FUEL OIL SYSTEM
&
FUEL INJECTION EQUIPMENT
11

An English language learning unit
based on authentic materials

B. Pritchard, M. Borucinsky , J. Luzer, A. Spinčić

http://www.machineryspaces.com

http://www.marinediesels.info/index.html

http://marengine.com/home

http://www.kittiwake.com/bunker-fuel-testing-analysis

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Part I.

I. The Basics of Fuel Oil System

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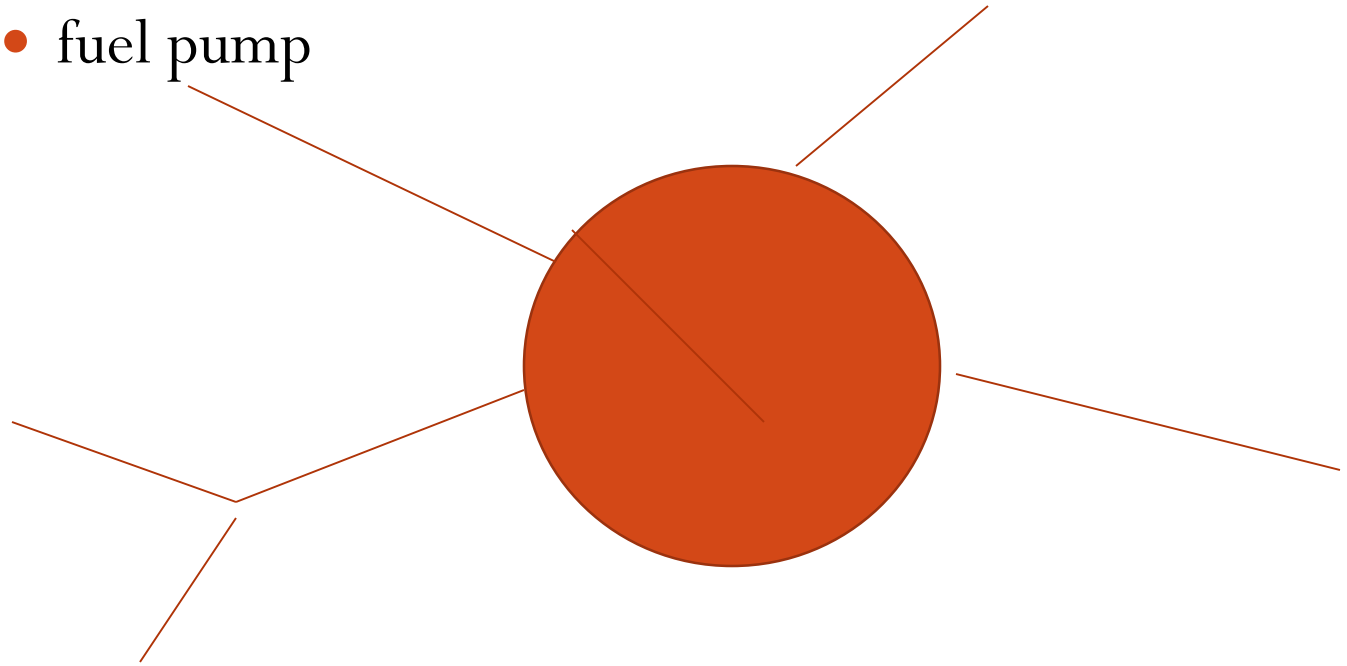
Word spider – fuel oil system terms

- fuel pump



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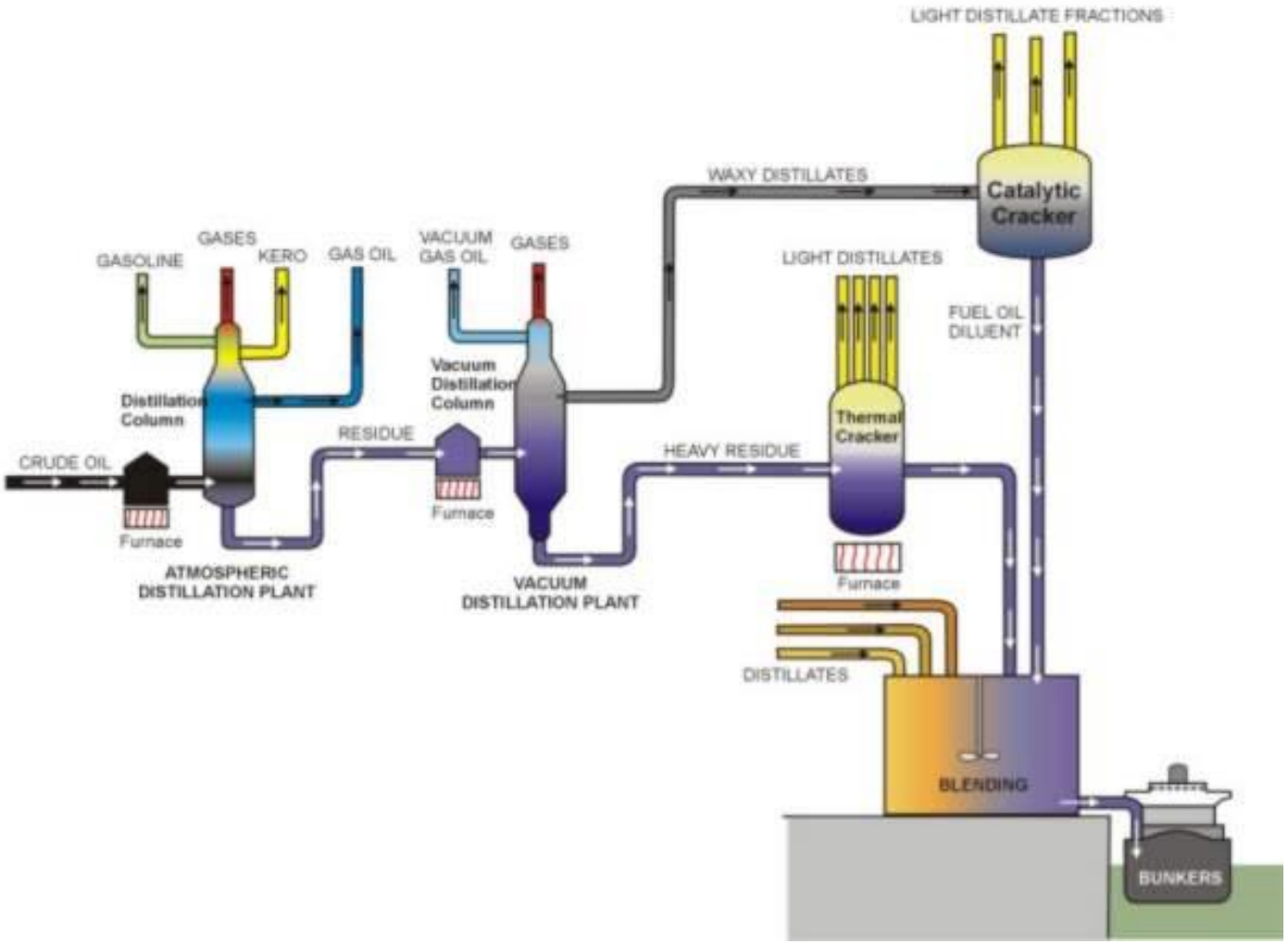
I. The Basics of Fuel Oil Systems

- Marine diesel engines are designed to burn heavy residual fuel. This is made up of the residues after the lighter and more costly fuels and gases have been taken out of the crude oil at the refinery.
- The graphic below illustrates the process



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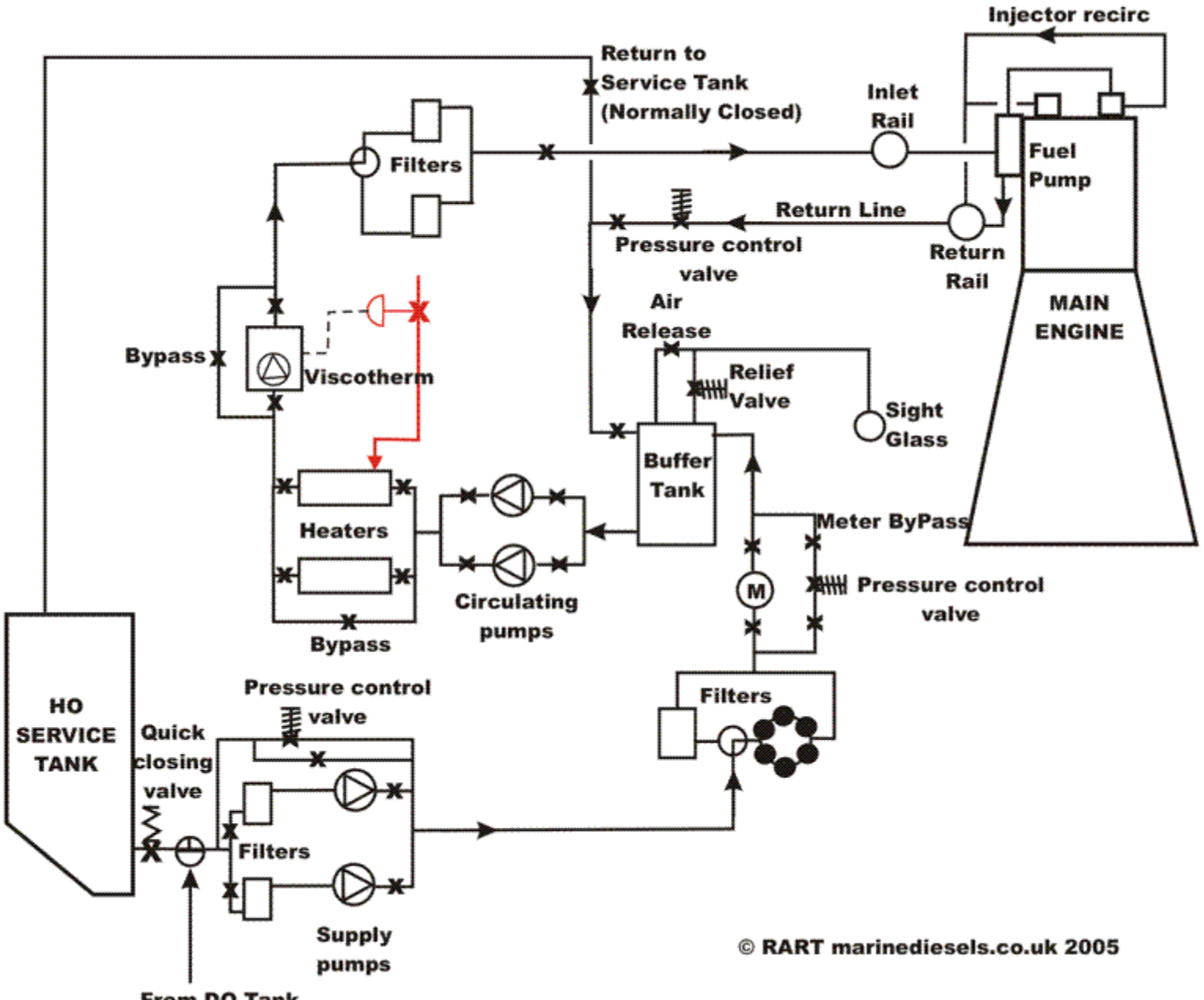
The fuel oil system for a diesel engine

- The fuel oil system for a diesel engine can be considered in two parts:
  - ..... and
  - .....
- Fuel supply deals with the provision of .....

The fuel oil system for a diesel engine

- The fuel oil system for a diesel engine can be considered in two parts:
  - **the fuel supply** and
  - **the fuel injection systems**.
- Fuel supply deals with the provision of fuel oil suitable for use by the injection system.

The diagram below shows a Fuel oil supply system for a large 2 stroke crosshead engine. However the set up is typical of any fuel system for a marine diesel engine operating on heavy residual fuel.



Speaking skills – pair work

1. Using the drawing in the previous slide discuss the diagram of the fuel oil supply system for a large two-stroke crosshead engine

2. Present the same diagram in speaking while your colleague has to make the corresponding drawing of the fuel oil supply system

Fuel oil supply for a two-stroke diesel engine

- A slow-speed two-stroke diesel is usually arranged to operate continuously on **heavy fu**el and have available a **diesel oil** supply for manoeuvring conditions.
- In the system shown in the Figure above, the oil is stored in **tanks** in the double bottom from which it is pumped to a **settling tank** and heated. After passing through **centrifuges** the cleaned, heated oil is pumped to a **daily service tank**. From the daily service tank the oil flows through a three-way valve to a **mixing tank**.

Name and give the sequence of tanks and other equipment in the flow of fuel oil of a marine diesel engine:

- **tanks in the double bottom**
- _____
- _____
- _____
- etc.

