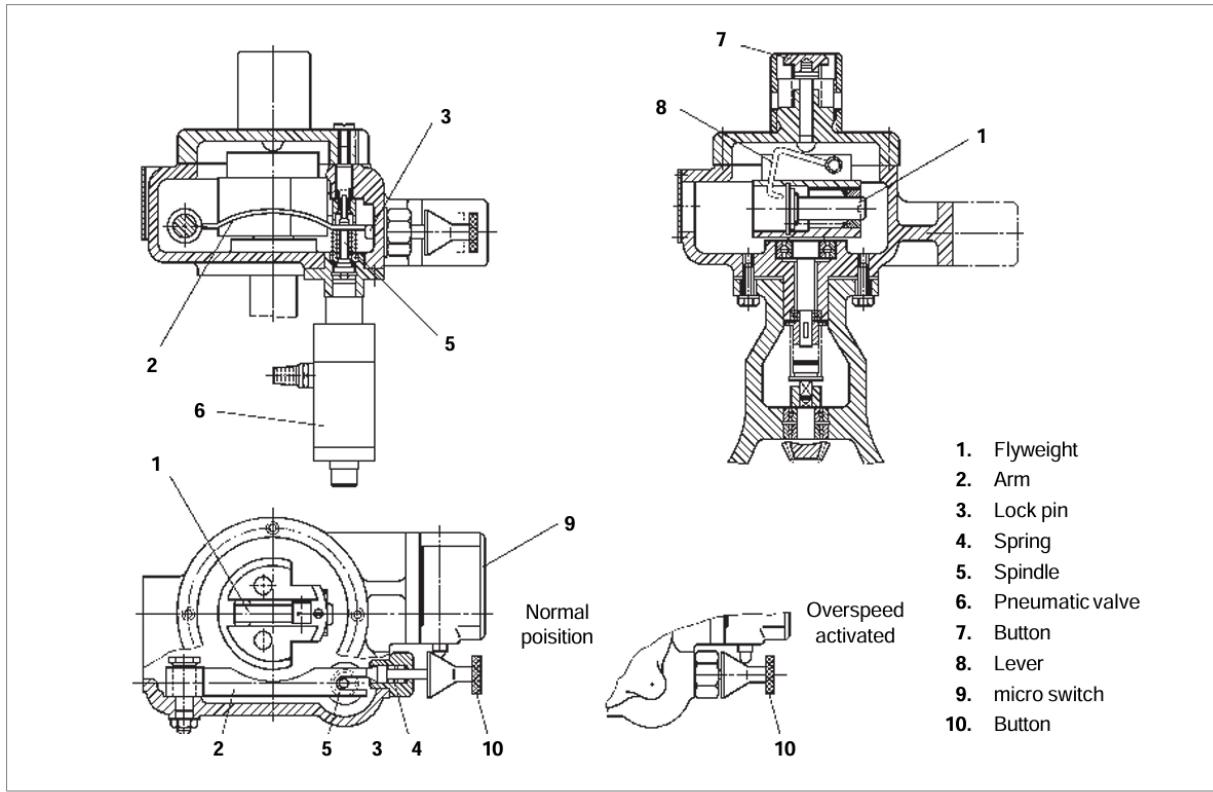


Fig 1. Mechanical overspeed (SSH 81).

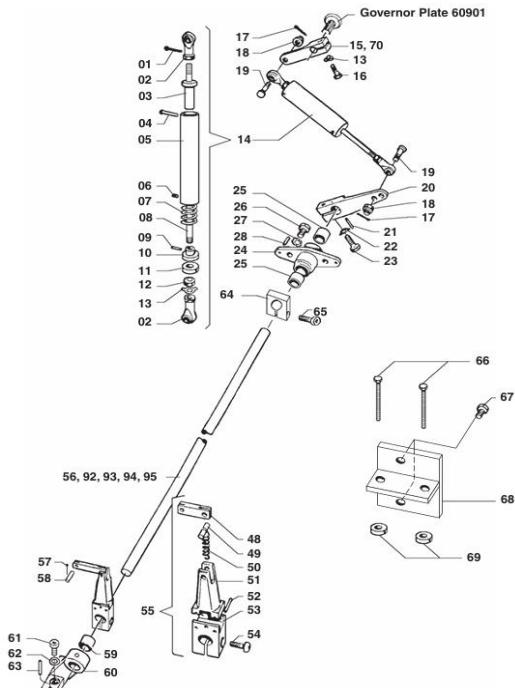
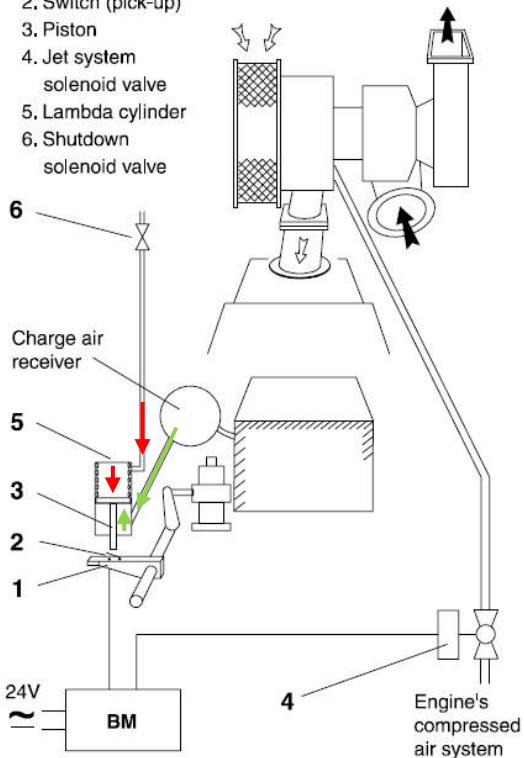
The engine can be stopped manually by pressing down the button (7), see fig. 1, which will activate the spring-loaded fly weight (1) through the lever (8).

If the overspeed has been activated the overspeed must be reset before the engine can be started. Reset is done by means of the button (10).

The overspeed alarm (SAH 81) is activated by means of the micro switch (9).

Lambda cylinder

1. Regulating arm
2. Switch (pick-up)
3. Piston
4. Jet system
solenoid valve
5. Lambda cylinder
6. Shutdown
solenoid valve

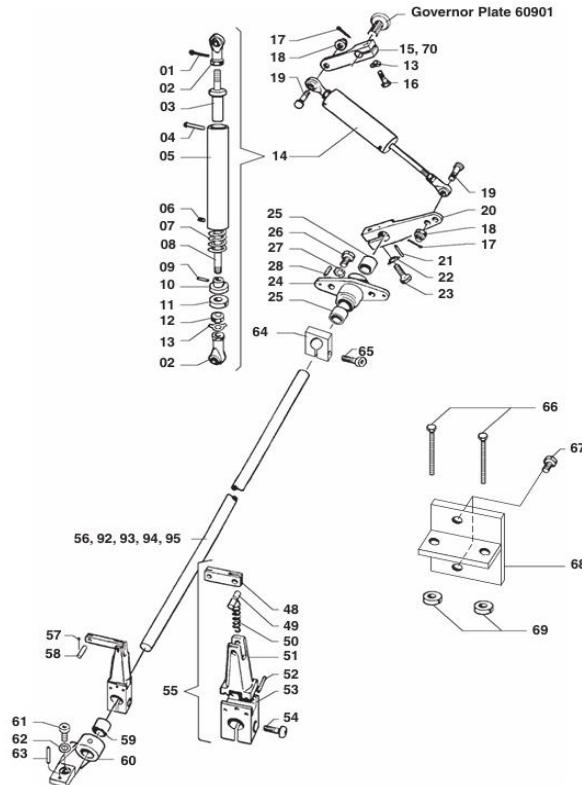
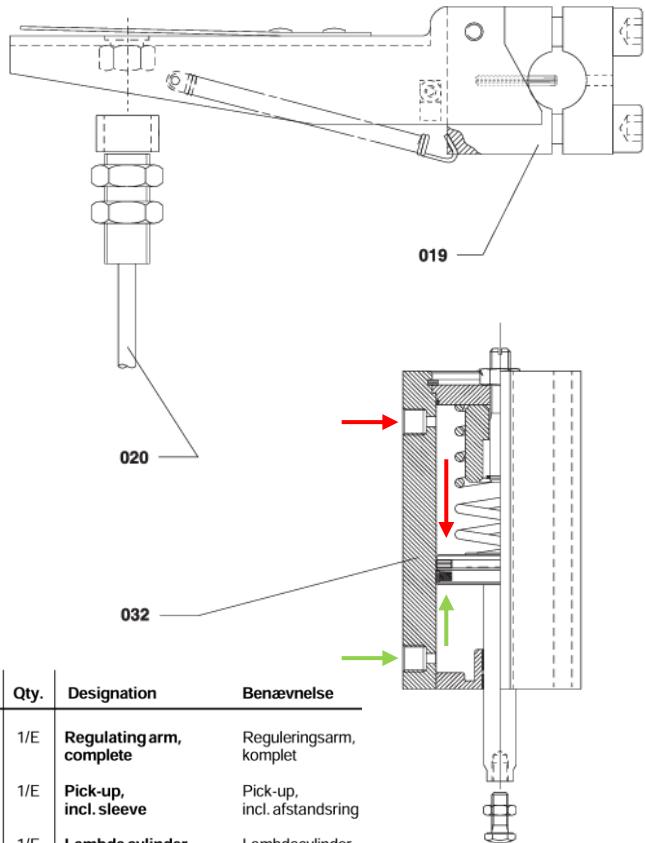


Lambda cylinder

Lambda cylinder is located near the governor linkage assembly and prevents excessive fuel from being injected into the cylinder during G/E initial start.

