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RECOMMENDATIONS CONCERNING THE DESIGN OF HEAVY FUEL TREATMENT PLANTS FOR DIESEL ENGINES

(supersedes CIMAC Recommendation No. 9)

**The International Council
on Combustion Engines**

**Conseil International des
Machines à Combustion**

FOREWORD BY THE PRESIDENT

The Recommendation “The design of heavy fuel treatment plants for diesel engines” describes best practices that have been tested and which qualified to give reliable performance over a wide range of normal and abnormal operating conditions.

The guidelines are drawn up for designers, shipbuilders and operators. These guidelines may also be used as reference document when investigating fuel system related problems caused either by malfunction of the fuel system, the fuel quality defect or faulty management by the operators.

The Recommendation is very informative including a lot of practical guidelines about the design of the fuel oil treatment system and fuel oil properties as well.

I am sure that this Recommendation will be widely applied by designers, ship owners and operators. My sincere thanks to the members of the working group 'Heavy Fuels' for the efforts to prepare the new Recommendation.

Matti Kleimola, President
May 2006

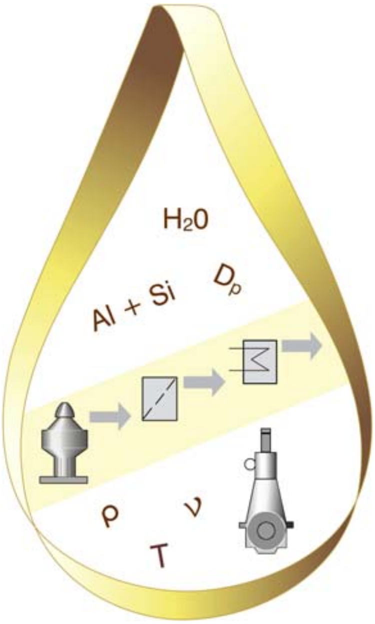
CONSEIL INTERNATIONAL
DES MACHINES A COMBUSTION

INTERNATIONAL COUNCIL
ON COMBUSTION ENGINES

CIMAC is an international organisation, founded in 1950 by a French initiative to promote technical and scientific knowledge in the field of internal combustion engines (piston engines and gas turbines). This is achieved by the organisation of congresses and working groups.

It is supported by engine manufacturers, engine users, technical universitites, research institutes, component suppliers, fuel and lubricating oil suppliers and several other interested parties.

The National Member Associations (NMAs), National Member Groups (NMGs) and Corporate Members (CMs) as well as previous CIMAC Recommendations are listed in the back of this publication.



This document has been elaborated by the CIMAC Working Group "Heavy Fuels" and approved by CIMAC in May 2006.

This document is intended to be a living document and the Working Group is keen to revise or add to the content based on soundly based proposals from any part of the marine industry. Such proposals may be sent to CIMAC Central Secretariat via cimac@vdma.org

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Note!
All system drawings in this paper should be regarded as sketches only.

SCOPE

The purpose of this document is to provide designers, shipbuilders and operators with best practice guidelines for the design of fuel systems for commercial ships burning fuels that comply with “CIMAC Recommendation Regarding Requirements for Heavy Fuel for Diesel Engines" (CIMAC Recommendation No. 21, 2003).

The guidelines encompass well established best practice designs that have been proved to give reliable performance over a wide range of normal and abnormal operating conditions. The ability to cope with abnormal fuel related situations is an important criterion to ensure safe and reliable vessel operations.

These guidelines may also be used as reference material when investigating fuel system related problems caused either by malfunction of one or more elements of the fuel system itself, incorrect management by the operators or a fuel quality defect.

1 DEFINITION OF THE FUEL OIL TREATMENT SYSTEM

The purpose of the fuel treatment system is three-fold:

- Cleaning of the fuel oil by removal of water, solids, and suspended matter to protect the engine from excessive wear and corrosion
- Conditioning of the fuel oil to prepare for best possible properties for injection to the engine and a good combustion
- To take care of oily sludge streams from separators, self-cleaning filters etc., with the task to:
    - reduce the sludge volume which has to be landed or incinerated
    - recover usable fuel oil
    - extract water to be transferred to the bilge water system

The treatment system consists of three sub-systems:

- Fuel oil cleaning system with part-systems for
    - settling
    - pumping
    - heating
    - separation
- Fuel oil conditioning system with part-systems for

  - fuel oil supply and pressurising
  - filtering
  - circulation and mixing
  - heating
  - viscosity control
- Oil recovery and sludge treatment system (option)

Figure 3:1 shows the layout of a typical fuel oil treatment system without being specific down to all details (see page 14).

2 FUEL OIL PROPERTIES

CIMAC Fuel Oil Recommendation No.21, regarding fuel quality for diesel engines, cover petroleum fuels for use in marine and stationary diesel engine plants. These are intended to apply to the properties of the fuel as delivered, i.e. before the appropriate treatment prior to use.