- A **flow meter** is fitted into the system to indicate fuel consumption. **Booster pumps** are used to pump the oil through heaters and a viscosity regulator to the engine-driven fuel pumps. The fuel pumps will discharge high-pressure fuel to their respective injectors.

  The viscosity regulator controls the fuel oil temperature in order to provide the correct viscosity for combustion. A pressure regulating valve ensures a constant-pressure supply to the engine-driven pumps, and a pre-warming bypass is used to heat up the fuel before starting the engine.

1. **Underline the fuel oil system terms in the slide above and give Croatian equivalents for the same**

1. **Write down the function of the following parts:**

- **flow meter**
- **booster pumps**
- **fuel pumps**
  viscosity regulator
- **pressure regulating valve**
- **pre-warming**

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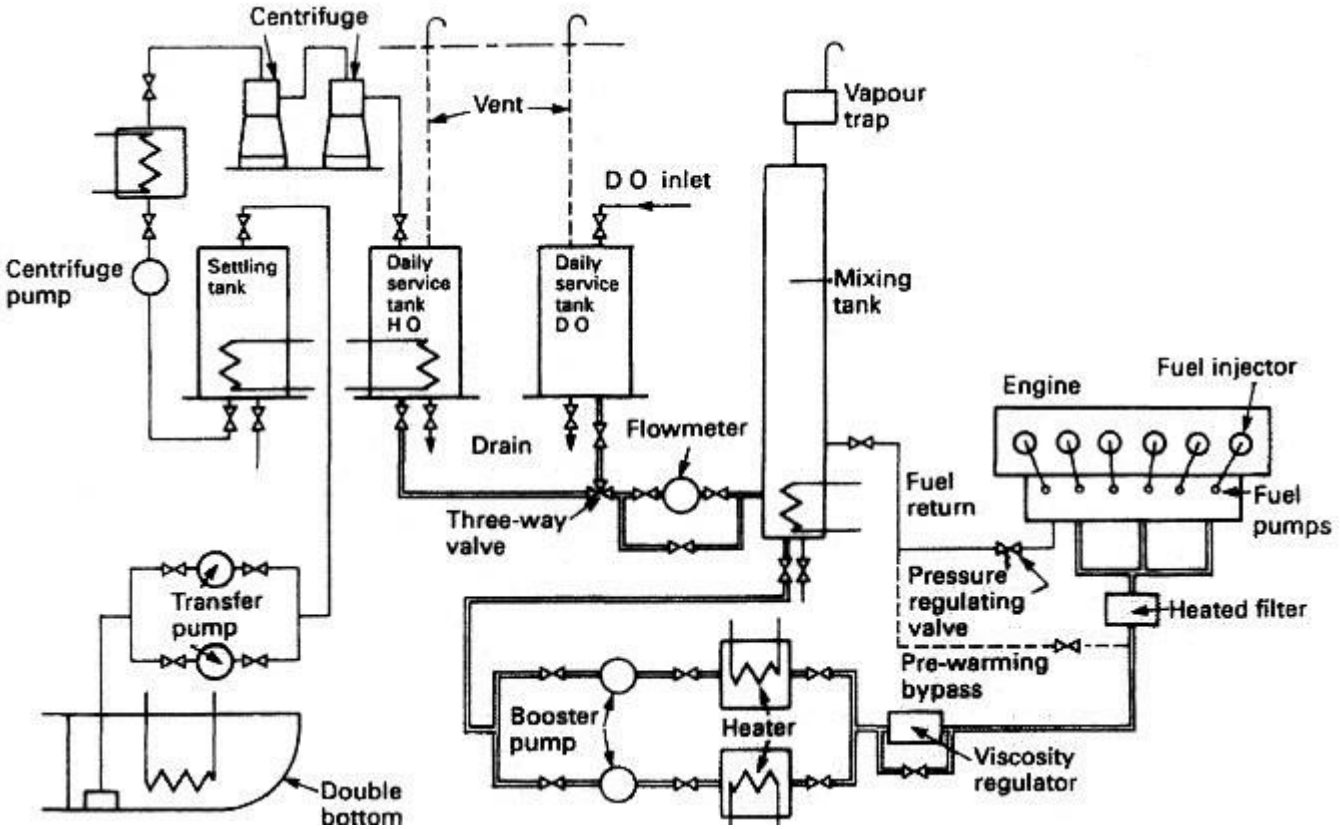
- A diesel oil daily service tank may be installed and is connected to the system via a three-way valve. The engine can be started up and manoeuvred on diesel oil or even a blend of diesel and heavy fuel oil. The mixing tank is used to collect recirculated oil and also acts as a buffer or reserve tank as it will supply fuel when the daily service tank is empty.
- The system includes various safety devices such as low-level alarms and remotely operated tank outlet valves which can be closed in the event of a fire.

Supply the missing verbs

- A diesel oil daily service tank may be _____ and is _____ to the system via a three-way valve. The engine can be started up and _____ on diesel oil or even a blend of diesel and heavy fuel oil. The mixing tank is used to _____ recirculated oil and also _____ as a buffer or reserve tank as it will _____ fuel when the daily service tank is empty.
- The system _____ various safety devices such as low-level alarms and remotely operated tank outlet valves which can _____ in the event of a fire.



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Speaking and writing skills

1. *Describe the function of the various tanks in the diagram above*

2. *Following the same diagram above describe the fuel oil system and the passage of fuel oil from the DB tank to the engine*

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Internal combustion engine procedure

- The fuel oil system for a diesel engine can be considered in two parts—the fuel supply and the fuel injection systems. Fuel supply deals with the provision of fuel oil suitable for use by the injection system.
- **Fuel oil supply for a two-stroke diesel engine**
  A slow-speed two-stroke diesel is usually arranged to operate continuously on heavy fuel and have available a diesel oil supply for manoeuvring conditions.

Supply the missing information

- **Internal combustion engine procedure**

  The fuel oil system for a diesel engine can be considered in two parts: ..... and .....

- Fuel supply deals with the ..... suitable for use by the injection system.
- A slow-speed two-stroke diesel is usually arranged to operate continuously on ..... and have available a diesel oil supply for ..... .

Match the text in the left-hand column with that of the right-hand column

a	In the system shown in the diagram above the oil is stored	1	through a three-way valve to a mixing tank.	
b	After passing through centrifuges	2	to indicate fuel consumption.	
c	From the daily service tank the oil flows	3	in tanks in the double bottom from which it is pumped to a settling tank and heated.	
d	A flow meter is fitted into the system	4	and a viscosity regulator to the engine-driven fuel pumps.	
e	Booster pumps are used to pump the oil through heaters	5	high-pressure fuel to their respective injectors.	
f	The fuel pumps will discharge	6	the cleaned, heated oil is pumped to a daily service tank.	

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- In the system shown in the diagram above, the oil is stored in tanks in the double bottom from which it is pumped to a settling tank and heated.
- After passing through centrifuges the cleaned, heated oil is pumped to a daily service tank.
- From the daily service tank the oil flows through a three-way valve to a mixing tank.
- A flow meter is fitted into the system to indicate fuel consumption.
- Booster pumps are used to pump the oil through heaters and a viscosity regulator to the engine-driven fuel pumps.
- The fuel pumps will discharge high-pressure fuel to their respective injectors.

Fill in the missing fuel oil system term

- In the system shown in the diagram above, the oil is stored in tanks in the double bottom from which it is pumped to a _____ and heated.
- After passing through centrifuges the cleaned, heated oil is pumped to a _____.
- From the daily service tank the oil flows through a three-way valve to a _____.
- A flow meter is fitted into the system to indicate _____.
- _____ are used to pump the oil through heaters and a viscosity regulator to the engine-driven fuel pumps.
- The fuel pumps will discharge high-pressure fuel to their respective injectors.

Jumbled sentences – change the order of chunks to make acceptable sentences

- the oil is stored in tanks in the double bottom in the system shown in the diagram abovefrom which it is pumped to a settling tank and heated
- after passing through centrifuges to a mixing tank the cleaned, heated oil is pumped from the daily service tank
- the oil flows through a three-way valve from the daily service tank to a mixing tank
- to indicate fuel consumption a flow meter is fitted into the system
- to pump the oil booster pumps are used through heaters and a viscosity regulator to the engine-driven fuel pumps
- to their respective injectors high-pressure fuel the fuel pumps will discharge

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- The **viscosity regulator** controls the fuel oil temperature in order to provide the correct viscosity for combustion. A pressure regulating valve ensures a constant-pressure supply to the engine-driven pumps, and a pre-warming bypass is used to heat up the fuel before starting the engine. A diesel oil daily service tank may be installed and is connected to the system via a three-way valve.

Supply the missing information

- The viscosity regulator controls the fuel oil temperature in order to ……
- A pressure regulating valve ensures a constant ……, and a pre-warming bypass is used to ……
- A diesel oil daily service tank may be installed and is connected to the system ……

Pair work: Discuss the following terms with your partner

- *viscosity regulator*
- *pressure regulating valve*
- *pre-warming bypass*
- *diesel oil daily service tank*

Part II

II. Operation on Heavy Fuel Oil

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II. Operation on Heavy Fuel Oil

Main engines designed to manoeuvre on heavy fuel oil are to be operated according to the manufacturer's instructions. All other types of main engines are to be manoeuvred on diesel oil according to the manufacturers' instructions.

In the event of problems during manoeuvring on engines using heavy oil there must be no hesitation in changing over to diesel oil irrespective of whether the engines are being operated using bridge control, or using engine room control.

It is the Chief Engineer's responsibility to inform the Master of the particular engine type's maximum period that it can safely remain in the stopped position. He is also to inform the Master of the procedures which will have to be carried out if the particular engine type's maximum period at standstill during manoeuvring is exceeded.

Cloze test: supply the missing word

(every fifth word has been deleted)

Main engines designed to _____ on heavy fuel oil are _____ be operated according to _____ manufacturer's instructions. All other _____ of main engines are _____ be manoeuvred on diesel _____ according to the manufacturers' _____.

In the event of problems _____ manoeuvring on engines using _____ oil there must be _____ hesitation in changing over _____ diesel oil irrespective of _____ the engines are being _____ using bridge control, or using engine room control.

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III. The fuel oil injection system for a diesel engine

The function of the fuel injection system is to provide the right amount of fuel at the right moment and in a suitable condition for the combustion process.

There must therefore be some form of measured fuel supply, a means of timing the delivery and the atomisation of the fuel. The injection of the fuel is achieved by the location of cams on a camshaft. This camshaft rotates at engine speed for a two-stroke engine and at half engine speed for a four-stroke.

There are two basic systems in use, each of which employs a combination of mechanical and hydraulic operations. The most common system is the jerk pump; the other is the common rail.

Supply the missing information

The fuel oil injection system for a diesel engine

- The function of the fuel injection system is to provide …… and in a suitable condition for the combustion process.
- There must therefore be some form of measured fuel supply, a means of …… and …… fuel.
- The injection of the fuel is achieved by ……
- This camshaft rotates at engine speed for a two-stroke engine and at ……
- There are ……, each of which employs a combination of mechanical and hydraulic operations.
- The most common system is ……; the other is ……

PART III

III. The fuel oil injection system for a diesel engine

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- **Delivering right amount of fuel**

  The function of the fuel injection system is to provide the right amount of fuel at the right moment and in a suitable condition for the combustion process. There must therefore be some form of measured fuel supply, a means of timing the delivery and the atomisation of the fuel.