When the G/E overspeeds, compressed air is sent to the lambda cylinder, which in turn restricts the fuel rack connected to the linkage assembly, thereby restricting fuel injection into the cylinder and preventing overspeed.

Lambda cylinder

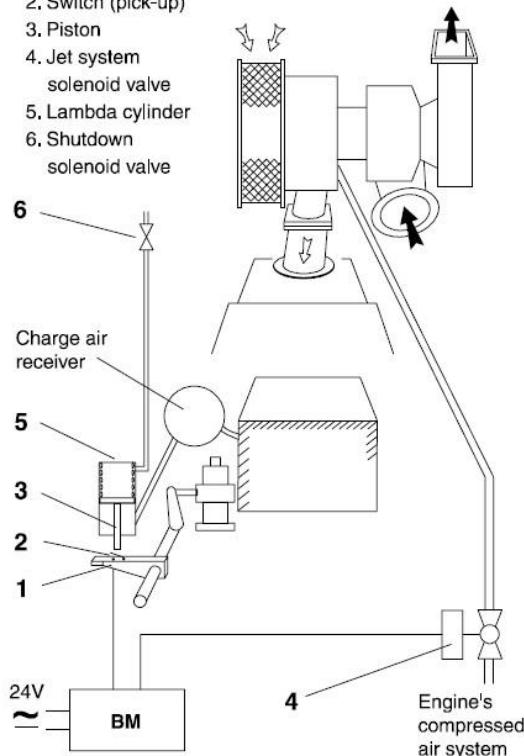


Lambda cylinder

As the load on the G/E increases, the pressure of the charging air increases, overcoming the spring force and lifting the piston, releasing the fuel injection restriction of the fuel rack.

Lambda cylinder

1. Regulating arm
2. Switch (pick-up)
3. Piston
4. Jet system
solenoid valve
5. Lambda cylinder
6. Shutdown
solenoid valve



Lambda cylinder

The purpose with the lambda controller is to prevent injection of more fuel in the combustion chamber of an auxiliary engine on the ship, than can be burned during a momentary load increase. This is carried out by controlling the relation between the fuel index and the charge air pressure.

The Lambda controller is also used as stop cylinder.

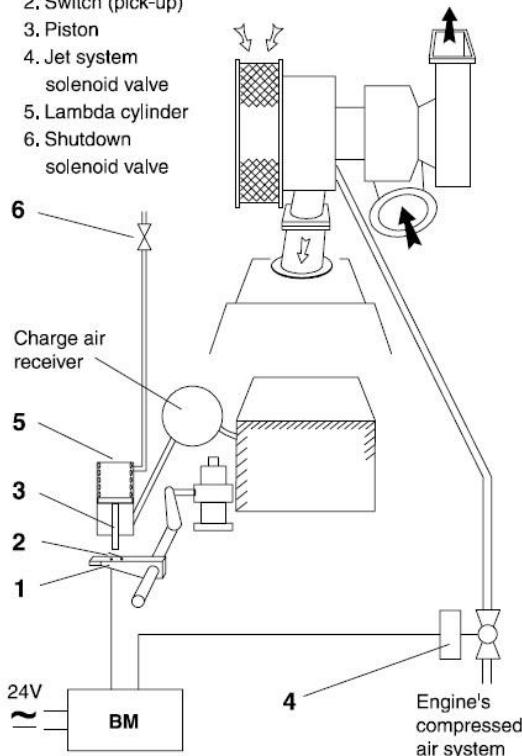
Advantages of Lambda Controller

The lambda controller has the following advantages:

- Reduction of visible smoke in case of sudden momentary load increases on auxiliary engines.
- Improved load ability.
- Less fouling of the engine's exhaust gas ways.
- Limitation of fuel oil index during starting procedure.

Lambda cylinder

1. Regulating arm
2. Switch (pick-up)
3. Piston
4. Jet system
solenoid valve
5. Lambda cylinder
6. Shutdown
solenoid valve



Principle of Lambda Controller

In case of a momentary load increase, the regulating device will increase the index on the injection pumps and hereby the regulator arm (1) is turned, the switch (2) will touch the piston arm (3) and be pushed downwards, whereby the electrical circuit will be closed.

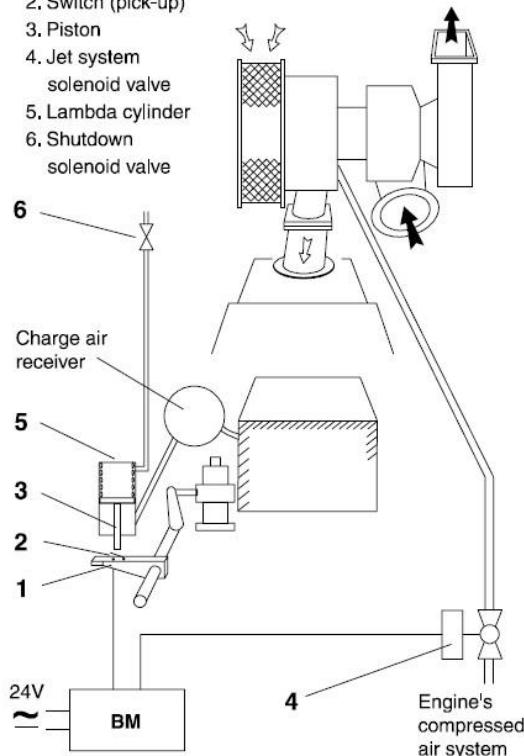
Thus, the solenoid valve (4) opens. The jet system is activated, the turbocharger accelerates and increases the charge air pressure, thereby pressing the piston (3) backwards in the lambda cylinder (5). When the lambda ratio is satisfactory, the jet system will be deactivated.

At a 50% load change the system will be activated for about 3-8 seconds.

If the system is activated more than 10 seconds, the solenoid valve will be shut off and there will be a remote signal alarm for "jet system failure".

Lambda cylinder

1. Regulating arm
2. Switch (pick-up)
3. Piston
4. Jet system
solenoid valve
5. Lambda cylinder
6. Shutdown
solenoid valve