All fuel properties, including those properties, which are not listed in CIMAC Recommendation No. 21 but are of concern to the user, can be grouped into the following categories:

1. Fuel properties that are influenced by the fuel cleaning installation and its layout, such as: water, Sodium, abrasive solids, ash content and sediment.
2. Fuel properties that have an impact on the performance of the fuel cleaning system itself, such as: fuel density, viscosity, stability, and presence of contaminants like used lubricating oil.

3. Other fuel properties, which are not influenced by the fuel cleaning system, and which do not affect the operation of the fuel cleaning system. This category includes several of the properties listed in CIMAC Recommendation No. 21, which are important for engine operation (e.g. Carbon Residue, Vanadium content, Sulphur content, Specific Energy, Ignition Properties), together with other parameters that are important for safety (e.g. Hydrogen Sulphide), compliance with safety regulations (e.g. Flash Point), or for compliance with environmental regulations (e.g. Sulphur, Asphaltenes, Nitrogen).

   As properties in this third category are not influenced by, or do not influence, fuel treatment, they will not be discussed further in this document.

Finally, consideration needs to be given to the fuel properties after the treatment system, at the engine inlet. This is not something, which can be considered in isolation, but is rather a function of the properties of the fuel as delivered, and the effectiveness of the fuel treatment system in modifying those properties that are affected by treatment. Nonetheless, individual engine builders will have their own specifications for what is acceptable for their particular engines; and these will, coupled with the properties of the fuel as delivered, determine the required performance of the fuel treatment system.

2.1 Category 1 - Fuel properties influenced by the cleaning system

The purpose of the fuel cleaning system is to reduce the level of contaminants to an acceptable level in order to protect the engine.

2.1.1 Water

Water can enter the fuel during refining, distribution, storage, or handling onboard. The water in the fuel oil may be present as free water (which can generally efficiently be removed by the centrifugal separators), or as emulsified water (which can be difficult to separate from the fuel oil). Water not removed from the fuel will lower the energy content of the fuel, and may lead to operational problems in fuel systems not designed for it (e.g. corrosion, higher operating temperatures for viscosity-controlled fuel injection, or higher viscosity at fuel injection).

The nature of water can be fresh (non-saline) or saline. Fresh water, such as condensate or tap water, is often partly emulsified, which lowers the overall separation efficiency. Saline water has a higher density and seems to be less inclined to form emulsions, possibly due to its content of electrolytes. The separation efficiency of saline water is normally higher than for fresh water due to these two factors. If saline water is not efficiently removed it may lead to corrosion and deposits, causing significant operational problems for the fuel treatment plant, engine, exhaust system, and turbochargers.

2.1.2 Sodium

The most common source of Sodium in fuel is seawater. However Sodium-based additives are occasionally used in some refining processes, or for after-treatment of fuels to remove Hydrogen Sulphide. The residual additives may sometimes contribute to Sodium levels.

Sodium removal during centrifuging is mainly a function of how much of the Sodium salts are dissolved in the water. Sodium dissolved in water is removed along with the water. Sodium salts in solid crystalline form are also effectively removed during centrifuging. However Sodium, which is chemically bound to the organic molecules in the fuel, will not be removed by centrifuging.

The adverse effects of Sodium are due to its contribution to forming eutectic compounds. These are low-melting compounds formed from the ash elements present after combustion. The most common are salts of Vanadium and Sodium, with small amounts of other metals. The key feature of an eutectic compound is that its melting point is lower than that of the unmixed component compounds. If the melting point of the eutectic mixture is lower than the temperature of the exhaust system, any deposits will exist in a molten form. This can lead to hot corrosion, which can attack exhaust valves, exhaust system components, piston tops, turbocharger nozzle rings and blade surfaces. Another adverse effect of Sodium is the acceleration of deposit formation in the exhaust ducts and turbine components. When continuously operating engines on fuel with high Sodium content, cleaning of turbocharger using wet or dry cleaning should be carried out more frequently.

For more details of the effect of Sodium (and Vanadium) on ash behaviour, see Volume 21 (2003) Annex 7.

2.1.3 Abrasive solids (Catalyst Fines)

The main class of abrasive solids found in fuels are catalyst fines. Particles of iron oxides (rust), sand and dirt may also be present, but will tend to be relatively large and dense, and therefore more readily removed by centrifuging.

Catalyst fines are composed of aluminium oxide and silicon oxide, and hence their presence is measured by determining the amount of Aluminium plus Silicon in the fuel. On the Mohs' scale of hardness, catalyst fines are almost as hard as diamond. These particles can range from sub-micron size up to approximately 50 microns (or occasionally even higher). Too high levels of catalyst fines at the engine inlet will lead to abrasive wear of the fuel system components and on piston rings and cylinder liners. To control the maximum amount of catalyst fines delivered to the engine, many engine builders specify a maximum limit of 7-15 mg/kg of Aluminium plus Silicon at engine inlet.