- **Delivering right amount of fuel**

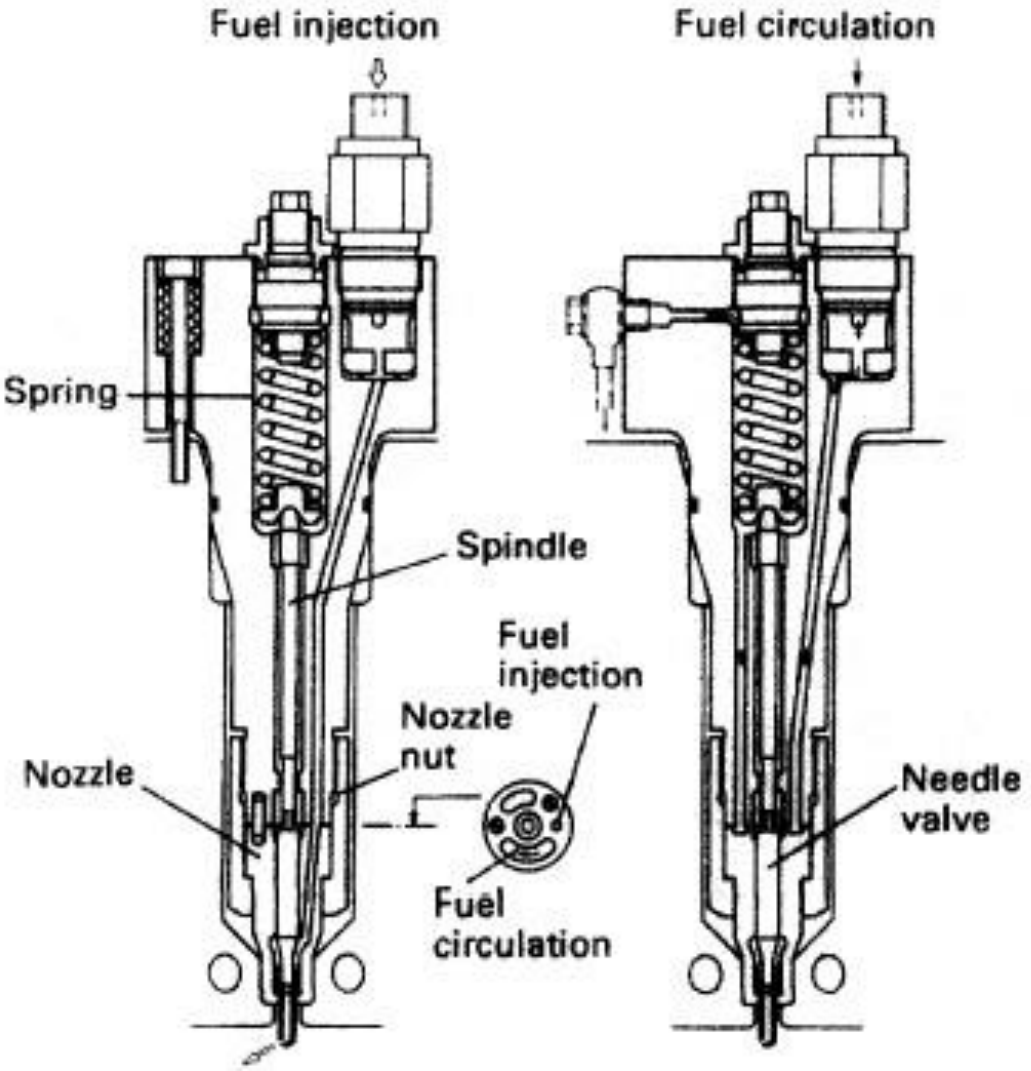
  The function of the fuel injection system is to provide the right amount of fuel at the right moment and in a suitable condition for the combustion process. There must therefore be some form of measured fuel supply, a means of timing the delivery and the atomisation of the fuel.

The fuel oil injection system for a diesel engine

- The injection of the fuel is achieved by the location of cams on a camshaft. This camshaft rotates at engine speed for a two-stroke engine and at half engine speed for a four-stroke.
- There are two basic systems in use, each of which employs a combination of mechanical and hydraulic operations. The most common system is the jerk pump; the other is the common rail.

The fuel oil injection system for a diesel engine

- The injection of the fuel is achieved by the location of cams on a camshaft. This camshaft rotates at engine speed for a two-stroke engine and at half engine speed for a four-stroke.
- There are two basic systems in use, each of which employs a combination of mechanical and hydraulic operations. The most common system is the jerk pump; the other is the common rail.



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- A typical **fuel injector** is shown in Figure , It can be seen to be two basic parts, the **nozzle** and the **nozzle holder** or body. The high-pressure fuel enters and travels down a passage in the body and then into a passage in the nozzle, ending finally in a chamber surrounding the needle valve.
- The **needle valve** is held closed on a mitred seat by an intermediate spindle and a spring in the injector body. The spring pressure, and hence the injector opening pressure, can be set by a compression nut which acts on the spring.
- The nozzle and injector body are manufactured as a matching pair and are accurately ground to give a good oil seal. The two are joined by a nozzle nut.

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Ex.

- The needle valve will open when the fuel pressure acting on the needle valve tapered face exerts a sufficient force to overcome the spring compression. The fuel then flows into a lower chamber and is forced out through a series of tiny holes.
- The small holes are sized and arranged to atomise, or break into tiny drops, all of the fuel oil, which will then readily burn. Once the injector pump or timing valve cuts off the high pressure fuel supply the needle valve will shut quickly under the spring compression force.

Ex.

- The needle valve will open when the fuel pressure acting on the needle valve tapered face exerts a sufficient force to overcome the spring compression. The fuel then flows into a lower chamber and is forced out through a series of tiny holes.
- The small holes are sized and arranged to atomise, or break into tiny drops, all of the fuel oil, which will then readily burn. Once the injector pump or timing valve cuts off the high pressure fuel supply the needle valve will shut quickly under the spring compression force.

- All slow-speed two-stroke engines and many medium-speed fourstroke engines are now operated almost continuously on **heavy fuel**. A **fuel circulating system** is therefore necessary and this is usually arranged within the fuel injector. During injection the high-pressure fuel will open the circulation valve for injection to take place. When the engine is stopped the **fuel booster pump** supplies fuel which the circulation valve directs around the injector body.
- Older engine designs may have fuel injectors which are circulated with cooling water.

The common rail system

- The function of the **fuel injection system** is to provide the right amount of fuel at the right moment and a suitable condition for the combustion process. There must therefore be some form of metered supply, a means of **timing** the delivery, of **atomisation** and distribution of fuel.
- There are two basic system in use. One is the **common rail system**, in which a single pump supplies fuel at high pressure to a common **manifold** feeding the cylinders. Injection of the fuel to each cylinder takes place through a **fuel valve** operated from the camshaft which releases a metered amount of fuel into each cylinder at the instant it is required.

Supply the missing text

- The function of the fuel injection system is to provide the right amount of fuel …… and a suitable condition for the combustion process. There must therefore be some form of metered supply, a means ……, of atomisation and distribution of fuel.
- There are two basic system in use. One is the ……, in which a single pump supplies fuel at high pressure to a common manifold feeding the cylinders. Injection of the fuel to each cylinder …… through a fuel valve operated from the camshaft which releases a metered amount of fuel into each cylinder …… it is required.

The common rail system – jumbled text – give the right sequence of sentences

1. There are two basic system in use.
2. The function of the fuel injection system is to provide the right amount of fuel at the right moment and a suitable condition for the combustion process.
3. Injection of the fuel to each cylinder takes place through a fuel valve operated from the camshaft which releases a metered amount of fuel into each cylinder at the instant it is required.
4. There must therefore be some form of metered supply, a means of timing the delivery, of atomisation and distribution of fuel.
5. One is the common rail system, in which a single pump supplies fuel at high pressure to a common manifold feeding the cylinders.

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The jerk pump system

- The other system is known as the **jerk pump system**, in which the fuel is metered and raised in pressure by a separate fuel pump for each cylinder. The pump is timed to force the fuel through the injector into the cylinder at the appropriate moment.
- The great majority of medium and slow speed engines use the latter system. Fig.11.1. shows a jerk type fuel pump.

Jerk pump – sisaljka s razvodnim klipom, Bosch-pumpa

Supply the right term

- The other system is known as _____, in which the fuel is metered and raised in pressure by a separate _____ for each cylinder. The pump is timed to force the fuel through the _____ into the cylinder at the appropriate moment.
- The great majority of medium and _____ engines use the latter system. Fig.11.1. shows a _____ type fuel pump.

- The **plunger** is actuated by a cam and a roller follower. A **helical spring** is fitted to return the plunger on its down stroke and to maintain contact of follower on the cam.
- When the follower is on the base circle of the cam, the pump plunger is at the bottom of its stroke and the **inlet port** in the barrel is uncovered allowing the fuel to fill that portion of the barrel above the plunger.
- The plunger is **a close fit** within a barrel. As the cam rotates the plunger rises and *seals off* **the inlet and relief ports** and at this point of the stroke the pumping action starts./ See Fig.11.2.(a).

Supply the missing part of the sentences below

- The plunger …… a cam and a roller follower.
- A helical spring …… to return the plunger on its down stroke and to maintain contact of follower on the cam.
- When the follower is on the base circle of the cam, the pump plunger is …… and the inlet port in the barrel is uncovered allowing the fuel to fill that portion of the barrel above the plunger.
- The plunger is …… within a barrel.
- As the cam rotates the plunger rises and seals off the inlet and relief ports and …… the pumping action starts.

- Further upward movement of the plunger causes the fuel to be raised in pressure and expelled through the delivery valve to the **injector**. A helical groove (or helix) extends from the top of the plunger part way down its cylindrical surface.
- When the edge of the **helix** uncoveres the relief port, the high pressure in the fuel above the plunger is released and pumping ceases / See Fig.11.2.(b)/, altough the plunger continues to move upwards.
- The **amount of fuel delivered** will vary in accordance with the effective length of the stroke. This is controlled by rotating the plunger in the barrel by means of **rack and pinion**, the latter being machined on the outside of a sleeve . The **sleeve** fits over the plunger engaging it with keys.(Fig.11.3.) The rack position, therefore, determines the quatity of fuel supplied.

Supply the missing terms

- Further upward movement of the p_____ causes the fuel to be raised in pressure and expelled through the d_____ _____ to the injector.
- A helical groove (or _____) e_____ from the top of the plunger part way down its cylindrical surface.
- When the edge of the helix uncoveres the r_____ _____ , the high pressure in the fuel above the plunger is released and pumping c_____ , although the p_____ continues to move upwards.
- The amount of fuel d_____ will vary in accordance with the effective length of the stroke.
- This is controlled by rotating the plunger in the b_____ by means of r_____ and pinion, the latter being machined on the outside of a sleeve.
- The s_____ fits over the plunger engaging it with k_____ .
- The rack position, therefore, determines the quatity of f_____ supplied.

Supply the missing terms

- Further upward movement of the _____ causes the fuel to be raised in pressure and expelled through the _____ to the injector.
- A helical groove (or _____) _____ from the top of the plunger part way down its cylindrical surface.
- When the edge of the helix uncoveres the _____ , the high pressure in the fuel above the plunger is released and pumping _____ , altough the _____ continues to move upwards.
- The amount of fuel _____ will vary in accordance with the effective length of the stroke.
- This is controlled by rotating the plunger in the _____ by means of _____ and pinion, the latter being machined on the outside of a sleeve.
- The _____ fits over the plunger engaging it with _____ .
- The rack position, therefore, determines the quatity of _____ supplied.

- The **timing of the injection** is controlled by the instant that the pump plunger closes the inlet and relief ports. This instant **can be adjusted** with the reference to the camshaft and crankshaft position by raising or lowering the plunger by the screw in the **tappet** shown in Fig.11.4. Raising the level of the screw will advance the **point of injection**.
- After leaving the **pump delivery valve**, the fuel is conveyed by high pressure steel piping to the **injector**. The fuel flows at high velocity through small holes in the **injector nozzl**e causing it to divide up into fine spray which penetrates throughout the combustion chamber.
- The high pressure of the fuel necessary to do this must be created sharply at **the commencement of injection** and must be just as sharply dropped when the injection ceases in order to avoid **dribbling**.

Supply the missing text

- The timing of the injection is controlled by the instant that the pump plunger ……
- This instant can be adjusted with the reference to the camshaft and crankshaft position by …… by the screw in the tappet shown in Fig.11.4.
- Raising the level of the screw will …… .
- After ……, the fuel is conveyed by high pressure steel piping to the injector.
- The fuel flows at high velocity through small holes in the injector nozzle causing it …… which penetrates throughout the combustion chamber.
- The high pressure of the fuel necessary to do this must be created sharply …… and must be just as sharply dropped when …… in order to avoid dribbling.

- The function of the fuel injection system is to provide the right amount of fuel at the right moment and in a suitable condition for the combustion process. There must therefore be some form of measured fuel supply, a means of timing the delivery and the atomisation of the fuel.

  The injection of the fuel is achieved by the location of cams on a camshaft. This camshaft rotates at engine speed for a two-stroke engine and at half engine speed for a four-stroke. There are two basic systems in use, each of which employs a combination of mechanical and hydraulic operations. The most common system is the jerk pump; the other is the common rail.

Supply the missing adjective

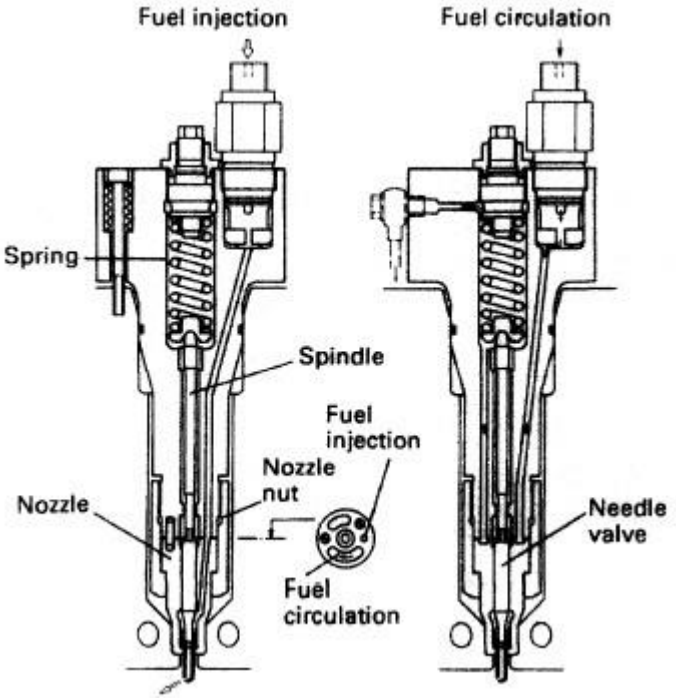
Delivering right amount of fuel

- The function of the fuel injection system is to provide the _____ amount of fuel at the _____ moment and in a _____ condition for the combustion process.
- There must therefore be _____ form of _____ fuel supply, a means of timing the delivery and the atomisation of the fuel.
  This camshaft rotates at engine speed for a two-stroke engine and at _____ engine speed for a four-stroke.
- There are two _____ systems in use, each of which employs a combination of mechanical and _____ operations.
- The most _____ system is the jerk pump; the other is the common rail.