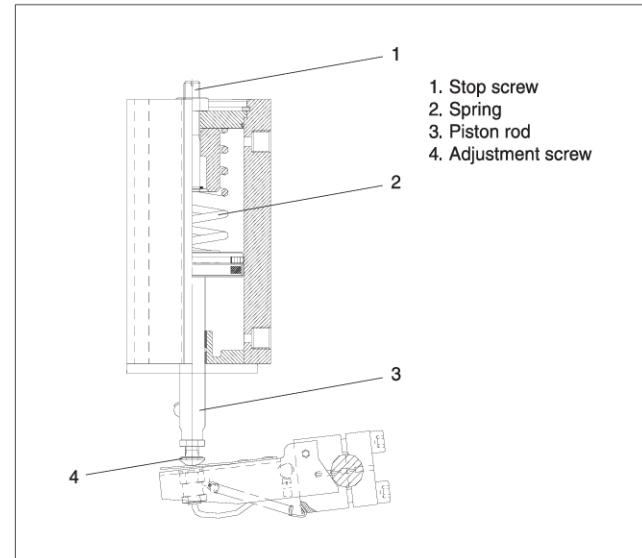
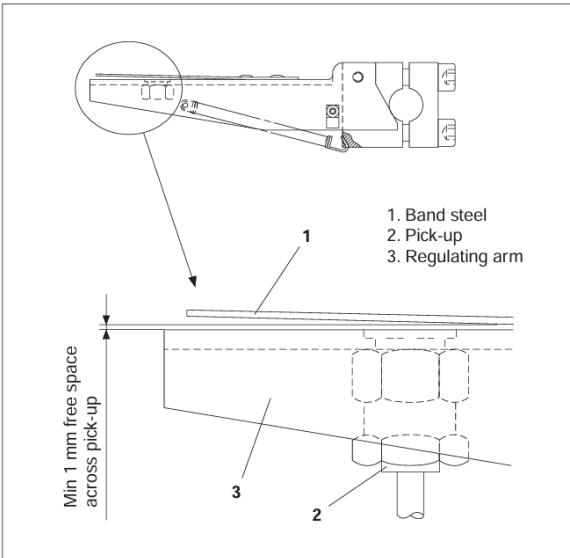
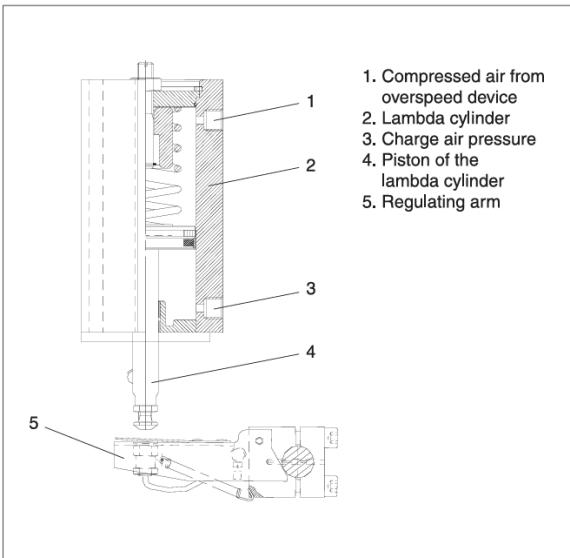
Fuel oil limiting during start procedure

During the start procedure the lambda controller is used as an index limiter.

Hereby heavy smoke formation is prevented during start procedure and further the regulating device cannot over-react.

The jet system is blocked during the starting procedure until the engine has reached about 110 RPM.

Lambda cylinder



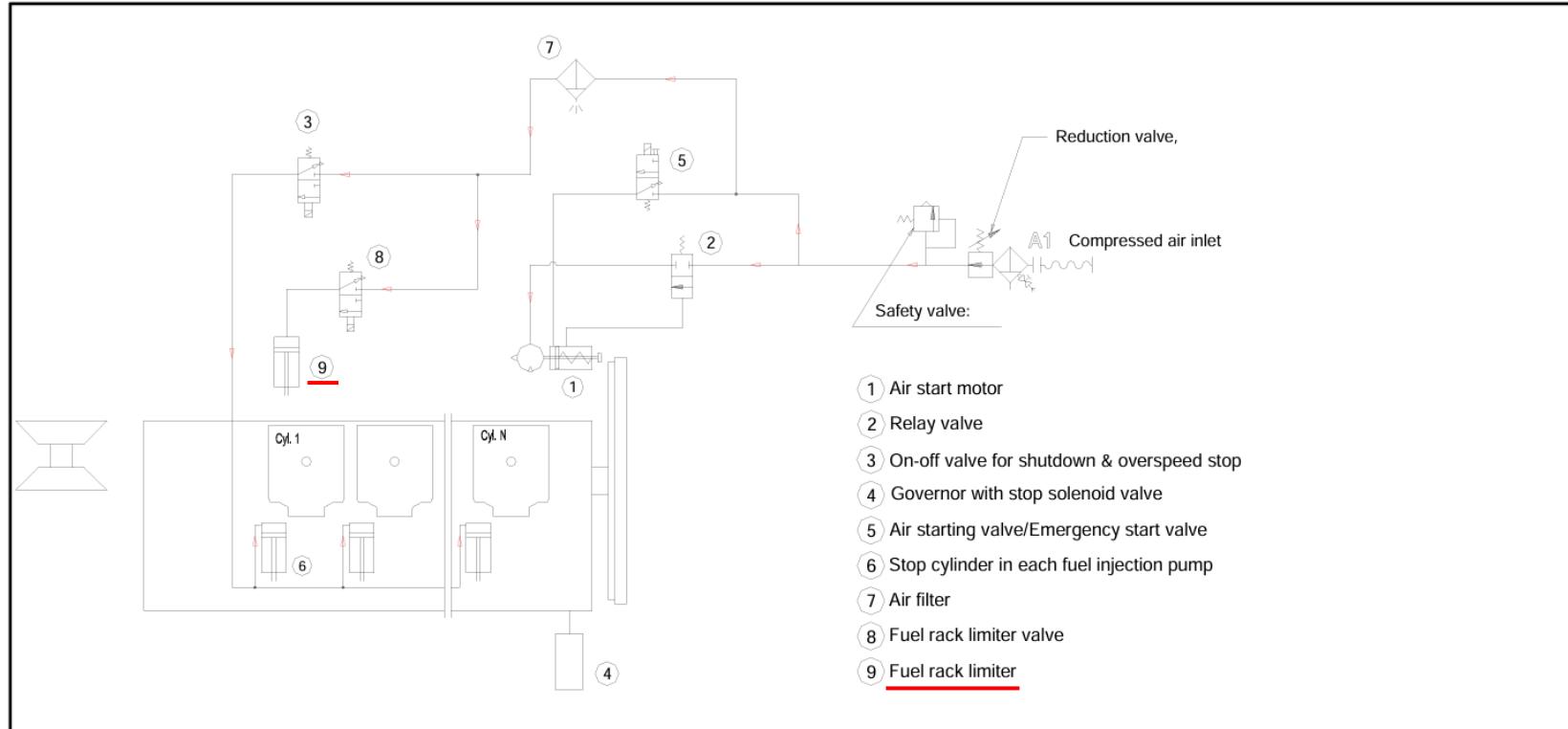
Lambda cylinder



Lambda cylinder



Fuel rack limiter (\approx Lambda cylinder)



Fuel rack limiter (\approx Lambda cylinder)

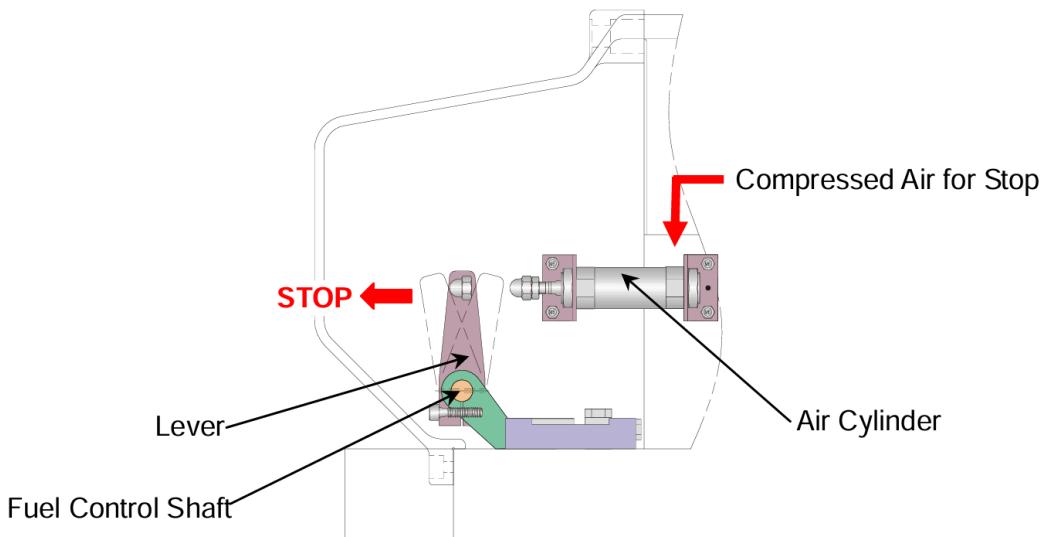


Fig. 5 Mechanical fuel limiter for starting (시동용 기계적 연료 제한 장치)

During starting period, the turbocharger is out of normal operation and therefore diesel engine is always in the incomplete combustion due to lack of air, which results in heavy smoke.

Digital governors have fuel limiting function for starting, while hydraulic governor normally has not.

However, the engine has adjustable fuel limiter for starting period regardless of the governor type.