An efficiently operating fuel cleaning plant is the only practical way of ensuring that the contaminant particles are removed. Measuring the fuel's Aluminium and Silicon concentrations before and after the fuel cleaning plant gives an indication of the efficiency of the system in removing catalyst fines. (See also Section 8- Sampling).

Abrasive wear damage can occur even when analysis of the fuel "as bunkered" indicates that the content of catalyst fines is low. Possible explanations for this are:

- sampling has been carried out incorrectly, resulting in a non-representative sample and hence a misleadingly low result for Aluminium and Silicon in the fuel
- analysis for Aluminium and Silicon has been carried out incorrectly
- In rough weather catalyst fines which have accumulated on the bottom of the bunker and settling tanks can be stirred up in such quantities that efficient purification cannot be ensured.
- the fuel cleaning plant is not operating efficiently due to operational problems.
- there may be high abrasive wear due to factors other than high levels of catalyst fines

If it is suspected that an engine is operating on fuel with an elevated level of catalyst fines, it is recommended that operation of the centrifugal separators are monitored closely, including taking "before" and "after" samples to check the correct operation. Monitoring the frequency of back-flushing and pressure drop through the automatic self cleaning filter (main filter), can indicate a change of fuel quality or cleaning efficiency. It is also advisable to carry out more frequent inspections of susceptible engine parts in order to give early warning of any accelerated wear.

2.1.4 Ash content

The ash content is an indication of the amount of incombustible material, mainly derived from metals that are either inherent to the fuel or originate from external contamination. The metals are present in the ash as oxides and/or sulphates. Most of the time, the dominant metals are Vanadium and Nickel. These cannot be removed by centrifugation, as they are part of the fuel's organic structure. Catalyst fines and salts from seawater also contribute to the ash. The cleaning system, by reducing the catalytic fines and other particles, has a direct influence on part of the fuel's ash content, but its effect is small.

2.1.5 Sediments (Asphaltenic sludge)

Asphaltenes have a slightly higher density than the fuel oil and will therefore be separated from the fuel by the centrifuge, if present in the fuel as particles of sufficient size. In a stable fuel, the small amounts removed will have no significant effect on the properties of the fuel delivered to the engine, but will give a small loss of burnable fuel (see section 2.2.3).

2.2 Category 2 - Fuel properties influencing the performance of the cleaning system

Properties influencing the performance of the fuel cleaning system itself are:

- Density
- Viscosity
- Fuel stability and compatibility
- Used lubricating oil

2.2.1 Density

Fuel oil density is the key property governing the ability of the centrifugal separators to remove contaminants. The difference in density between the contaminants in the fuel and the fuel oil itself is the driving force for the centrifugal cleaning process. For example, if the fuel oil density were to reach 1017 kg/m^3 at 15 °C it would equal the density of fresh water at the normal separation temperature of 98 °C. The driving force for the centrifugal separation process would become zero and all water would remain dispersed in the fuel oil.

Depending on the type of centrifugal cleaning system available (conventional or high-density), and the operation mode (purifier or clarifier) the maximum fuel density is limited to 991 and 1010 kg/m^3 at 15 °C respectively.

2.2.1.1 Fuel oil density 991 kg/m^3

This density limit is a necessary condition for centrifuges of purifier type.
As long as the density does not exceed this limit it will be possible to run the purifier with a stable water seal, which is crucial for the function of the centrifuge.

2.2.1.2 Fuel oil density 1010 kg/ m^3

This density limit is chosen for centrifuges of clarifier type in order to still maintain a reasonable separation of water. If the fuel oil density exceeds this limit the possibility to separate water will gradually decrease to be zero at a density of 1017 kg/m^3 at 15 °C.

2.2.2 Viscosity

The viscosity of the fuel oil is of significant importance for both the cleaning system and the injection to the engine.

The ability of the centrifugal separators to remove water and solids from the fuel is dependent on the fuel's viscosity. The centrifugal separator capacity is inversely proportional to the viscosity at the separation temperature. The lower the fuel's viscosity, the higher the separation efficiency. The recommended separation temperature for fuel oils with a viscosity above 180 cSt is 98 °C. For lighter grades, the recommended separation temperature may be lower but is generally specified as a range
e.g. 180 cSt, 90-98 °C

The desired fuel viscosity range at the injectors, to obtain an optimal spray pattern and good atomisation of the fuel, is specified by the engine manufacturers. As the viscosity decreases with increasing temperature, to active the desired fuels viscosity the temperature of the fuel has to be adjusted accordingly (see also 5.7 and 5.8).

2.2.3 Fuel stability or compatibility

Asphaltenes are complex, high molecular weight aromatic-type hydrocarbons, which are normally held in colloidal suspension in the fuel. The equilibrium between the aromatic hydrocarbons in the fuel matrix and the Asphaltenes is responsible for maintaining the stability of the fuel. The fuel can become unstable when this equilibrium is disturbed. Blending of a heavy fuel oil with a paraffinic distillate fuel, or blending of two heavy fuel oils with widely different aromatics content (as shown by widely differing density and viscosity), may reduce the aromaticity of the fuel matrix, and can result in agglomeration and precipitation of Asphaltenes in the form of sludge. This is known as “incompatibility”.