- A typical fuel injector is shown in Figure … , It can be seen to be two basic parts, the nozzle and the nozzle holder or body. The high-pressure fuel enters and travels down a passage in the body and then into a passage in the nozzle, ending finally in a chamber surrounding the needle valve.

- The needle valve is held closed on a mitred seat by an intermediate spindle and a spring in the injector body. The spring pressure, and hence the injector opening pressure, can be set by a compression nut which acts on the spring. The nozzle and injector body are manufactured as a matching pair and are accurately ground to give a good oil seal. The two are joined by a nozzle nut.

  - **Mitred: a joint made by beveling each of two parts to be joined,**
    - **usually at a 45° angle, to form a corner, usually a 90° angle**



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Supply the missing injector term

- A typical fuel injector is shown in Figure … , It can be seen to be two basic parts, the _____ and the _____ or body. The high-pressure fuel enters and travels down a _____ in the body and then into a passage in the nozzle, ending finally in a chamber surrounding the _____.
- The _____ valve is held closed on a mitred _____ by an intermediate _____ and a spring in the injector body.
- The spring pressure, and hence the injector opening pressure, can be set by a _____ which acts on the spring.
- The nozzle and injector body are manufactured as a matching pair and are accurately _____ to give a good oil seal.
- The two are joined by a _____ nut.

- The needle valve will open when the fuel pressure acting on the needle valve tapered face exerts a sufficient force to overcome the spring compression. The fuel then flows into a lower chamber and is forced out through a series of tiny holes. The small holes are sized and arranged to atomise, or break into tiny drops, all of the fuel oil, which will then readily burn. Once the injector pump or timing valve cuts off the high pressure fuel supply the needle valve will shut quickly under the spring compression force.

Supply the missing information

- All slow-speed two-stroke engines and many medium-speed fourstroke engines are now operated ……
- A fuel circulating system is therefore necessary and this is usually arranged ……
- During injection the high-pressure fuel will open the ……
- When the engine is stopped the fuel booster pump supplies fuel which ……
- Older engine designs may have fuel injectors which ……

IV.

IV-a Fuel Oil Systems - Heavy oil separation control & Fuel Tanks guideline

IV-b Marine fuel oil treatment - use of filters and strainers

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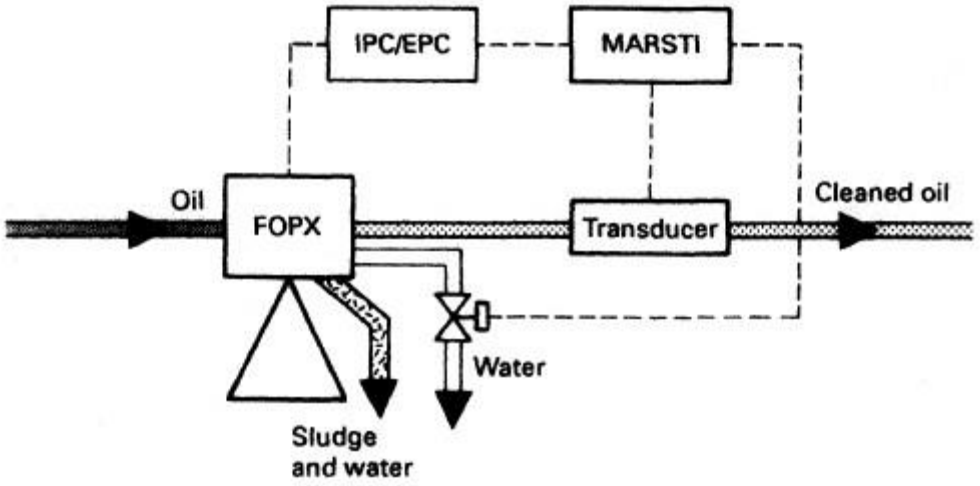
How clean oil can be discharged in a separation process ?

- Changes in refinery techniques are resulting in heavy fuel oils with increased density and usually contaminated with catalytic fines. These are small particles of the catalysts used in the refining process. They are extremely abrasive and must be removed from the fuel before it enters the engine. The generally accepted maximum density limit for purifier operation is 991 kg/m3 at 15*C.

- In the ALCAP separation system the separator has no gravity disc and operates, to some extent, as a clarifier. Clean oil is discharged from the oil outlet and separated sludge and water collect at the periphery of the bowl. When the separated water reaches the disc stack, some water will escape with the cleaned oil. The increase in water content is sensed by a water-detecting transducer in the outlet .

  The water transducer signal is fed to the MARST 1 microprocessor which will discharge the water when a predetermined level is reached. The water will be discharged from sludge ports in the bowl or, if the amount is large, from a water drain valve.

The ALCAP system has also proved effective in the removal of catalytic fines from fuel oil.



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General Safety and good practice with regard to Fuel Oil Systems and pipelines

- This procedure shall ensure that full and proper maintenance is carried out to accepted and safe standards. Leakage from fuel pressure systems are a serious fire hazard. The PMS is required to include the following checks: Fuel pump restraining bolts must be proven tight by testing with a torque spanner at frequent intervals. Please include such a test in your PM system with an interval of 3 months. The supports and retaining devices of the low pressure fuel system must be checked at regular intervals and be proved tight and providing adequate restraint. The lining of such devices must also be examined for wear and renewed if they provide insufficient support. Please include such a test in your PM system with an interval of 3 months.

De-Sludging & Cleaning of Fuel Tanks

- It is essential that all fuel tanks are regularly "de-sludged" using the sludge cocks provided. They must never be operated by artificial means. The presence of water in appreciable quantities must be immediately brought to the attention of the Chief Engineer.

  This is to be carried out at four hourly intervals on a conventional watchkeeping vessel. Prior entering a bad weather area and whilst in heavy weather conditions, the frequency of draining must be increased. On vessels operating for periods of time with unmanned engine room spaces, the interval between sludging during the manned period is to be four hours.

  For the unmanned period, this is to be detailed by the Chief Engineer in the Night Order Book, however it is to be not less than three times during that period i.e. at commencement of the unmanned period, during the late evening inspection of the Engine Room spaces, and at the end of the unmanned period. All other double bottom and/or deep bunker tanks are subject to Classification inspection and would normally only be inspected on a 60 month frequency.

- Each Service and Settling fuel tanks, on a rotational basis, are to be emptied at intervals not exceeding 36 months or at Dry Dock. This is for the purpose of sighting the internal condition, in particular any build up of sludge, solids and other contaminants. Manual cleaning is to be done if applicable, during a safe period at a safe location, with suitable notice to the Master. Testing of all float alarms where applicable should be done at this time.

  It is strictly forbidden to enter a fuel tank unless the appropriate "enclosed space entry permit" conditions have been complied with and the permit issued. Known contamination with solids such as "Catalytic Fines" can only be dealt with by taking the tank out of service, isolation, and subsequent manual cleaning. The opportunity must be taken when tanks are cleaned to test any heating coils fitted, and check/overhaul all the tank mountings including examination of vent pipes for obstruction etc.

Heating of sludge oil tanks, waste oil and oily water bilge tanks in order to extract water

- Care must be taken when using internal heating coils. The heating of a water/oil mix from any such oil or sludge tank must be deemed as a critical operation . While preparing the checklist, it should be kept in mind that any heating of the sludge/oil water mix will expand the volume of the liquid and may cause an overflow of the tanks. A maximum filling level for such tanks must be identified that leaves a safety margin for this expansion. This level should be recorded on the checklist. Operations must be recorded in the ORB

IV-b Marine fuel oil treatment - use of filters and strainers

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- **Filters and strainers**

  Mechanical separation of solid contaminants from oil systems (fuel and lubricating) is achieved by the use of filters and strainers. A strainer is usually a coarse filter to remove the larger contaminating particles. Both are arranged as full flow units, usually mounted in pairs (duplex) with one as a standby.

  The **strainer** usually employs a mesh screen, an assembly of closely packed metal plates or wire coils which effectively block all but the smallest particles. It is usually fitted on the suction side of a pump and must be cleaned regularly or when the pressure differential across it become unacceptable.

  Where suction conditions are critical the strainer will be fitted on the discharge side of the pump. When cleaning is undertaken the other unit will be connected into the system by changeover valves or levers and oil circulation will continue. The particles of dirt collect on the outside of the strainer element or basket and can be removed by compressed air or brushing.

- A **strainer** should be cleaned as soon as it is taken out of the system, then reassembled and left ready for use.

  Magnetic strainers are often used in lubricating oil systems, where a large permanent magnet collects any ferrous particles which are circulating in the system. The magnet is surrounded by a cage or basket to simplify cleaning.

  Fine **filters**, again in pairs, are used to remove the smallest particles of dirt from oil before the oil enters the finely machined engine parts in either the fuel injection system or the bearings of the rotating machinery. Fine filters are full-flow units which clean all the oil supplied to the engine. The filtering substance may be a natural or synthetic fibrous woollen felt or paper.

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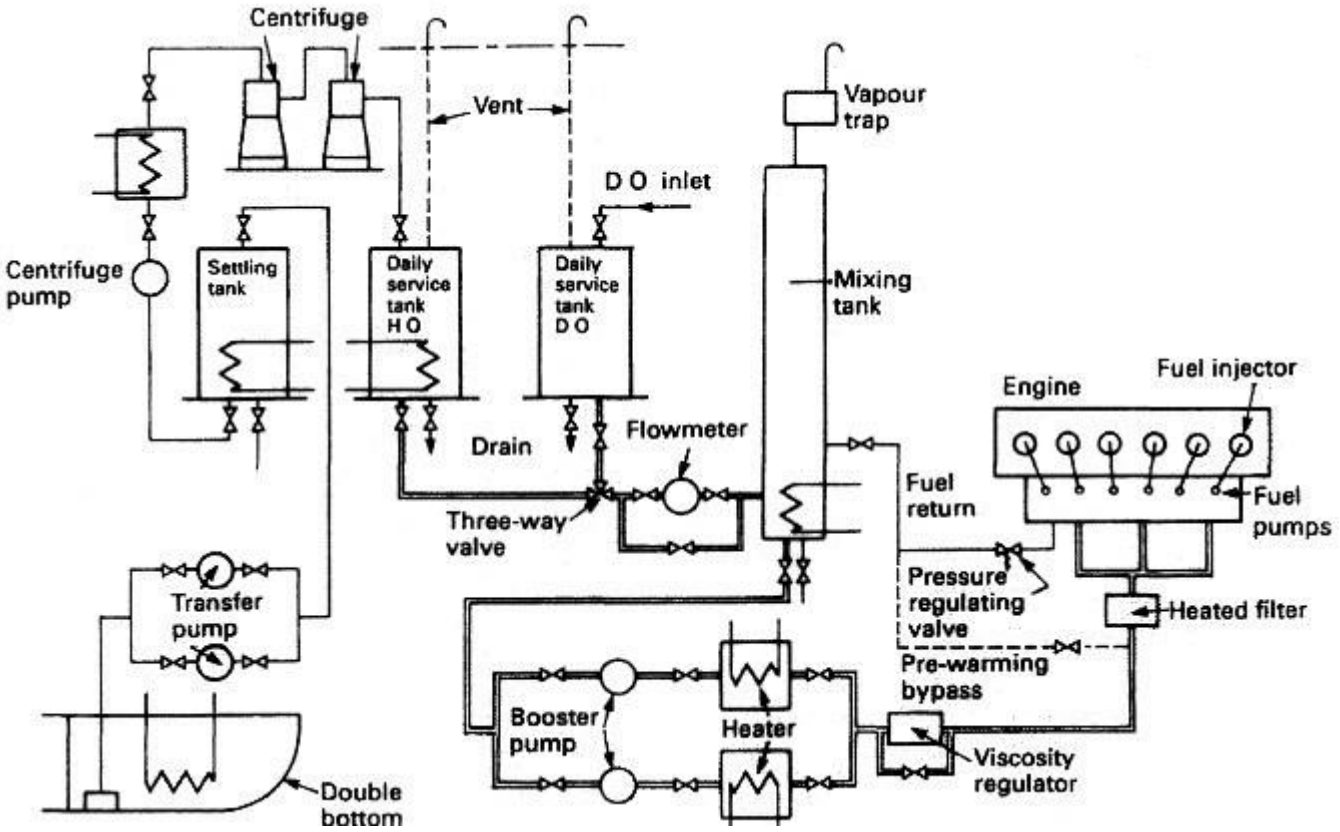