Fuel rack limiter (\approx Lambda cylinder)

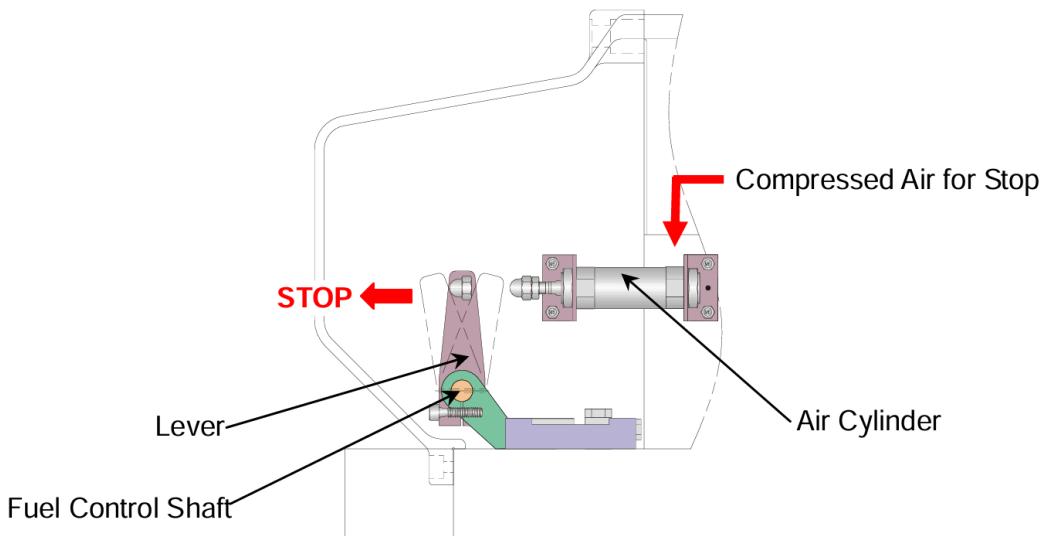
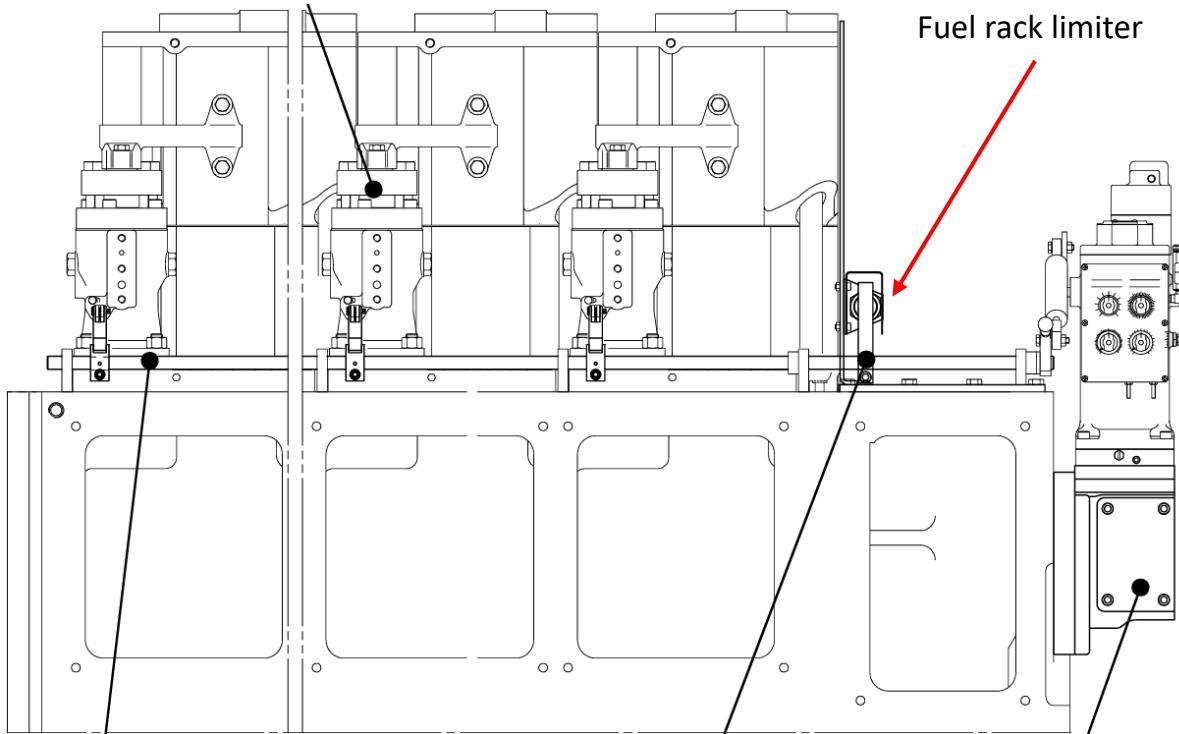


Fig. 5 Mechanical fuel limiter for starting (시동용 기계적 연료 제한 장치)

The fuel limiter piston is used for starting limiter to avoid excessive fuel injected into cylinder during starting period to avoid heavy smoke.

During starting period, the engine automation system activate starting solenoid valve to supply compressed air to push the fuel limiter piston as shown in fig 5.

Fuel rack limiter (\approx Lambda cylinder)

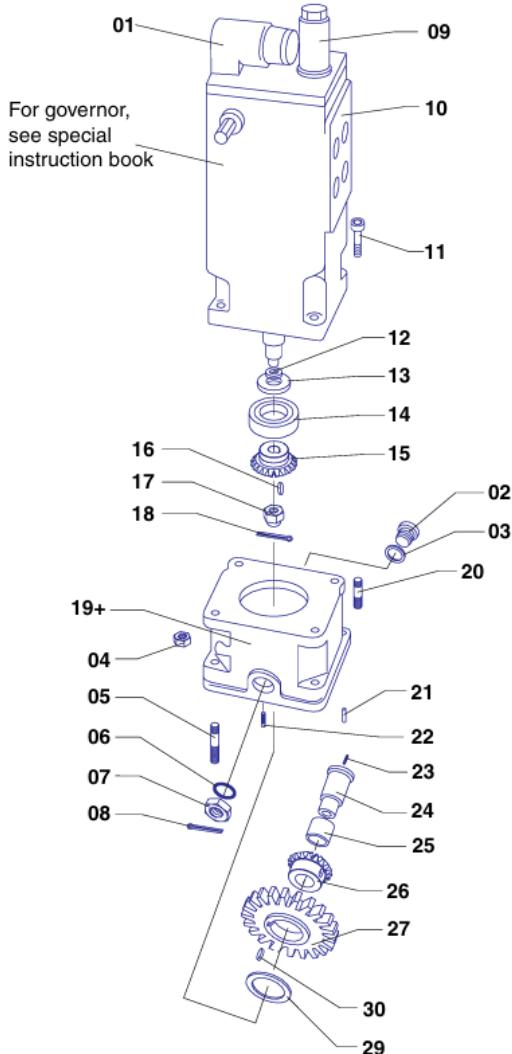


Govenor

Most of the governors installed in G/E use Woodward products.

Woodward hydraulic-mechanical and electronic governors provide reliable and precise control of engine speed and output in every type of engine application.

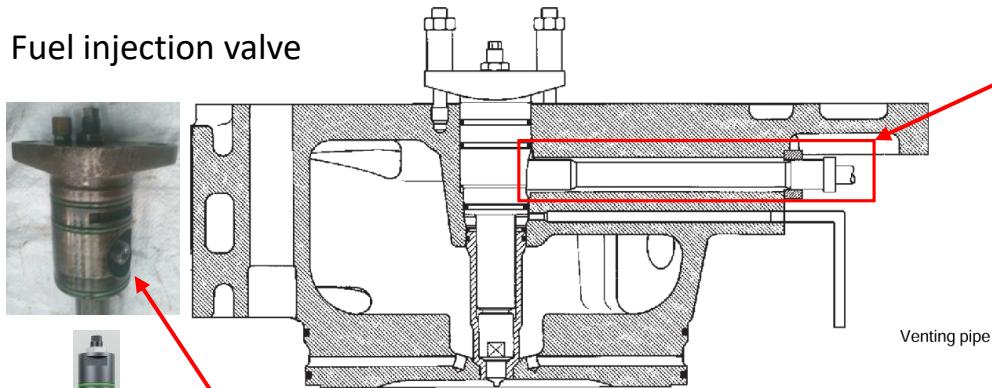
The main purpose of the governor is to control the amount of oil injected into the engine cylinder by adjusting the fuel rack of the fuel injection pump connected to the governor linkage assembly to maintain a constant RPM of the G/E.