For the above reason, fuels from different origins should be kept in segregated storage, as much as possible.

If a fuel contains excessive amounts of asphaltenic sludge, the centrifugal separators may become completely choked and proper fuel treatment becomes impossible.

Adjustment of the cleaning system settings cannot rectify this situation. The unstable fuel has to be removed from the system and replaced by a stable fuel oil.

2.2.4 Used lubricating oil (ULO)

CIMAC Fuel recommendation No. 21 (2003) contains limits on Calcium (Ca), Zinc (Zn) and Phosphorous, P to prevent, as far as possible, the addition of ULO to marine fuels. Various laboratory studies of centrifuge performance have been carried out, and some of these (but not all) indicate that ULO has an adverse effect on centrifuge performance [Ref. 2:1].

This issue of control of Used Lubricating Oil in fuels is discussed at greater length in CIMAC Recommendation regarding fuel quality for Diesel Engines No. 21 (2003) Annex 10.

2.3 Properties before the engine

The CIMAC Recommendation regarding fuel quality for diesel engines No. 21 (2003) refer to the desired quality of fuel as delivered to the customer. This is prior to any fuel treatment to reduce the amount of contaminants. The quality of the fuel oil at the engine inlet is directly related to the fuel treatment system and fuel storage arrangement, as well as being influenced by the “as delivered” properties.

Specific quality concerns at engine inlet may originate from poor distillate fuel filtration, poor heavy fuel cleaning system performance or poor quality of fuel as bunkered.

When the recommendations for the fuel treatment systems, including storage, settling, and service tanks, are not followed, the risk of inferior fuel quality at the engine inlet is significantly increased.

Fuel analysis is the only way to monitor the quality of fuel as delivered at the time and place of custody transfer, before and after the fuel cleaning onboard and at the engine inlet. Regular monitoring of the fuel cleaning plant will provide information, which will help to make decisions about the maintenance cycles of the equipment as well as potential engine problems resulting from malfunctioning or inadequate operation. (See also Section 8 – Sampling).

The cleaning plant is initially designed for a specific grade of fuel, i.e. for a specific range of fuel characteristics. If the quality of the fuel is beyond this range, the efficiency of the cleaning plant will be reduced, and hence the fuel quality at engine inlet will be lower, leading to higher maintenance costs. In such circumstances it is recommended to adjust the fuel cleaning system settings to handle the fuel and to ensure the fuel quality meet the necessary requirements. .

In order to protect the engine, the engine manufacturers give clear recommendations for the fuel grades to be used. These recommendations also include guidance values and maximum contamination levels for those characteristics which are critical at the engine inlet and those which can be tolerated by their engine design.

Engine builders generally specify the desired limits for certain fuel properties at the engine inlet. The most important properties covered are viscosity, Aluminium plus Silicon (Al plus Si) and Water. For viscosity, a range is normally specified, while for Al plus Si, and water, a maximum value is specified. Various engine builders specify different limits, but the ranges spanned by the various recommendations are:

- Viscosity: acceptable bands lie in the range 10-24 mm^2/s (cSt)
- Al+Si: maximum limits specified range from 7 to 15 mg/kg (ppm)
- Water: maximum limits specified range from 0.2 to 0.3 v/v %

References:

2:1 Coghill D., The Effects on Centrifuge Performance of the Addition of Used Lubricating Oil in Residual Fuel – Results of a Joint Study between BP Marine and Alfa Laval, paper presented at the International Bunker Conference, Oslo, October 1999.

Other useful information :

2:2 International Maritime Organization (IMO), Convention for Safety of Life at Sea (SOLAS) 1974, Amendment 1, Chapter II - 2, Regulation 15.

2:3 The Flammability Hazards associated with the Handling, Storage and Carriage of Residual Fuel Oil, Published by the Oil Companies International Marine Forum (OCIMF), December 1989.

2:4 International Safety Guide for Oil Tankers and Terminals (ISGOTT). Published by the International Chamber of Shipping.

2:5 Prevention of air pollution from ships. On-board NOx measurement and monitoring. Document presented by Japan to IMO MEPC 49 (July 2003).