Fig: Fuel oil system for cargo ships

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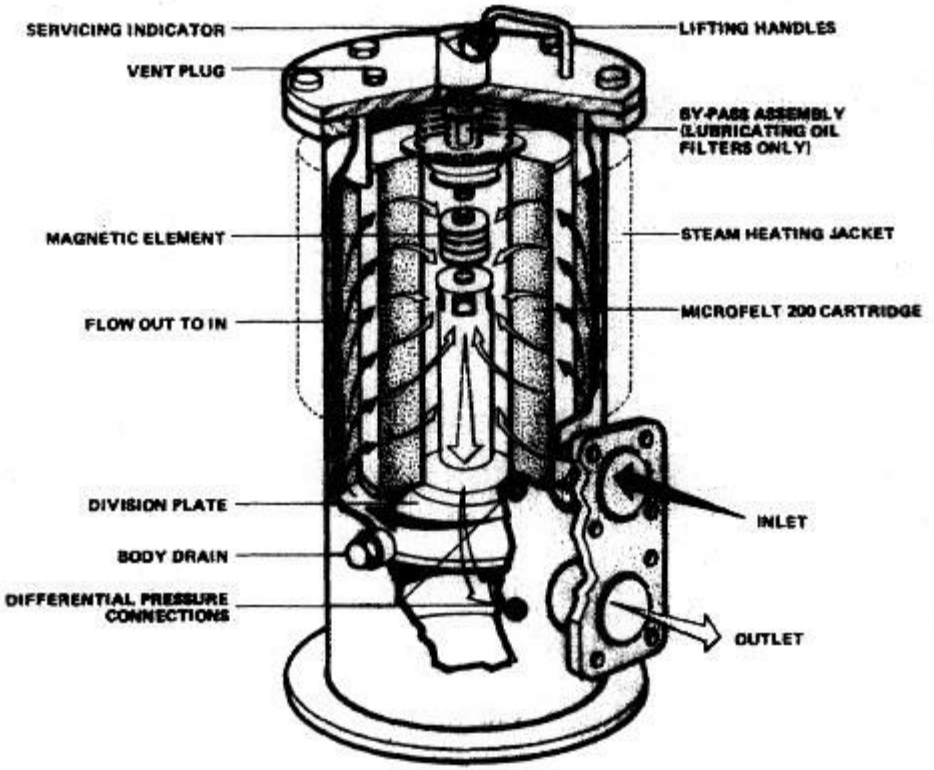


A felt-type fine filter is shown in Figure

- A **steel division plate** divides the steel pressure vessel into an upper and a lower chamber. Dirty oil passes into the upper chamber and through the filter element, then the filtered oil passes down the central tube to the lower chamber and out of the unit. A magnetic filter can be positioned as shown in the central tube.

  A **spring-loaded bypass** is shown in the diagram, for lubricating oil filters only, to ensure a flow of oil should the filter become blocked. The cartridge in the design shown is disposable although designs exist to enable back-flushing with compressed air to clean the filter element as required. The filter unit shown will be one of a pair which can be alternately in service.

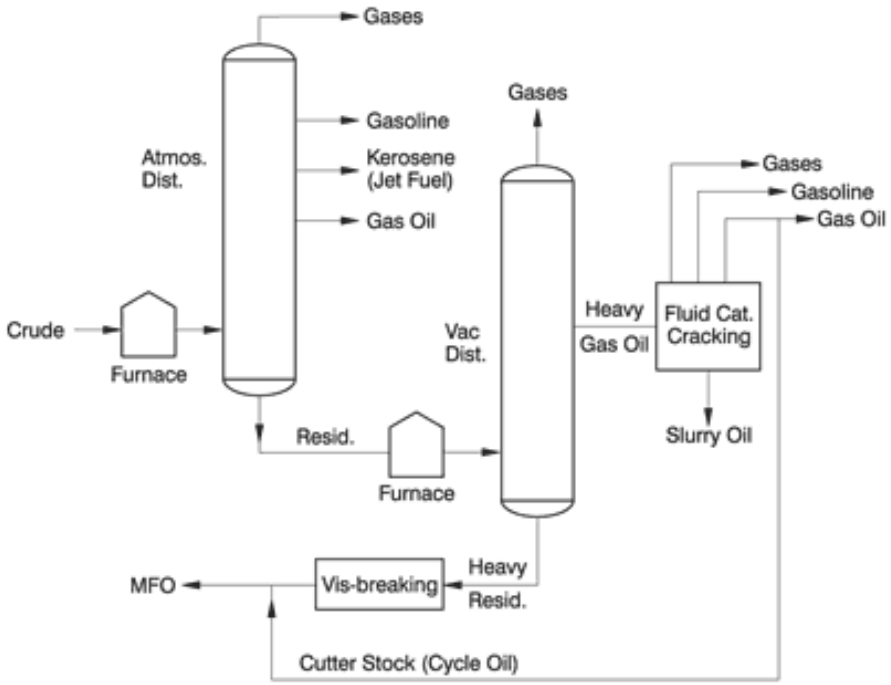
  In **full-flow filtration systems** all the oil passes through the filter on its way to the engine. In a by-pass system most of the oil goes to the lubrication system and a part is by-passed to a filter. A higher pressure drop across the filter can then be used and a slower filtration rate. A centrifugal filter can be used in a by-pass system where the oil passes through a rotor and spins it at high speed . Dirt particles in the oil are then deposited on the walls of the rotor and the clean oil returns to the sump. This type of filter cannot block or clog and requires no replaceable elements. It must be dismantled for cleaning of the rotor unit at regular intervals.

PART V.

V. Fuel oils for marine use

B. Pritchard, M. Borucinsky , J. Luzer, A. Spinčić

Heavy Fuel Refinery Process

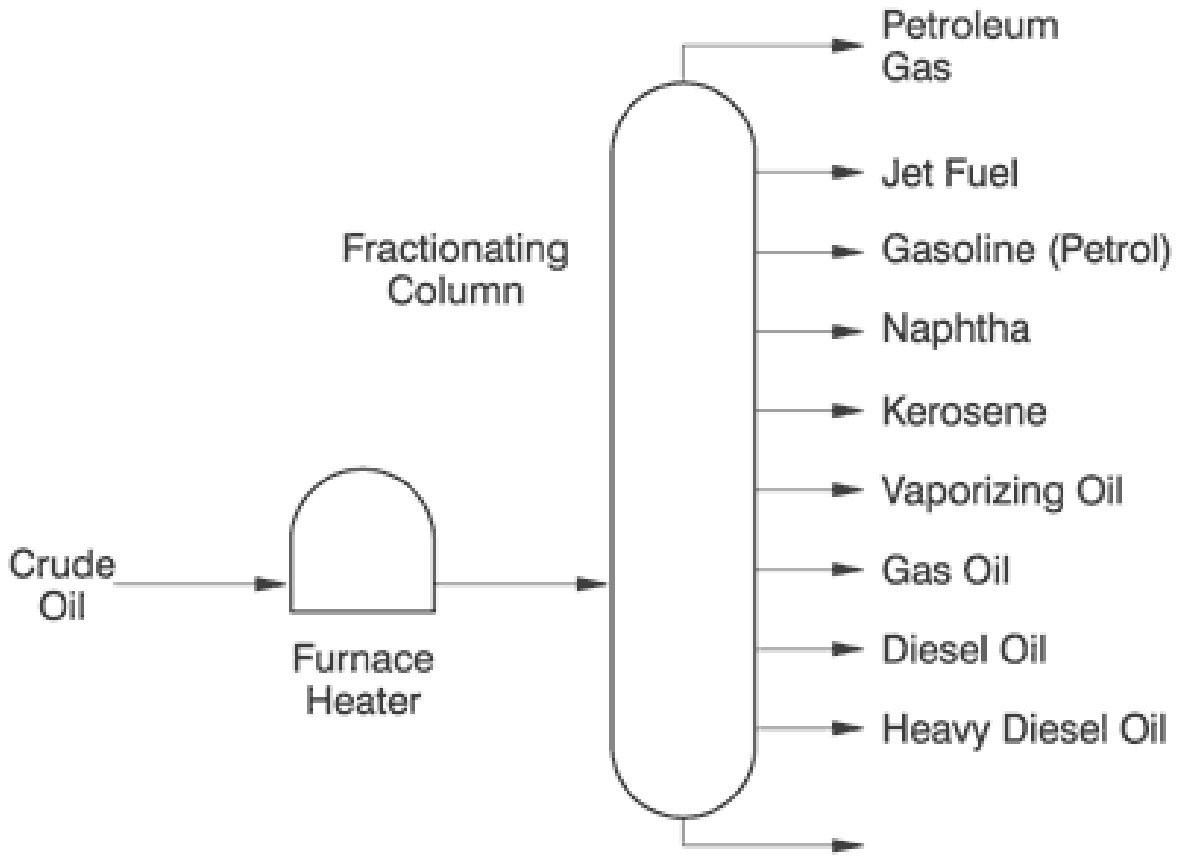


Refining of crude oils for marine use

- Crude oil is, at the present time, the source of most fuel oils for marine use. Synthetic fuels are being developed but will probably be too expensive for ship propulsion. Solid fuel, such as coal, is returning in a small way for certain specialised trade runs. The various refined products of crude oil seem likely to remain as the major forms of marine fuel.

  The refining process for crude oil separates by heating and distillation the various fractions of the oil. Paraffin fuel would be used in gas turbine plants, gas oil in high- and medium-speed diesel engines and crude oils in slow-speed and some medium-speed diesels. Paraffin and gas oil are known as 'distillates', which are free flowing, easily stored and can be used without further treatment. Residual fuels, however, are very viscous or thick at normal temperatures, and require heating before use.

- Additional treatment to remove harmful chemicals or sulphur may be required for all or some of the refined products, depending upon their application. Finally blending or mixing of the various oils is done to provide a range of commercial fuels for different duties.


Petroleum Gas
Jet Fuel
Gasoline (Petrol)
Naphtha
Kerosene
Vaporizing Oil
Gas Oil
Diesel Oil
Heavy Diesel Oil
Fractionating Column
Crude Oil
Furnace Heater

Refining Fuel

- In the early days of refining, straight run fuel oil was derived from the residue of the atmospheric or vacuum distillation process. Product entering the fuel oil market was of a consistent quality which meant that there were few problems. As demand for distillate products increased, refiners introduced secondary refining processes that affected the fuel oil characteristics.
- In the crude oil distillation process (boiling off), there are four broad fuel product fractions generated in ascending order of boiling point temperature:

  - **Refinery gas (primarily methane, ethane and hydrogen)**
  - **Liquefied petroleum gas (primarily propane and butane)**
  - **Gasoline and distillate fuels**
  - **Residual fuel oil**

Residual fuel

- The **last fraction**, residual fuel is often non boiling, or at least it will not boil without resultant thermal degradation. Distillate fuels are further subdivided into several categories for specific uses again in ascending order of (overlapping) boiling point:
  - **Kerosene**, used for commercial jet turbine engine fuels, for small heaters etc
  - **Diesel**, used during cold weather conditions for automotive or truck fuels in "compression ignition" engines
  - **Heating oil** used for residential heating furnaces and also used in warmer conditions as diesel fuel for larger land-based, on and off-road engines, such as trucks, buses, earth moving and material lifting and moving equipment, farm equipment and railroad diesel locomotives. As gas oil it is used as fuel for industrial heaters and boilers
  - Finally, the "heaviest", or **highest boiling point fractions** are often blended with residual oil to make fuels for **ocean going ships** and large industrial steam boilers

Bunker Fuel Terminology

- Bunker Fuel Definition: there are two basic types of marine fuels - **distillate** and **residual**. A third type is a mixture of these two, commonly called "**intermediate**".
- Distillate fuel is composed of petroleum fractions of crude oil that are separated in a refinery by a boiling or "**distillation**" process.
- Residual fuel or "**residuum**" is the fraction that did not boil, sometimes referred to as "tar" or "petroleum pitch".

Fuel Type & Fuel Grades Common Industry Name

Fuel for marine use in engines and boilers has the following types and grades:

- **Distillate DMX, DMA, DMB, DMC Gas Oil** or **Marine Gas Oil**
- **Intermediate IFO 180 380 Marine Diesel Fuel** or
- **Intermediate Fuel Oil (IFO)**
- **Residual RMA-RML Fuel Oil** or **Residual Fuel Oil**

Additionally, it is common for different suppliers to use their own in-house terminology as illustrated below.