Fuel oil high pressure pipe

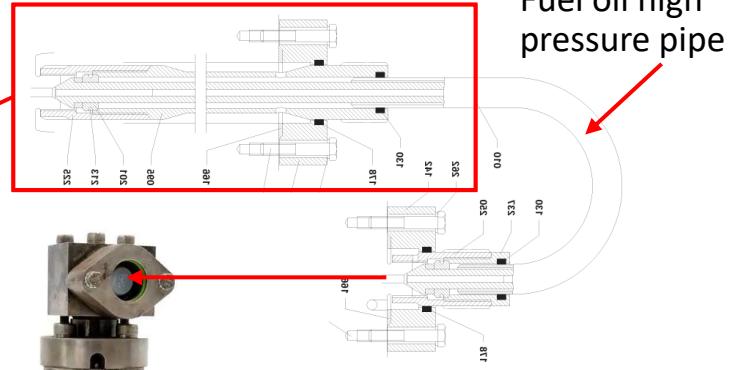
The connection between injection pump and fuel injector is a shielded high pressure pipe. The high pressure pipe is equipped with connection tapers matching to similar taper facings on the threaded connectors on the injection pump and the fuel injector.

Fuel injection valve

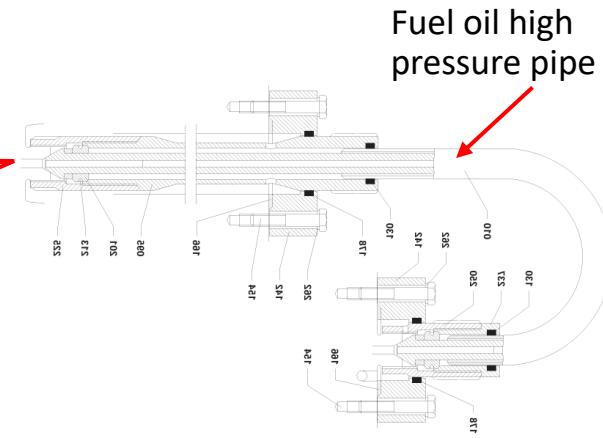
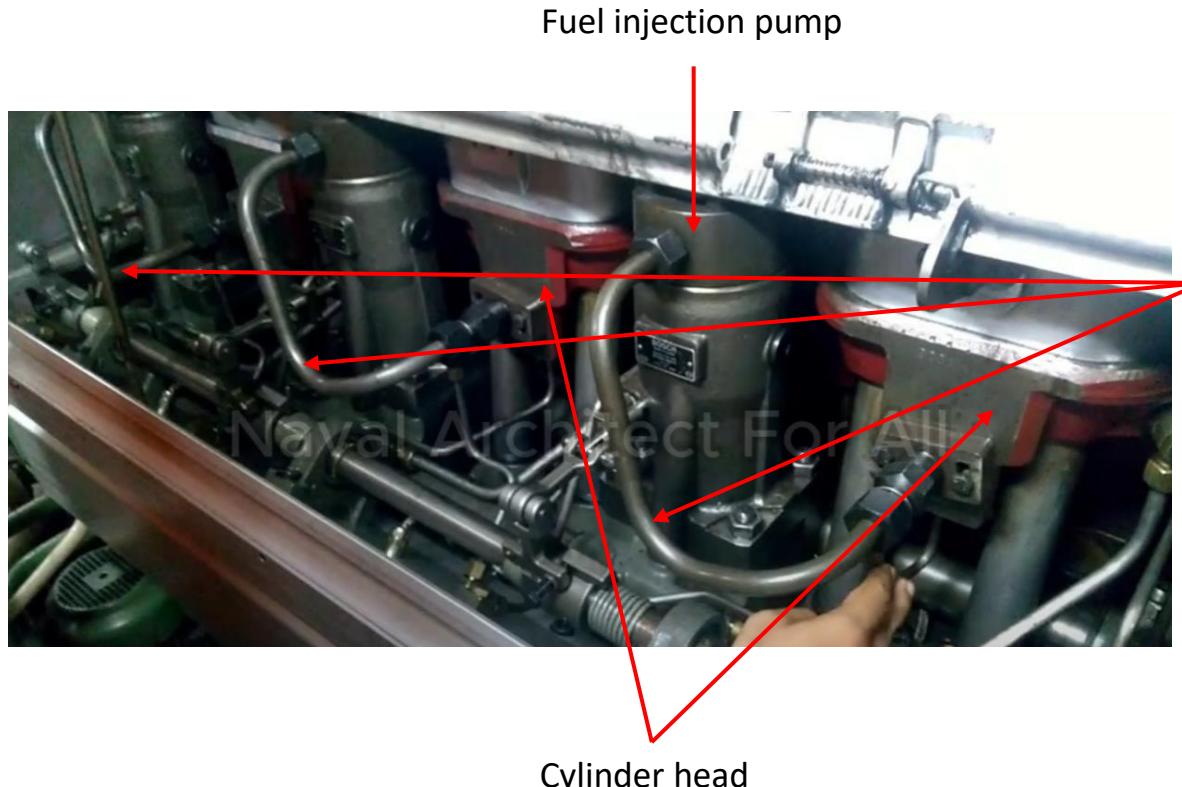


Fuel oil high pressure pipe is connected to the fuel injection valve

Fuel injection pump



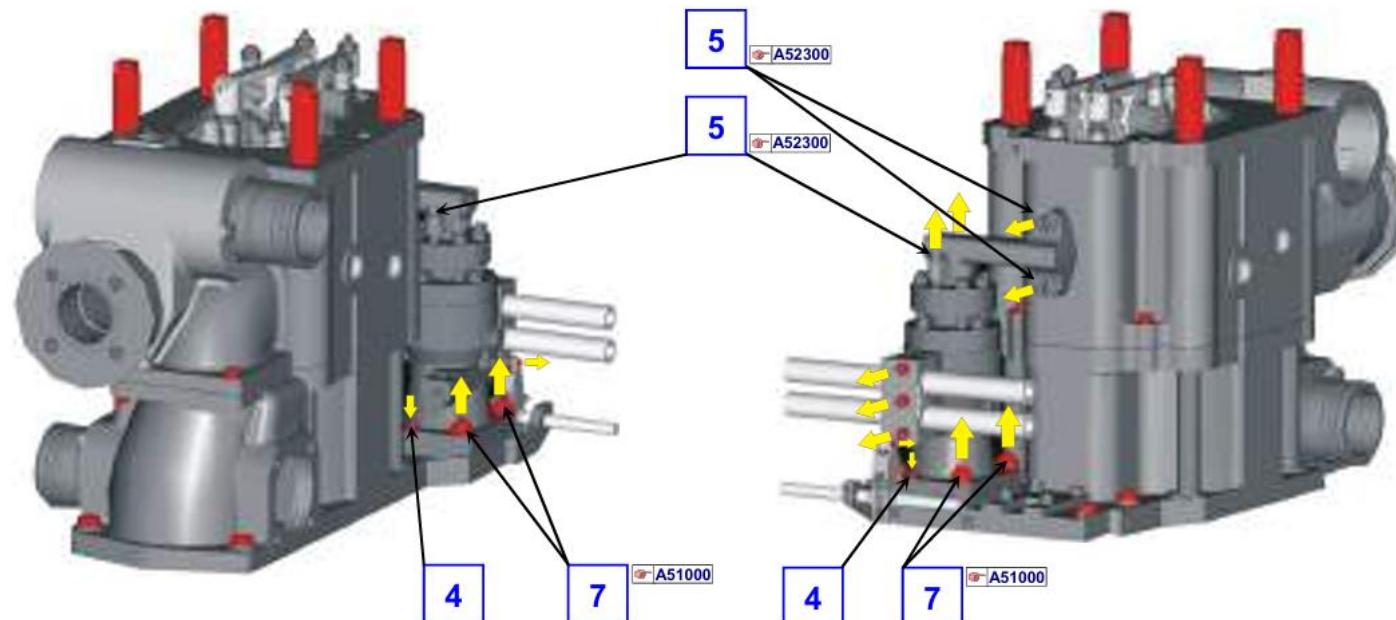
Fuel oil high pressure pipe



Fuel oil high pressure pipe (HiMSEN)



Fuel oil high pressure pipe (HiMSEN)