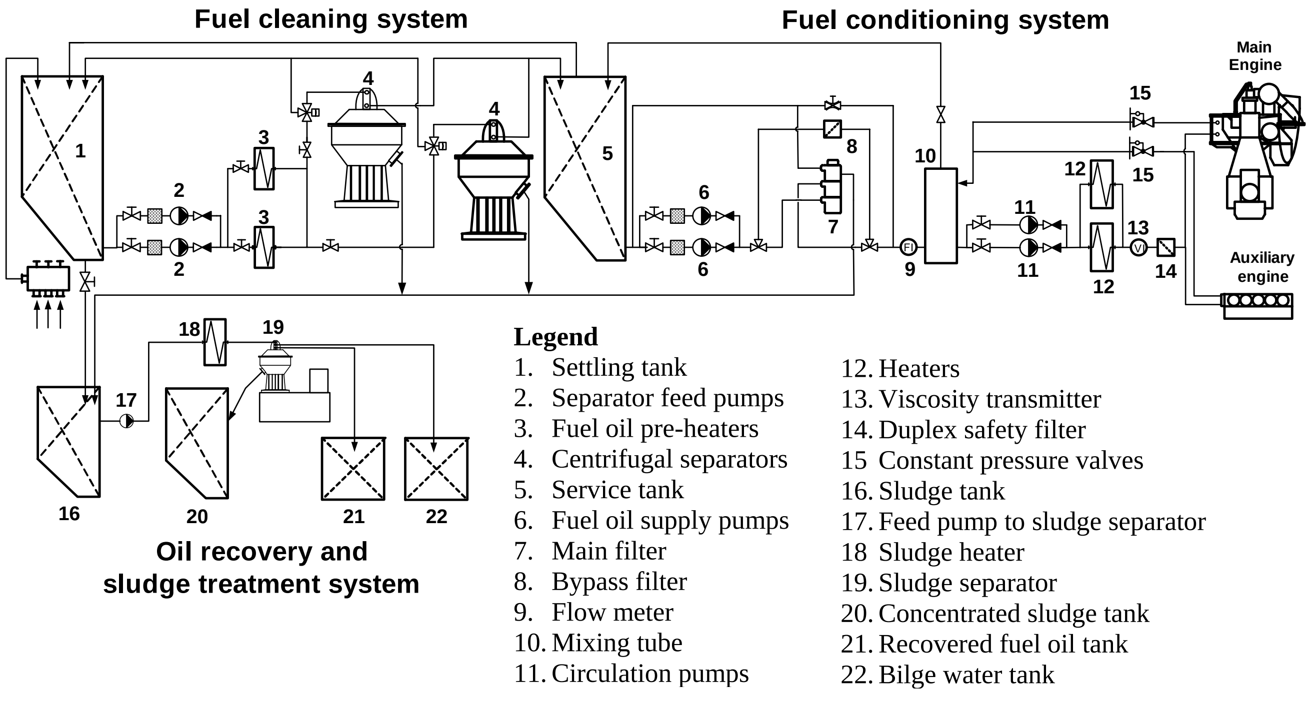
2:6 Annex VI of Marpol 73/78. Regulations for the Prevention of air pollution from Ships and NOx Technical Code

3 THE FUEL OIL SYSTEM

3.1 General Layout

These guidelines represent a best practice fuel treatment layout, comprising:

- transfer pumps
- settling tanks
- fuel oil cleaning system
- service tank
- fuel oil conditioning system
- sludge treatment system (option)
- possible layout for Marine Diesel Oil treatment.



Legend

1. Settling tank
2. Separator feed pumps
3. Fuel oil pre-heaters
4. Centrifugal separators
5. Service tank
6. Fuel oil supply pumps
7. Main filter
8. Bypass filter
9. Flow meter
10. Mixing tube
11. Circulation pumps
12. Heaters
13. Viscosity transmitter
14. Duplex safety filter
15 Constant pressure valves
16. Sludge tank
17. Feed pump to sludge separator
18 Sludge heater
19. Sludge separator
20. Concentrated sludge tank
21. Recovered fuel oil tank
22. Bilge water tank

Figure 3:1. Fuel oil treatment system

The total system including all sub-systems and their main components is described in the order following the oil flow through the system from bunker storage tanks to the ships engine.

Modern ship design with the requirements of unmanned machinery space has led to the development of the single settling tank bunker fuel system. However, best practice would dictate that a system with duplicate tank and piping be specified and used.

The flow scheme shown in fig.3:1 presents a system with the following features:

- Bunker valve manifold and transfer pumps with automatic control to keep the settling tank full.
  Although not part of the treatment plant, the application of several separate main bunker tanks is strongly recommended.
- Provisions should be included in the system for a metered supply of fuel additives. A position before the settling tanks is recommended. As there is no general agreement as to which additives would be used no exact views can be presented and therefore the connection is not shown in the diagram.
- Settling tank with heating facilities.
- Fuel oil cleaning system comprising:
  - -Oil feed pumps
  - -Oil pre-heaters
  - -Three-way-valve for re-circulation during start up and alarm situations
  - -Fuel oil separators
  - -Piping allowing parallel and individual operation
- Separator sludge tank
- Provision of an alarmed overflow tank. This provides added security in the event of overfilling of the settling tank or the service tank
- Two service tanks with associated piping and heating facilities:
  - -A recirculation pipe for excess separated fuel oil from the service tank to the settling tank
  - -Piping to make it possible to re-centrifuge the fuel oil in the service tank in by-pass (not shown in the diagram).
- A pressurised fuel conditioning system comprising:
  - -Supply pump plus stand-by pump including strainers on suction side
  - -Automatic self-cleaning fine filter as main on the cold side (alternative position can be in place of the main engine duplex safety filter.).