In-house marine fuel oil terminology

Mobil	Chevron	Esso	Shell	Texaco
Motorship Fuel Oil	Intermediate Bunker Fuel (BF*)	Bunker Fuel Oil (BFO)	Marine Fuel Oil (MFO*)	Interfuel (IF*)
Light Marine Fuel Oil (LMFO)	Intermediate Bunker Fuel (BF*)	Intermediate Fuel (IF*)	Marine Fuel Oil (MFO*)	IF*
Marine Diesel Oil (MDO)	Marine Diesel Oil (MDO)	Marine Diesel Oil (MDO)	Marine Diesel Oil (MDF)	Marine Diesel Oil (MDO)
Distillate Marine Diesel Oil	Light Diesel	Light Diesel Oil (LDO)	Marine Diesel Fuel or Gas Oil (MDF/GO)	Marine Distillate
Marine Gas Oil (MGO)	Gas Oil (GO)	Marine Gas Oil (MGO)	Gas Oil (GO)	Gas Oil (GO)

Notes: * Denotes a specific grade, usually shown by viscosity of the grade in **cSt** at 50°C

DMA

- The product that is supplied as DMA is sometimes specially manufactured at local refineries with a higher *sulphur content* and lower price than land-based fuels rebranded for marine use. When that supply is short of demand, "Home-Heating Oil" (No 2 fuel oil) is used, provided the flash is above 60ª C, which it normally is. Similarly, DMC is sometimes supplied by local refineries from "cycle oil" (lower boiling point than No 2 fuels), and is sometimes blended in the supply terminal from DMA and residual fuel oils. DMA is the common fuel for tugboats, fishing boats, crew boats, drilling rigs and ferry boats. Ocean-going ships that take residual fuel oil bunkers also take distillate fuels for use in auxiliary engines and sometimes for use in port. The common fuels are DMC, IFO-180 and IFO-380, depending on the specific engines in service. DMB is infrequently specified, and is not available in all ports. Where it is not available, DMA is supplied, sometimes in a barge that has transported DMC or IFO (hence, a "dirty" cargo hold that would contaminate DMA).

Properties of fuel oils

Fuel oils have various **properties** which determine their performance and are quoted in specifications.

- The **specific gravity** or **relative density** is the weight of a given volume of fuel compared to the weight of the same volume of water expressed as a ratio, and measured at a fixed temperature.
- **Viscosity** is a resistance to flow. A highly viscous fuel will therefore require heating in order to make it flow. Measurement of viscosity is by Redwood, Saybolt or Engler instrument flow times for a given volume of fuel.
- The **ignition quality** of a fuel is measured by the time delay between injection and combustion, which should be short for good controlled burning. Ignition quality is indicated as cetane number, diesel index and calculated cetane index; the higher the value the better the ignition quality of the fuel.
- The **flash point** is a figure obtained and used mainly to indicate the maximum safe storage temperature. The test determines the temperature at which the fuel will give off sufficient vapours to ignite when a flame is applied. Two values are possible: an open flash point for atmospheric heating, and a closed flash point when the fuel is covered while heating.

- **Low-temperature properties** are measured in terms of pour point and cloud point. The pour point is slightly above the temperature at which the fuel just flows under its own weight. It is the lowest temperature at which the fuel can be easily handled. At the cloud point waxes will form in the fuel. Below the cloud point temperature, pipe or filter blocking may occur.
- The **carbon residue** forming property of a fuel is usually measured by the Conradson method. Controlled burning of a fuel sample gives a measure of the residual carbon and other remains. Sulphur content is of importance since it is considered a cause of engine wear. A maximum limit, expressed as a percentage by weight, is usually included in specifications.
- The **calorific value** of a fuel is the heat energy released during combustion. Two values are used, the more common being the Higher Calorific Value, which is the heat energy resulting from combustion. The Lower Calorific Value is a measure of the heat energy available and does not include the heat energy contained in steam produced during combustion but passing away as exhaust. The measurement is obtained from a bomb calorimeter test where a small fuel quantity is burnt under controlled conditions.

  The various **fuel properties** have different effects on performance of the engine and the storage and handling requirements of the system. Blending and the use of various additives will also influence both the engine and the system.

- **Viscosity** will affect jerk-type injector pumps and injector operation since the liquid fuel is the operating medium. The pump mechanism is lubricated by the fuel which, if it is of low viscosity, will cause wear. Cloud point and pour point values are important when considering the lowest system operating temperatures. Wax deposited in filters and fuel lines will cause blockages and may restrict fuel flow to the engine. The cetane number or diesel index will determine injection timing and also influences the combustion noise and production of black smoke.

  The **temperature** in a fuel system should be progressively increased in order to deliver fuel at the correct viscosity to the injectors or burners. System cleanliness is also very important to reduce wear on the many finely machined parts in the fuel injection equipment. Regular attention to filters and general system cleanliness is essential. Various additives are used to, for instance, remove lacquer from metal surfaces, reduce wear and prevent rust.

- Fuel oils require **treatment** before passing to the engine. This will involve storage and heating to allow separation of water present, coarse and fine filtering to remove solid particles and also centrifuging.

  The **centrifugal separator** is used to separate two liquids, for example oil and water, or a liquid and solids as in contaminated oil. Separation is speeded up by the use of a centrifuge and can be arranged as a continuous process. Where a centrifuge is arranged to separate two liquids, it is known as a 'purifier'. Where a centrifuge is arranged to separate impurities and small amounts of water from oil it is known as a 'clarifier'.

  The **separation of impurities** and water from fuel oil is essential for good combustion. The removal of contaminating impurities from lubricating oil will reduce engine wear and possible breakdowns. The centrifuging of all but the most pure clean oils is therefore an absolute necessity.

QUESTIONS AND DISCUSSION

1. What does the fuel injection equipment provide ?
2. Mention the kinds of injection system ussually employed.
3. What is the main characteristic of the common rail fuel injection system ?
4. How is fuel injected in this system ?
5. In what does the jerk pump system differ from the common rail system ?
6. Which of the two systems of fuel injection is used to a greater extent today ?
7. Why is arack and a pinion device fitted to the jerk pump ?
8. What is the function of the delivery valve ?
9. Why is it a non-return valve ?
10. Why is the injector nozzle one of the most important component of the fuel injection system ?
11. What is the function of the needle valve ?
12. Why must the injector, particularly the nozzle and the needle, be inspected and serviced regularly ?
13. What is dribbling ? How is it prevented ?

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I. Label the Fig.11.5 and describe briefly the function of each component show in the diagram

II Describe the operation principle of the jerk pump illustrated in Fig.11.6. in the stages (A), (B) and (C), following the headlines:

- Position of plunger and helical groove relative to ports
- Actuation of plunger
- Result of plunger motion
- Flow of fuel (see thicker arrows)

III . The terms listed below summarize the main function of the fuel injection equipment. Define the meaning of each.

- Metering
- Timing
- Atomisation
- Distribution

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IV. State how:

- metering is controlled
- timing is adjusted
- atomisation and distribution are ahieved

V. State which of the statements given below are TRUE and which are FALSE. If FALSE, state why.

1. In the common rail system a separate injector pump serves each cylinder.
2. The jerk pump system is also known as the individual-pump injection system as the bulk of the job is carried out by the pump itself, which raises pressure, meters the charge and times the injection.
3. The term "helix" refers to the helical spring fitted in the barrel to return the plunger on its down stroke.
4. The timing of the injection can be altered by raising or lowering the pump plunger in relation to the cam.
5. Timing is adjusted by rotating the plunger in the barrel by means of a rack and pinion.
6. Atomisation is the usual term to indicate the proper distribution and penetration of fuel in the combustion chamber.
7. In all injection fuel pumps of the jerk type the plungers and barrels are so accurately fitted that no packing of any king is used.
8. The barrel and plunger of the injector pump are interchangeable: if a plunger or cylinder is worn out or damaged each may be easily replaced.
9. When the pump plunger releases the pressure in the barrel both the needle valve in the nozzle and the delivery valve snap back on to their seats to prevent dribbling.

VREMENSKE REČENICE (Time Clauses) 1

- ***When the follower is on the base circle of the cam**, the pump plunger is at the bottom of its stroke.*
- ***As the cam rotates** the plunger raises and seals off the inlet port.*
- ***When the port is opened to the groove**, the high pressure in the fuel above the plunger is released and pumping ceases.*

Istaknutim rečenicama izraženo je vrijeme zbivanja radnje. Vremenske rečenice se uvode veznicima when (kada) i as (dok).

Evo još nekoliko primjera vremenskih rečenica:

- The followers are fitted clear of the cams, **whilst** they are moved axially.
- **Once** the valve is open, the pressure of the exhaust gases assists in expelling them through the open valve.
- One section of the duplex filter can be cleaned **while** the engine continues to run.
- Portable extinguishers can contain a fire **before** it escalates.
- **After** the fuel leaves the pump delivery valve, it is conveyed to the injector

- Ove su rečenice uvedene veznicima **whilst, while** (*dok, za vrijeme dok*), **once** (*kada, jednom kada*), **before** (*prije, prije nego što*) i **after** (*nakon, nakon što*). Pored tih još se upotrebljavaju: **until** (dok, dok ne), **as soon as** (čim), **prior to** (prije nego), **whenever**(kadgod), **as long as** (dokle god, dok god).
- Kada je glavna rečenica u sadašnjosti ili budućem vremenu, vremenska rečenica je u prezentu što se vidi iz rečenica 1-8. Treba znati da u engleskom jeziku iza vremenskih rečenica nikad ne dolazi futur. Prezentu vremenske rečenice u engleskom odgovara oblik prezenta ili futur drugi, npr:

The chief engineer will examine the Engine Log when he has time.

- *Upravitelj stroja će pregledati Dnevnik stroja kada bude imao vremena.* (Futur II)

(10) Before the ship arrives into port, please advise the Engineer Superintendent.

- *Prije nego što brod stigne (ili "bude stigao") u luku, molim da obavijestiš strojarskog inspektora.*

(11) We shan't be able to leave port until the bunkering is fully completed.

- *Nećemo moći isploviti dok potpuno ne završimo krcanje goriva.*

(12) As soon as the temperature reaches the top value, stop the power supply.

- *Čim temperatura dosegne gornju granicu, isključi struju. (ili " čim temperatura bude dosegla …").*

1. Join the following sentences by using the time links in brackets: (*after, as, as soon as, before, until, when, while*)

Ex. The exhaust valve seat rings have worn out. They must be reconditioned by grinding.

- ***When the exhaust valve seat rings have worn out they must be reconditioned by grinding.***

1. The oil enters the cylinders. Impurities are extracted from the oil passing it through a filter.
2. The Third Engineer was at dinner. The supply pipe to the boiler burst.
3. Don't use the new lubricating oil. The filter elemnts is first changed.
4. The air flows through the diffuser. Its velocity falls and is converted into pressure.
5. I was leaving the engine room. I met the master.
6. The pressure of the exhaust gas is almost down to a minimum. It has passed through the turbine.
7. The crankshaft has to be handled outside the engine. It should be carefully supported.
8. The rotary vane of the spur wheel is turned together with the camshaft. The vanes come to rest against the stop segment.

II. Join each pair of sentences by using the time link in brackets. Remember that the Future Tense is not used in Time Clauses, use the Present Tense instead.

Ex. The ship will reach port. Its dangerous cargo will be unloaded. (as soon as)

- *As soon as the ship reaches port its dangerous cargo will be unloaded.*

1. The cadet will take your letter to the Post Office. He will go ashore. (when)
2. The refrigerator will continue to make that noise. We shall repair it. (until)
3. New main beraings will be fitted. The ship will laeve port. (before)
4. The heavy fuel oil will be heated. It will be properly atomised. (when)
5. The lubricating oil pump will be assembled. The necessary spare part will come. (as soon as)
6. The rain will stop. We'll go ashore. (when)
7. The mechanic will overhaul the crane winches. The ship will be at sea. (while)
8. The Superindendant will know the facts. He won't express an opinion about the causes of engine breakdown. (until)

3. Translate into English

1. Gorivo se ubrizgava u cilindar čim se oslobodi odgovarajuća količina goriva.
2. Nakon što se podigne brijeg bregaste osovine tada počinje pumpanje goriva.
3. Prije nego što gorivo dođe do ubrizgivača ono se stlači putem klipa za gorivo.
4. Dok je izlazni otvor pumpe začepljen, prekinuta je dobava goriva u cilindar.
5. Kada gorivo pod velikim pritiskom dođe do sapnice ono se razdvaja u sitnu "prašinu" i ulazi u cilindar.

Bunker Fuel Oil Specifications

Bunkering Fuel Oil & Distillates Fuel

- Fuel oil, especially residual fuel grades, has historically been ordered by viscosity, although distillate fuels are often ordered by using other criteria.