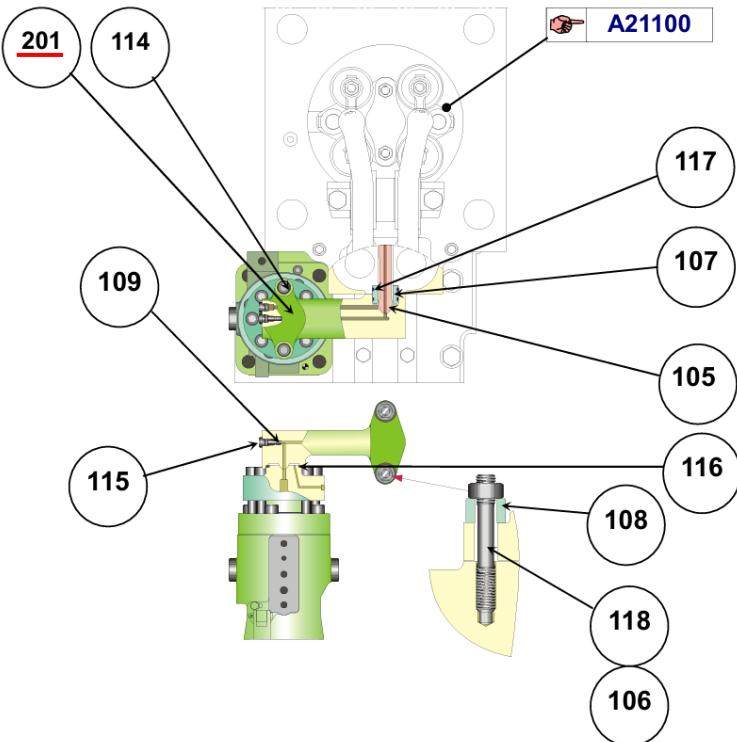


(a) Exhaust side

(b) Cam side

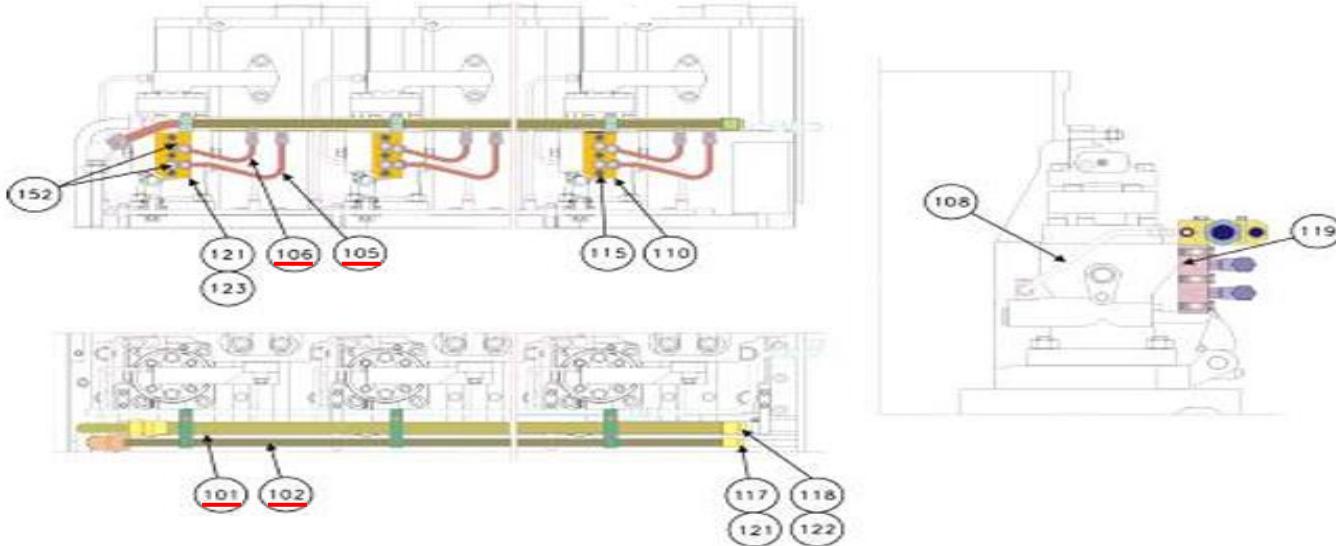
Fig. 2 Loosen the bolts for high pressure pipe block and fuel injection pump

Fuel oil high pressure pipe (HiMSEN)



Part List

Item No.	Description	Q'ty / Cyl.
105	Injection Pipe	1
106	Stud (M12)	2
107	Bush	1
108	Spherical Washer	2
109	Plugging Piece	1
114	Hex.Socket Bolt (M12)	2
115	Set Screw (M10)	1
116	O-ring	1
117	O-ring	2
118	Nut (M12)	2
200	Fuel High Pressure Block Ass'y(mono)	1
201	Fuel Delivery Block	1



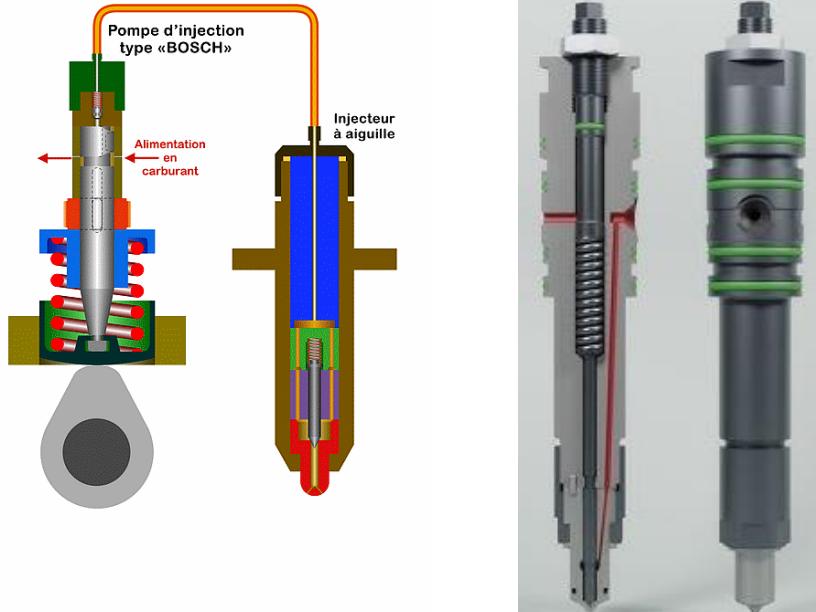
Part List

Item No.	Description	Q'ty / Eng.					Weight (kg)	Remarks / See Note
		5 Cyl	6 Cyl	7 Cyl	8 Cyl	9 Cyl		
101	Fuel oil inlet main pipe	1	1	1	1	1		
102	Fuel oil return main pipe	1	1	1	1	1		
105	Fuel oil inlet branch pipe	5	6	7	8	9	0.26	
106	Fuel oil return branch pipe	5	6	7	8	9	0.15	
108	Fuel oil leakage pipe	1	1	1	1	1		
110	Intermediate pipe	4	5	6	7	8	1.00	
115	Socket head bolt	15	18	21	24	27	0.05	
117	Plug	1	1	1	1	1	0.02	
118	Plug	1	1	1	1	1	0.10	
119	O-Ring	10	12	14	16	18		
121	Gasket	21	25	29	33	17		
122	Gasket	3	3	3	3	3		
123	Connection block	1	1	1	1	1		
152	Connector ø10XPF1/4	10	12	14	16	18		

Fuel injection valve

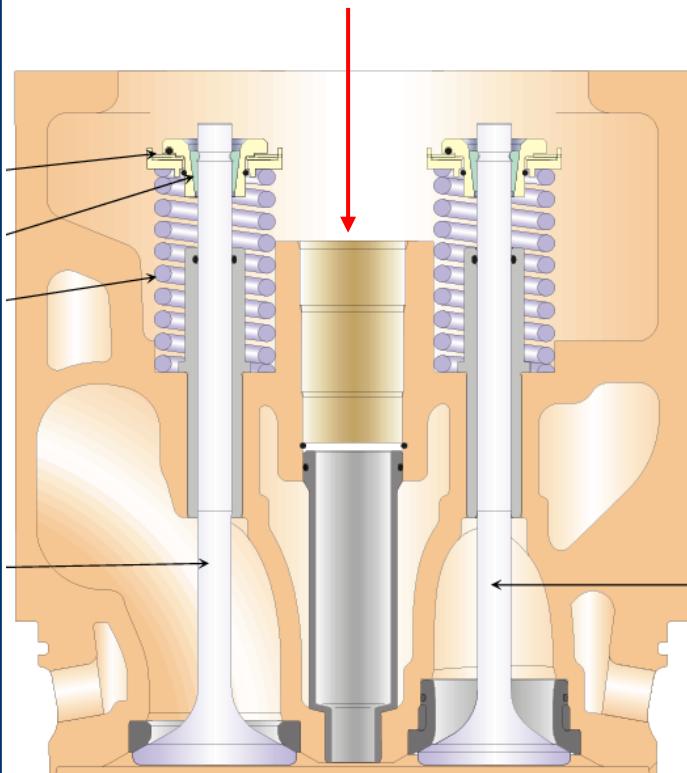
The fuel injection valve (FIV) is a component that injects atomized fuel into the cylinder.