  - -Re-circulation pipe to suction side of supply pump. This pipe can be fitted with cooling fins to ensure that the temperature will not rise too high when engine is slow speeding or idling.
  - -Flow transmitter on the cold side
  - -Circulation pump with stand-by pump
  - -Heater with stand-by heater in parallel
  - -Viscosity transmitter with controller
  - -A duplex safety filter close to fuel oil inlet to engine

- Oil recovery and sludge system

3.2 Bunker tanks

It is strongly recommended that the main fuel bunker tanks are arranged to avoid the mixing of newly bunkered fuel with fuel remaining on board.

The bunker storage tanks must be fitted with heating coils sufficient to maintain the fuel at a temperature necessary to achieve efficient pumping.

To avoid fuel solidifying in transfer pipes, when no fuel is transferred, heat-tracing must be used.

The transfer pumps should be of the positive displacement type, e.g. screw- pumps. This type of pump will minimise emulsification with any water present. Consideration should be given to this pump being of sufficiently large capacity to facilitate timely de-bunkering operations.

The transfer pumps can be equipped with automatic control to keep the settling tank full. The control range should be relatively narrow to stabilise the conditions in the settling tank (see sec. 3.3 Settling tanks and sec. 3.3.1 Design considerations).

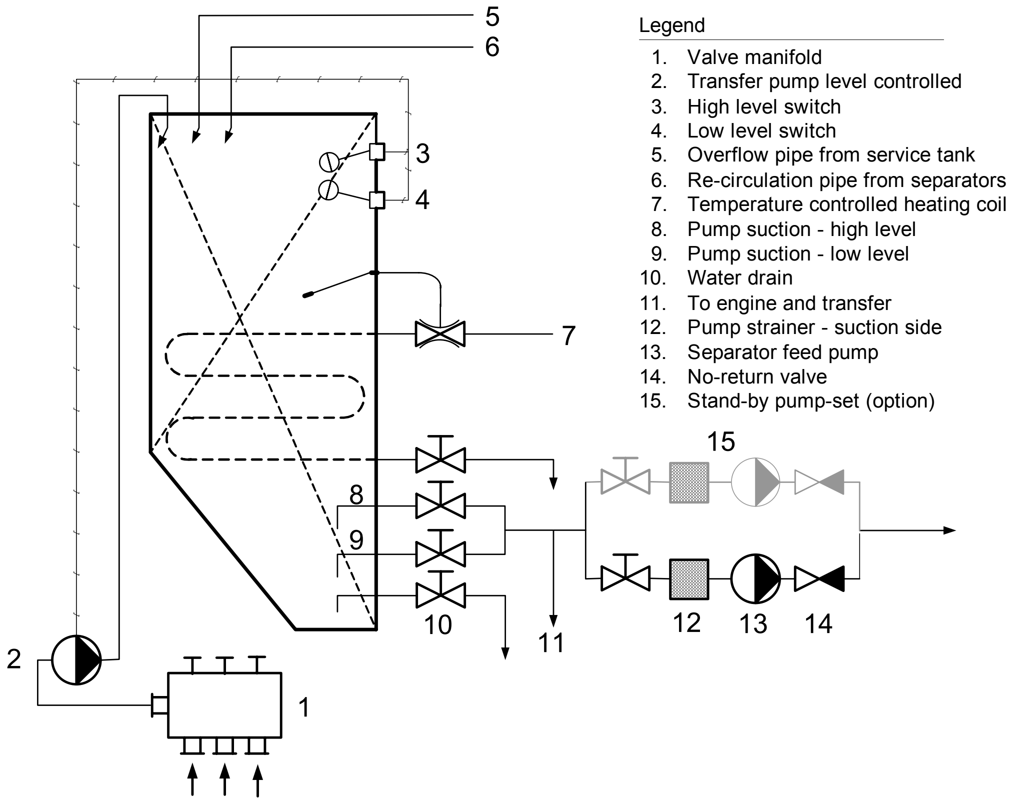
3.3 Settling tanks

The main function of the settling tank is:

- To allow sufficient time for the primary removal of water and solids from the fuel.
- to provide constant temperature feed to the cleaning system

To minimise turbulence caused by the supply and return flows, pipes should be directed towards the upper part of the tank wall (see fig. 3:2).
Thermal insulation of the settling tanks is recommended to avoid heat losses and help to keep the temperature in the engine room at a tolerable level.

During normal operation sediment, including cat fines, will collect at the bottom of the tank. Therefore provision for regular tank-cleaning and total drainage is necessary.