  Whilst viscosity is an important characteristic, it does not give an indication of the other fuel qualities. With viscosity as the sole criterion for ordering, engine operators remain unaware of these other characteristics.

- Similarly, the designers of machinery and fuel oil systems have not always been informed of the fuel characteristics to which they should be designing. It is therefore necessary to define the quality of the bunker oil during fuel oil bunkering over a range of parameters to which the engine plant is sensitive.

- **This section covers the following:**

Marine Fuel Quality & Quantity

- **Density**

  Fuel is delivered from the bunker barge by volume and confirmed by meter or tape soundings. It is paid for by mass with a conversion relying on an accurate density reading. The density meter provides that and more. CCAI, Density in Vacuo and Viscosity conversion.

- **Viscosity**

  Viscosity in conjunction with density is the defining parameter for fuel grade. Variations outside of the viscosity limit can often be accommodated with prior warning. Simple, robust and accurate indication of fuel viscosity at 50°C and 100°C. Calculate CCAI and convert between viscosity units.

- **Water**

  Why pay for water in your fuel? Maximum water contamination limits are established in ISO 8217 and can be easily checked with several water test options available from Kittiwake. You can also use this test to verify purifier performance and check you lubricating oils.

- **Compatibility**

  Mixing and blending fuels is often a necessary process but can lead to a whole world of difficulties. Asphaltimes become unstable and fall from solution blocking purifiers and filters. A simple test for single or blended fuel stability and following accepted ASTM test methods.

- **Cloud Point**

  Not often an issue with commercial ships but a serious consideration foe military vessels or those venturing in to arctic waters without tank heating. Also used to verify suitability of winter grade diesel fuels. Developed for the UK Ministry of Defence, identify single or multiple wax points in clean distillate fuels.

- **Flash Point**

  Refinery QC or contamination with light diesel fractions will lead to depressed flash point. Off specification fuels are a reason for debunkering and need to be treated carefully. Another rugged and accurate On-Site test aimed at identifying problems before they become expensive.

- **Pour Point**

  This is probably the easiest test to undertake without purchasing specialist equipment, even ours. Keeping a low pour point fuel warm and using it quickly will prevent sludging in tanks and blockage of lines when operating in temperate climates

- **Fuel & Lube Test Cabinet**

  A 15 year history in the deep sea marine market monitoring both in-service lubricants and bunker fuel deliveries. A single cabinet containing tests selected with an accuracy appropriate to the application. Simple to use, rugged test equipment and none hazardous consumables.
- Electronic Lab tests for Viscosity, Density and Fuel Compatibility.
- DIGI tests for Water, BN.
- ECON tests for Salt, Insolubles & Pour Point.

- **Power Plant Cabinet**
  Many diesel powerplant operate in very remote locations; laboratory facilities are typically unavailable, resulting in a need for accurate On-Site alternatives. The Power Plant Cabinet differs from the Fuel & Lube offer in that it has fully electronic Lab test for Water, BN and Insolubes. Targeted at users of multiple large medium speed diesel engine powerplant for in-service lubricants and bunker fuel deliveries. Simple to use, rugged test equipment and non-hazardous consumables.
- Electronic Lab tests for Viscosity, Density and Fuel Compatibility, Water, BN and Insolubles.
- ECON tests for Salt, Insolubles & Pour Point.

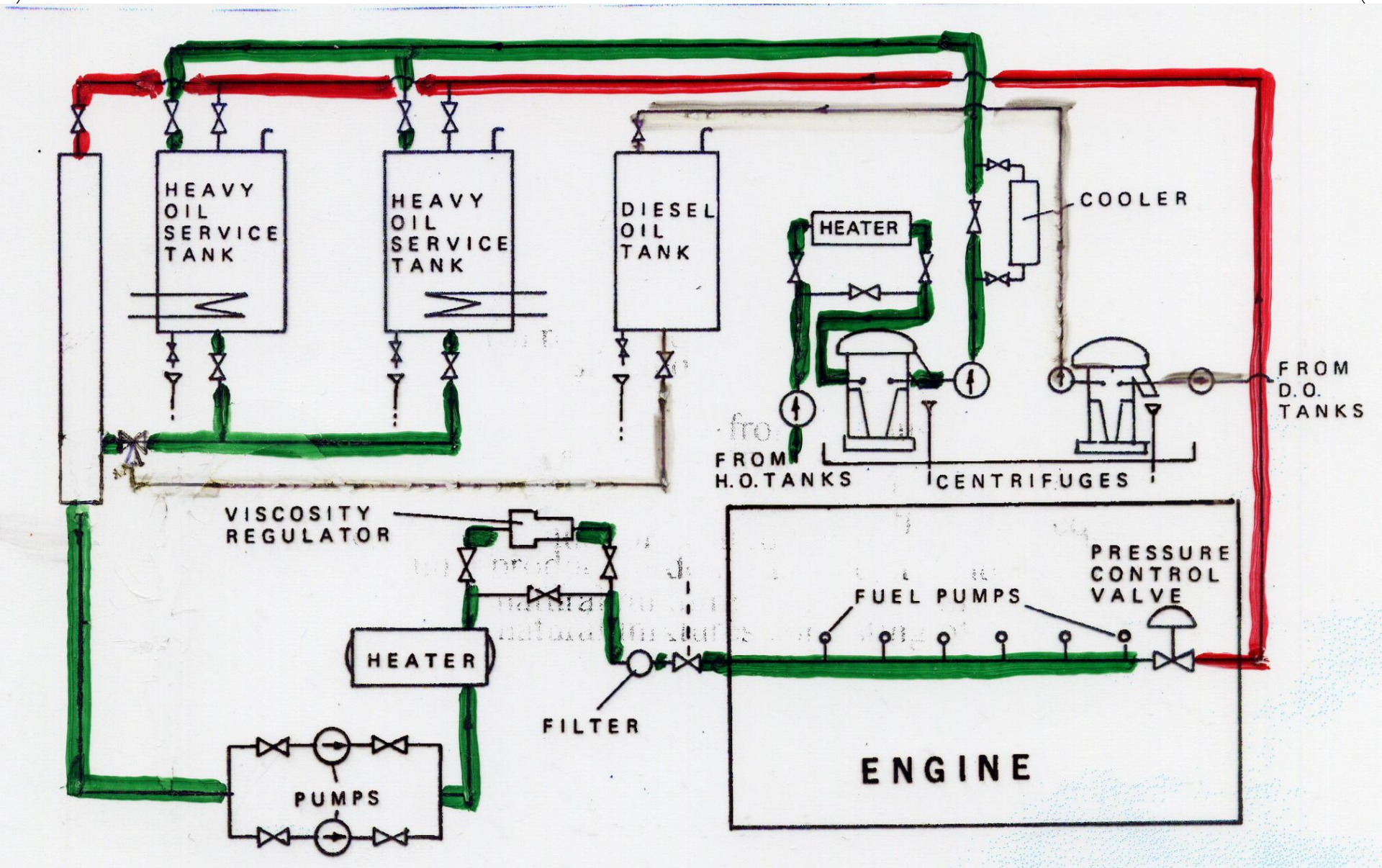

Fig. 45 Fuel oil system

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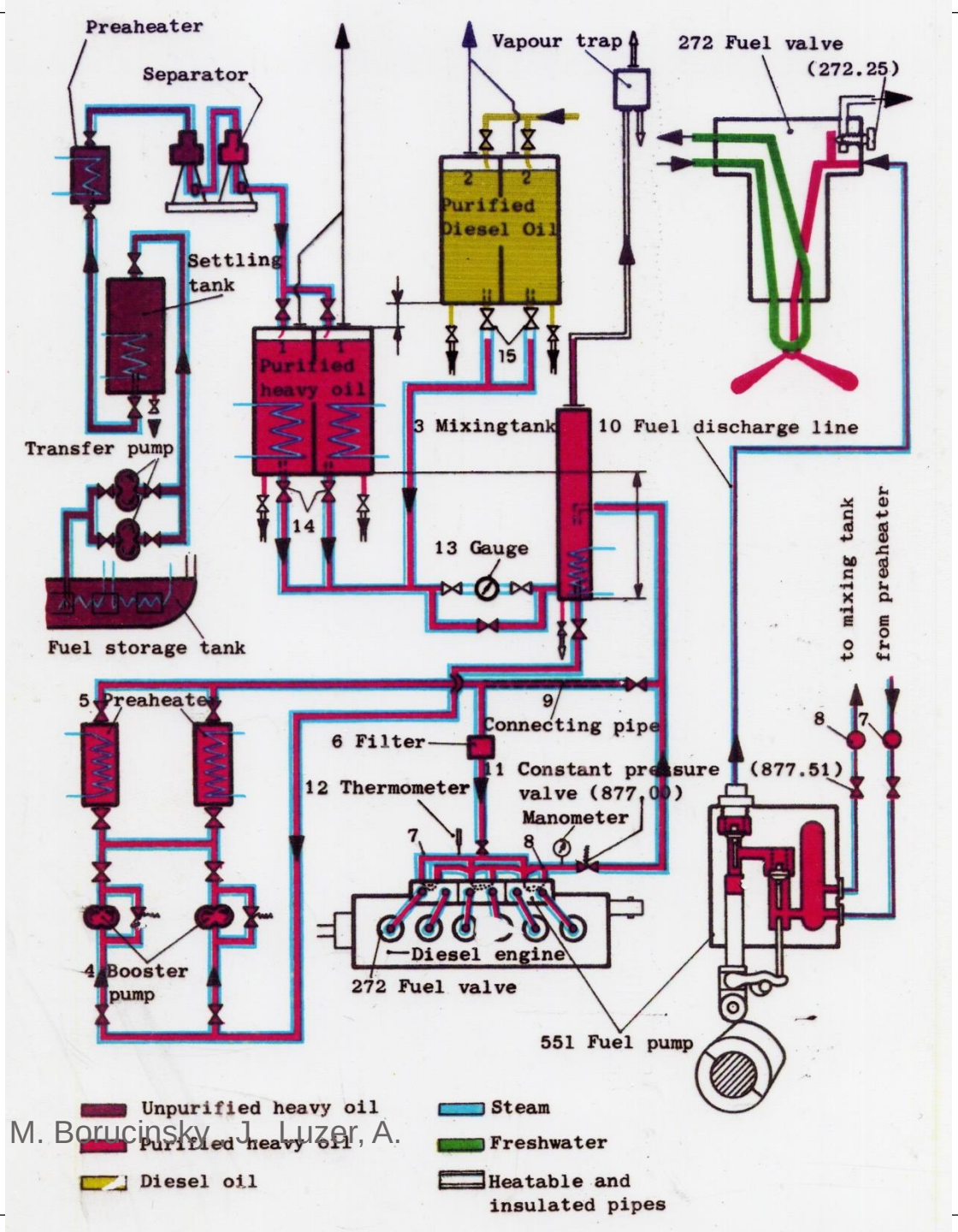