The FIV is mounted on the cylinder head and connected to the fuel oil high pressure pipe, receives pressurized fuel oil from the fuel injection pump, and injects atomized fuel.

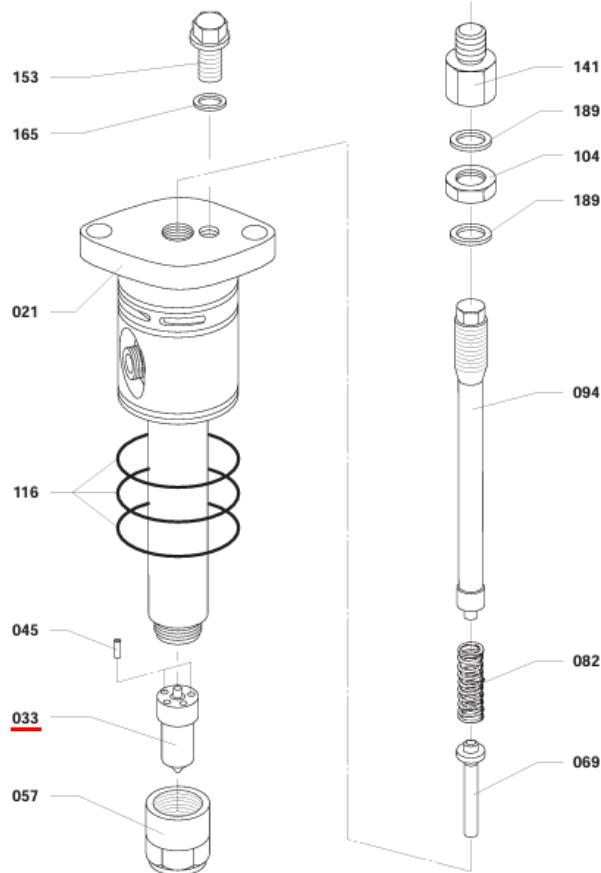


Fuel injection valve

The fuel injection valve (FIV) is inserted into the hole below.

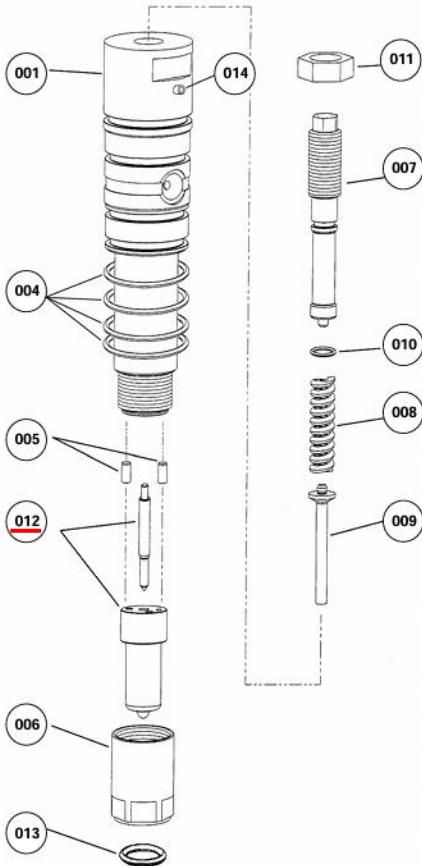


Fuel injection valve (MAN B&W)



Item No.	Qty.	Designation	Benævnelse
021	1/V	Injector housing	Ventilhus
<u>033</u>	1/V	Nozzle, complete	Forstøver, komplet
045	2/V	Dowel pin	Styrestift
057	1/V	Screw cap	Omløber
069	1/V	Thrust spindle	Trykspindel
082	1/V	Spring	Fjeder
094	1/V	Adjusting screw	Justeringsskrue
104	1/V	Nut	Metrikk.
116	3/V	O-ring	O-ring
141	1/V	Cap nut	Hættemetrikk.
153	1/V	Bolt	Bolt
165	1/V	Washer	Skive
177	1/C	Fuel injection valve, complete	Bændselsventili, komplet
189	2/V	Washer	Skive

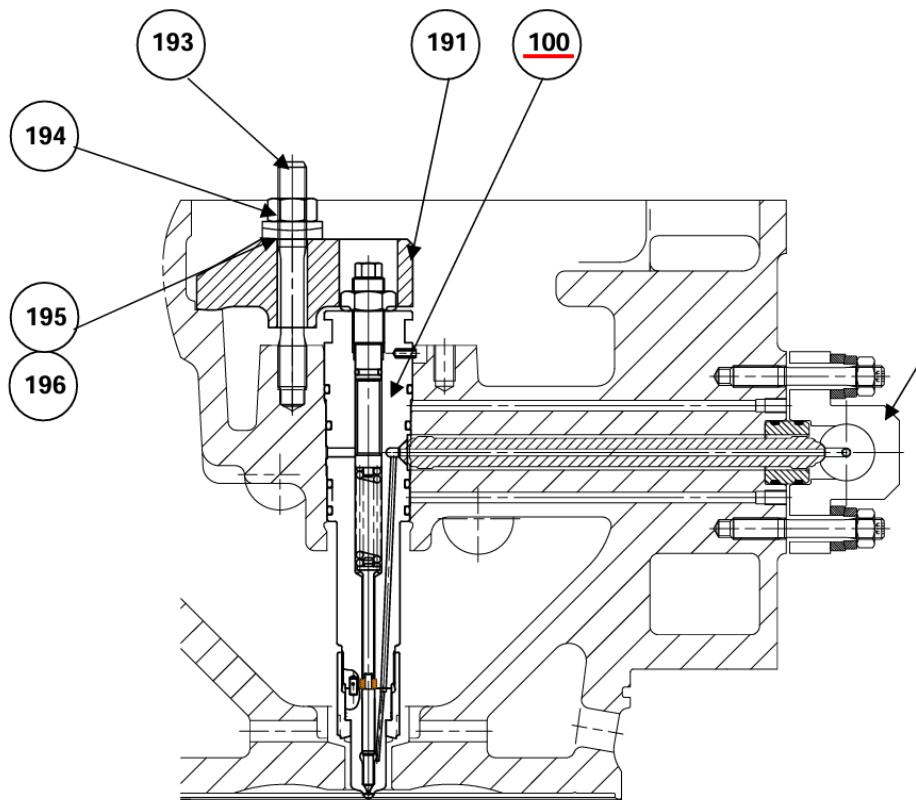
Fuel injection valve (HiMSEN)



Part List

Item No.	Description	Q'ty / Cyl.
001	Fuel injection valve body	1
004	O-ring	4
005	Dowel pin	2
006	Nozzle nut	1
007	Adjust bolt	1
008	Spring	1
009	Spindle	1
010	O-ring	1
011	Nut	1
012	<u>Atomizer assembly</u>	1
013	Seal ring	1
014	Spring pin	1