Legend

1. Valve manifold
2. Transfer pump level controlled
3. High level switch
4. Low level switch
5. Overflow pipe from service tank
6. Re-circulation pipe from separators
7. Temperature controlled heating coil
8. Pump suction - high level
9. Pump suction - low level
10. Water drain
11. To engine and transfer
12. Pump strainer - suction side
13. Separator feed pump
14. No-return valve
15. Stand-by pump-set (option)

Figure 3:2 Settling tank in a fuel treatment system

3.3.1 Design considerations

Level switches are fitted for frequent “topping-up” of the settling tank. This helps reduce temperature fluctuations at the suction point for the separator feed pump. Heating is usually provided by steam, hot water, thermal oil, or electric coils running through the tanks.
A temperature controller should be fitted to ensure that the oil is maintained at the optimum temperature to promote effective settling. The settling tank should have a sloping bottom to direct water and heavy sludge towards the drain valves.

The separator feed should be located well above the water drain point to prevent accumulated water and sludge being drawn into the fuel treatment system. A best practice fuel system design has a high and low suction into the fuel cleaning plant. Low suction is normally used. The high suction is only used when fuel problems are present such as high water or sludge content.

3.4 Cleaning of settling tanks and service tanks

The cleanliness of settling tanks and service tanks has a strong influence on the operation of the engines. Accumulated sludge can dislodge in rough weather, leading to clogging filters and centrifuges.

Therefore, it is important that both settling tanks and service tanks are emptied and cleaned regularly. Access for such maintenance needs to be considered in the design of the fuel system.

4 FUEL CLEANING SYSTEM

4.1 Centrifuge Supply Pumps

One positive displacement pump per centrifuge should be installed close to the settling tank. A strainer to remove any coarse solids from the oil should protect the pump suction.

Constant flow rate to the separators is essential to maintain good separation, especially for high-density oils.

The fuel feed rate through the centrifuge should be set to match the engines’ fuel consumption.
The flow rate should not be regulated according to short-term variations in fuel consumption.
Controllable pumps (by mechanical variator or frequency controlled motor) or constant flow regulating system should be used when the available pump has a capacity exceeding the required flow rate or when large changes in engine power due to operational requirements are necessary over extended periods of time.
By means of such a system it is possible to achieve the calculated required flow rate of the fuel treatment system and also to maintain a constant flow rate to the separators.
The excess flow of the pump, when using a constant flow regulating system, should be re-circulated to the settling tank (NOT TO THE SUCTION SIDE OF THE PUMP!).

4.1.1 Design considerations

The system shown in figure 4:1 uses one positive displacement pump per centrifuge. Note that two pumps are recommended - one running and one on stand-by. If there are more than one separator in the system only one on stand-by is needed. The pumps should be installed close to the settling tank to avoid long suction pipes, which can give problems with fluctuating flow, cavitation and vaporization.
A strainer should be installed before each feed pump to protect the pump from harmful solids. Suitable mesh size is 1.5 – 3 mm.

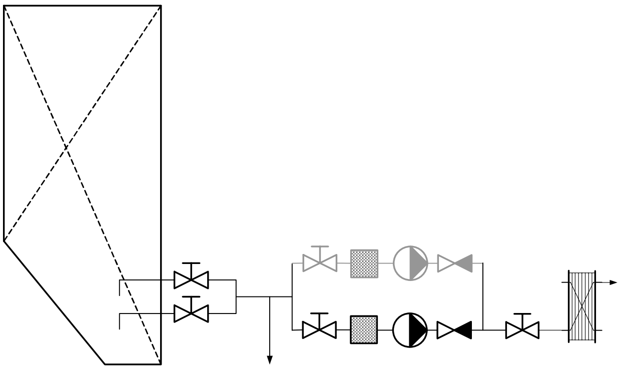


Figure 4:1 Pumping system in a fuel cleaning system

4.1.2 Pumps

4.1.2.1 Separate feed pumps

The feed pumps should be of positive displacement type, set for operation at constant flow rate.
The pump motor should preferably be of four-polar type for low speed to ensure gentle handling of the fuel and to avoid emulsification of water present and to avoid breaking solids into smaller pieces.
The capacity of each pump should, if possible, fit the required flow rate of the cleaning plant. Control of the flow rate to match the instantaneous fuel consumption of the engines is not recommended. If pumps with required capacity are not available, the pumps may be equipped with a flow-controlling device like a mechanical variator or a frequency controller. An alternative is to install a flow control device after the feed pumps to bleed off the excessive amount of oil and re-circulate this oil to the settling tank.

Throttling on the suction side of the pump must not be used to regulate the flow rate.

The pumps shall be equipped with built-on relief valves, set for an opening pressure of 400 kPa (4 bar) with full opening at 600 kPa (6 bar).

4.1.2.2 Built-on feed pumps

In many old fuel oil cleaning systems, integrated with the separator is a feed pump which is always of a gear type. A common fault with this design is that the built-on pump has far too high a capacity because it was designed to handle the full range of fuel grades. Ideally the capacity of the pump should not significantly exceed the required flow rate of the cleaning plant.