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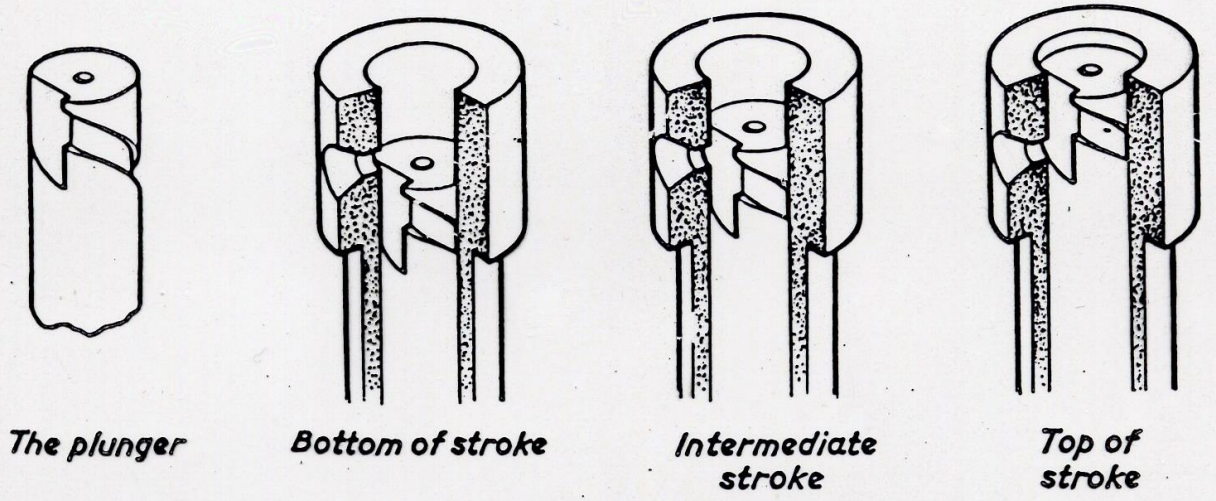
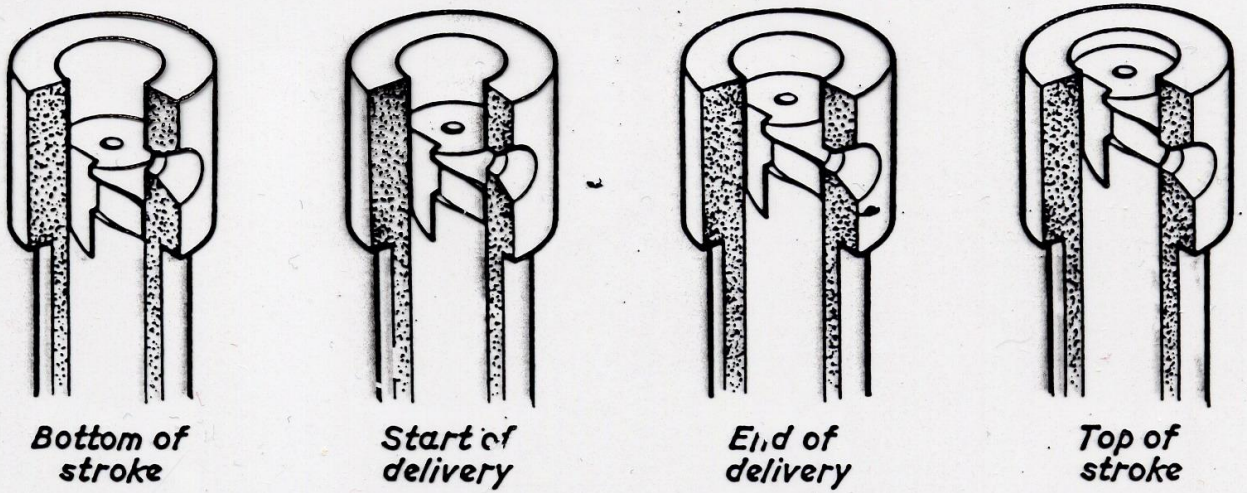


PLUNGER IN POSITION FOR NO DELIVERY

(Note: Vertical gash remains in communication with port throughout stroke)



PLUNGER IN POSITION FOR NORMAL DELIVERY

FIG. 35.—*How the fuel injection pump works.*

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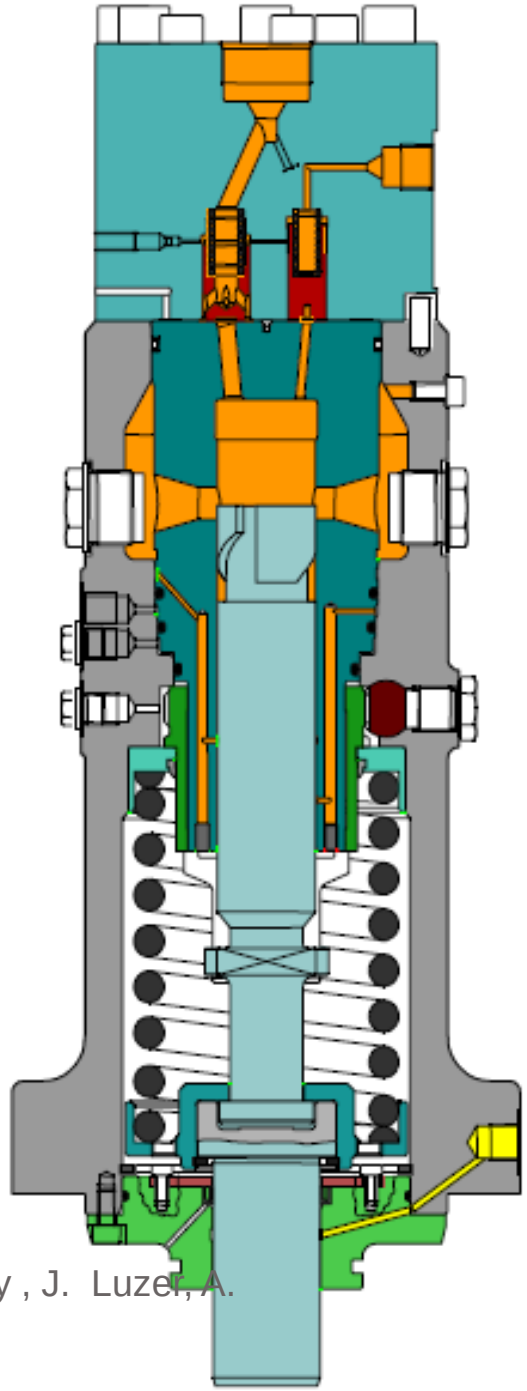

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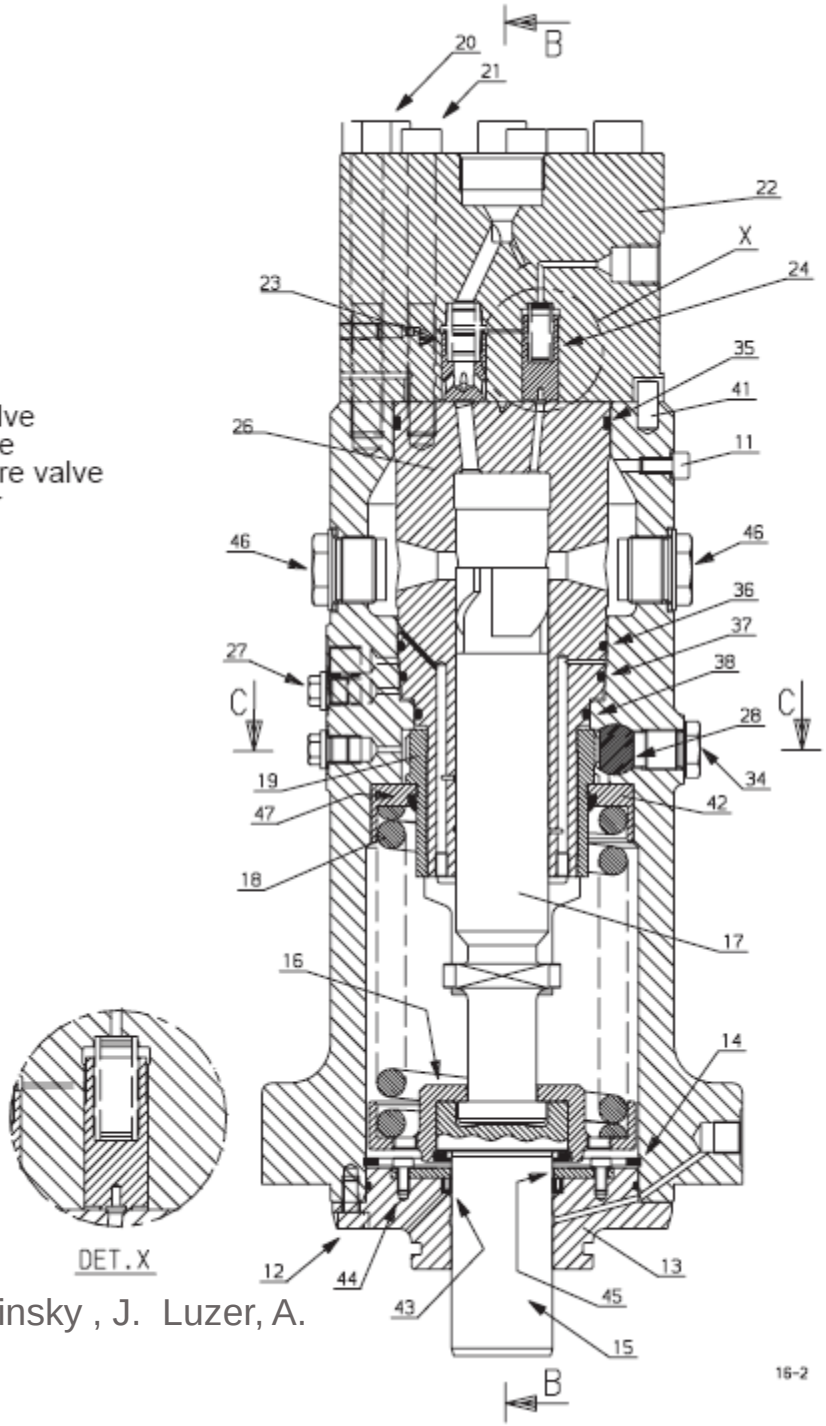
11 Venting plug
12 Screws
13 Flange
14 Retaining ring
15 Push spindle
16 Spring holder
17 Plunger
18 Spring
19 Control sleeve
20 Screw
21 Screw
22 Pump cover
23 Main delivery valve
24 Pilot control valve
25 Constant pressure valve
26 Element cylinder
27 Plug
28 Control rack
34 Grub screw
35 Seal ring
36 Seal ring
37 Seal ring
38 Seal ring
41 Fixing pin
42 Spring disc
43 Seal
44 Screw
45 Cover
46 Erosion plug
47 Seal



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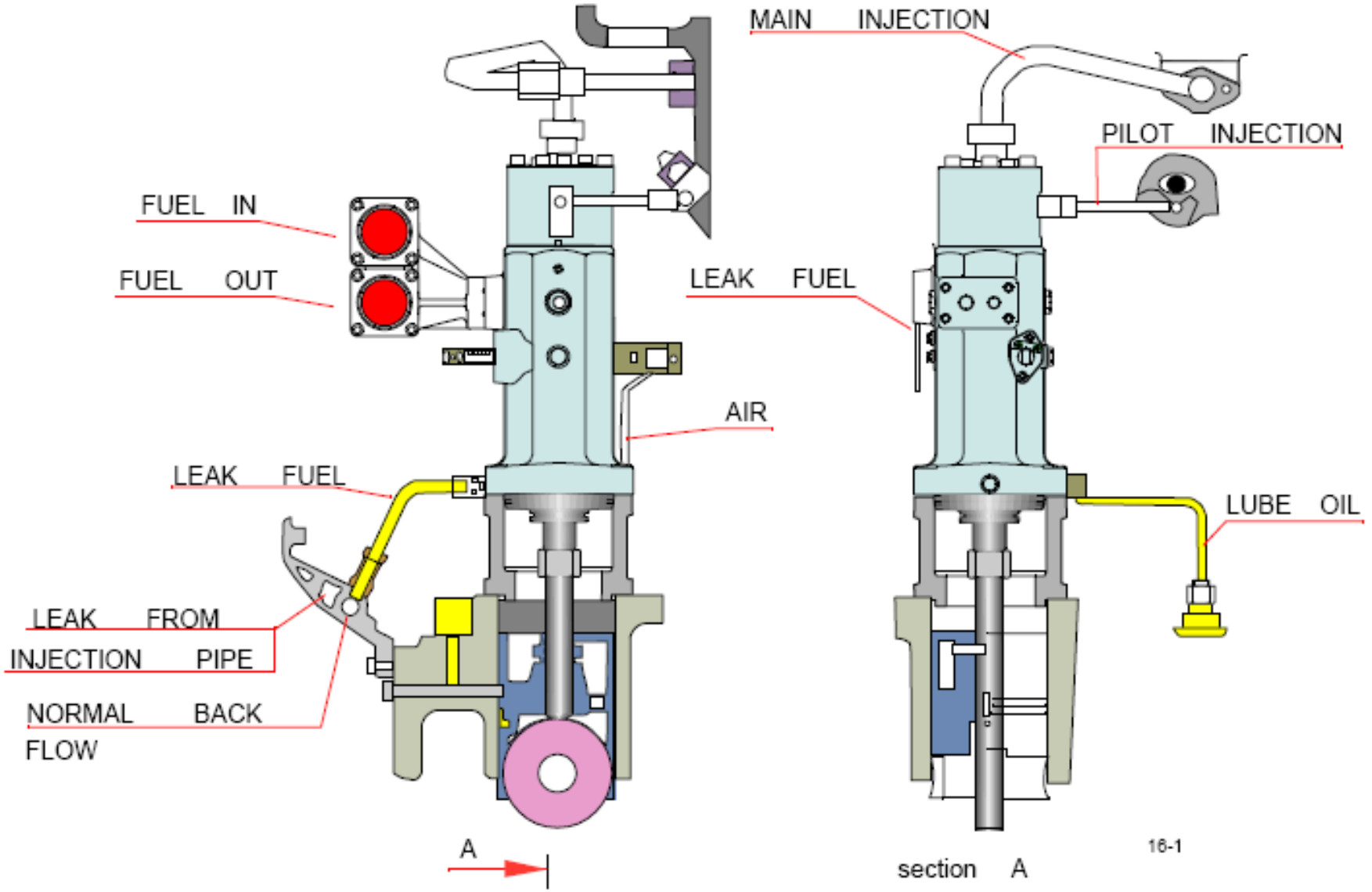

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