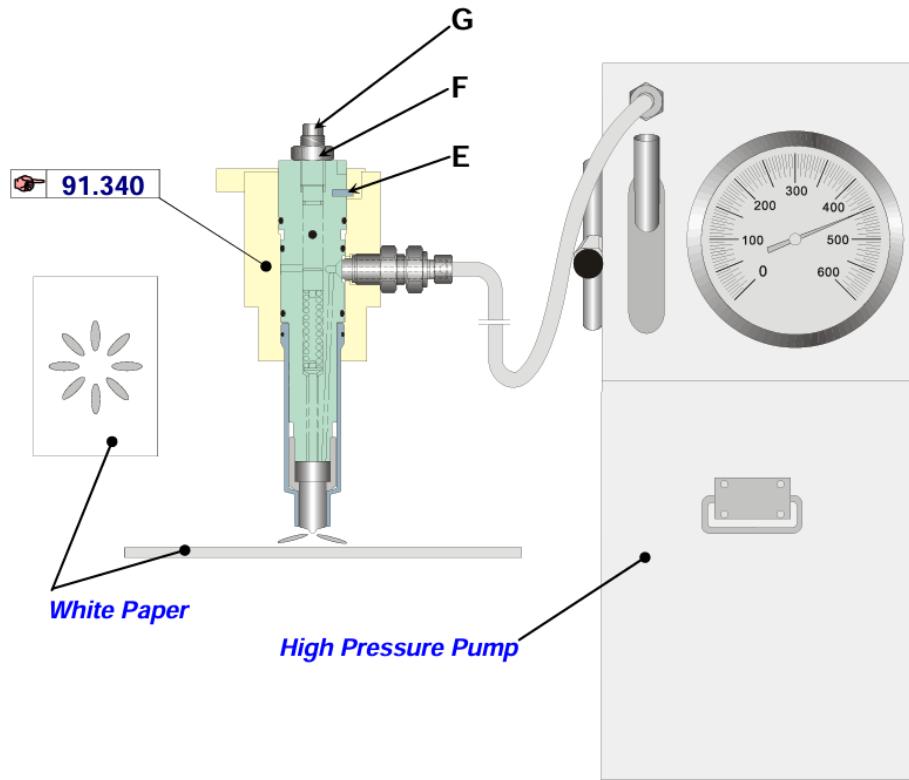
Fuel injection valve (HiMSEN)



Part List

Item No.	Description	Q'ty / Cyl.
100	Fuel injection valve complete	1
191	Support	1
193	Stud (M16)	1
194	Hexagon nut (M16)	1
195	Washer	1
196	Washer	1

Fuel injection valve (HiMSEN)



Valve opening pressure : 450 bar

Fig.2 Functional test of fuel injection valve (연료 분사 밸브의 기능 시험)

Fuel injection valve (HiMSEN)



Fig.1 Judging the nozzle bores. (left : open, right : partly clogged)



Fig.2 Judging the tightness (left : tight, right : dripping)

Checking Atomizing Condition

1. Checking procedure

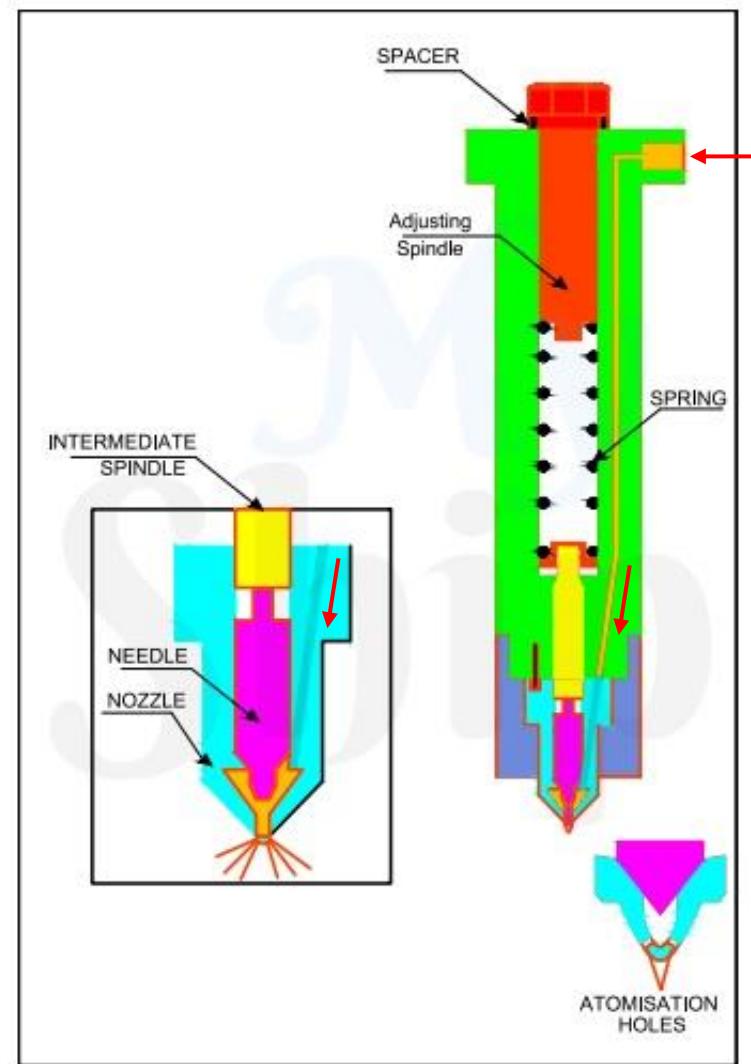
- 1) Actuate the hand pump evenly until the pressure gauge shows 250 bars.
- 2) The injection nozzle can be considered tight if no drop falls within a period of 5 seconds.

2. Criterion of decision – All nozzle holes open

- 1) Keeping the tightness: normal
- 2) Dripping on nozzle: re-conditioning or changing to a new one.

Fuel injection valve

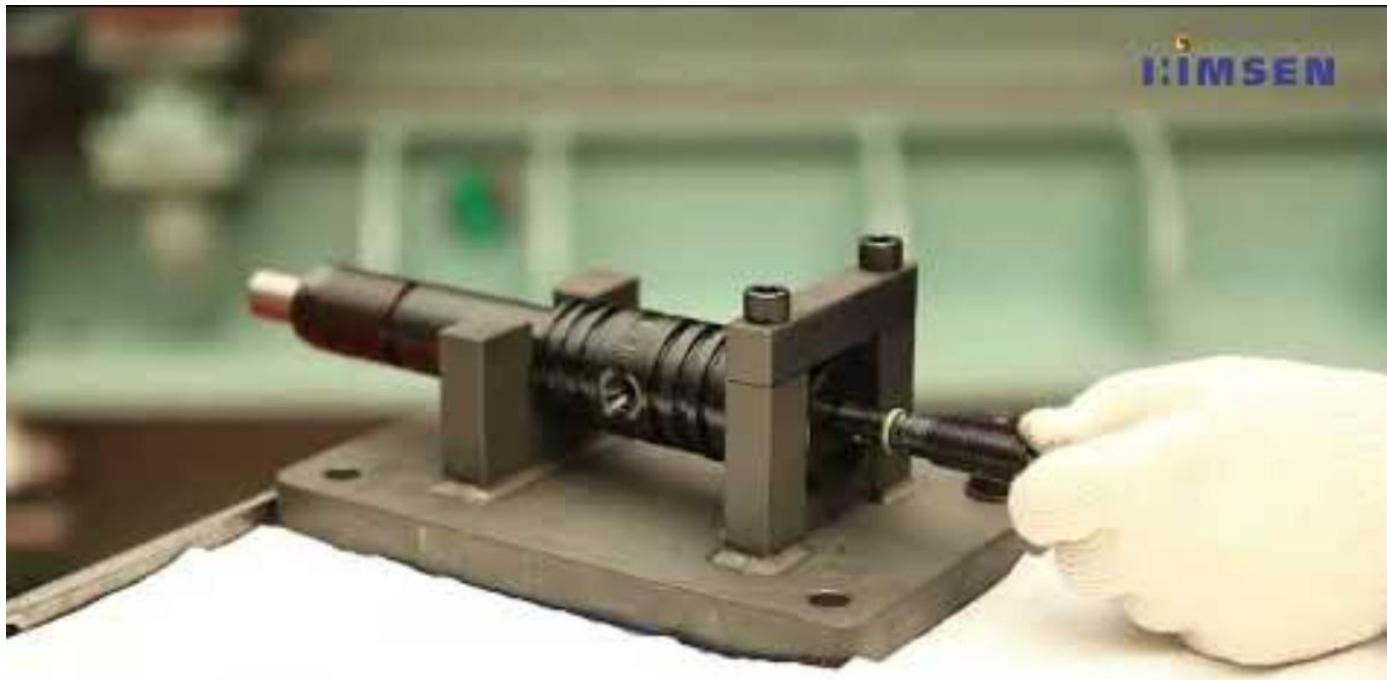
Pressurized fuel entering the FIV overcomes the spring force and lifts the needle of the nozzle, spraying it through several tiny holes and ultimately injecting atomized fuel into the cylinder.



Fuel injection valve



Fuel injection valve



4. Loosen the Adjusting bolt of FIV

References

- 1) https://en.wikipedia.org/wiki/Heavy_fuel_oil
- 2) <https://lubmarine.totalenergies.com/faq/glossary/heavy-fuel-oil-hfo>
- 3) <https://www.bbc.co.uk/bitesize/guides/zgx2k2p/revision/4>
- 4) <https://anchinv.com/oil-refining-and-petrochemical-industry-overview/>
- 5) <https://www.vesselfinder.com/vessels/details/9332810>
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