The separator is often located some distance from the settling tank leading to potential problems of pump cavitation and flow rate fluctuations. The problem increases significantly if the separator is located above the height of the settling tank, necessitating a large suction height. Pump cavitation and flow rate fluctuations may lead to emulsionfication of water and breaking of agglomerated solids into smaller pieces which make the separation much more difficult. Built on pumps are no longer recommended.

4.2 Pre-heating system

Preheating of heavy fuel oil before separation demands careful attention to the design and control of the heaters in order to avoid operational problems and to minimize the energy consumption of the heaters.
The most common heaters on board ships are steam heaters. Steam is often available at low cost. Other fluid heating sources are hot water and thermal oil.
In a large proportion of the smaller tonnage and in the lower range of the power industry electric heaters are frequently used.

4.2.1 Design considerations

Some of the most common sources of problems with fuel oil cleaning systems are undersized heaters, heaters that have poor temperature control and components that are not matched to each other to form a well designed control system.

In a cleaning system for HFO the normal processing temperature is 98 ± 2 ºC. Lighter oil grades may have lower recommended temperatures. The recommendation from the equipment supplier should be followed.

The temperature control is of utmost importance for the separator to operate at high efficiency. If the separation temperature is lowered from 98ºC to 90ºC the separator capacity has to be reduced by 35 % of the nominal rating to maintain the same separation efficiency!!

Steam is the most adaptable medium for heating purposes and a correctly sized steam valve is very important. A valve with equal percentage characteristic is recommended.
When the system is operating at the maximum recommended flow rate the steam valve should still have a flow margin of 25 to 50 % to ensure good control.

Electric heating necessitates care to select heating elements specially designed for fuel pre-heating, since local overheating may cause fuel cracking, with formation of high volatile components and hard carbon on the heater surfaces. To avoid this trouble the maximum electric load on the heater element should not exceed 1 to 2.5 watt/cm^2, depending on type of heater design.

In order to maintain a constant temperature within the given limits a Proportional / Integral (PI) controller should be used. A controller with only P-function will by definition give a temperature offset for all loads on the heater other than the design load.

There are several reasons why the temperature does not remain steady after being set correctly:

- If the 3-way valve between the heater and the separator re-circulates the oil to the suction side of the pump instead of re-circulation to the settling tank, the temperature will suffer from severe fluctuations, often more than ±10 ºC.
- If the temperature controller only has proportional mode of control, (P-controller), the system will not be able to eliminate temperature changes in the incoming oil.
- Changes can occur when topping up the settling tank with oil having a lower temperature than at normal operation or when stopping a diesel engine in port.
- An undersized or dirty heater will make it impossible to keep the correct temperature because of slow or insufficient response to incoming oil of low temperature.

4.2.2 Separator pre-heaters

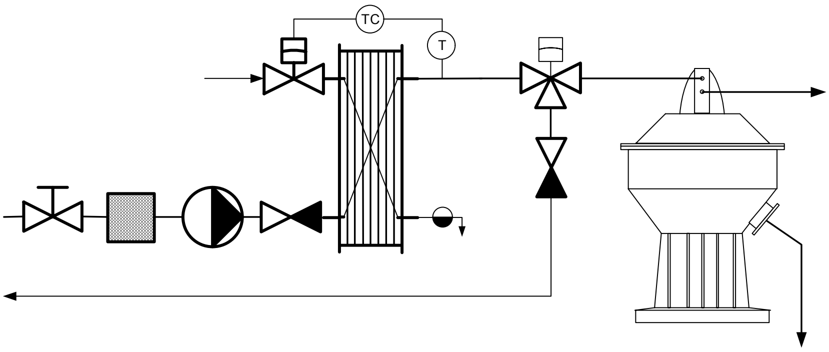


Figure 4:2 Heating-system in a fuel cleaning system

There is a distinct difference between heaters operating with steam, hot water or thermal oil as the heating medium compared to electric heaters.

The former are intrinsically safe in the respect that the temperature in the heater never will exceed the temperature of the heating medium. The heat transfer is the dependent parameter adapting to prevailing temperature, flow conditions and the degree of fouling on the heating surface.

Electric heaters have constant heat transfer with the temperature as the dependent parameter. The temperature is not limited by the heating process itself and will rise unlimited if not regulated by the control system.

When choosing heaters for preheating of fuel oil prior to the cleaning operation the following must be carefully considered, especially for heaters with high surface load such as electric heaters.

- A turbulent oil flow through the heater is required for optimum thermal efficiency and to avoid coking
- The heater must not have any “dead” zones where the flow is zero or close to zero where hot spots can occur with fouling as a consequence.
- The heater should be designed to prevent “short cut” of the oil flow through the heater.
- Short retention time in the heater to shorten the contact time between oil and heating surface. Short retention time also gives the system a fast response to changes in the process parameters, ensuring fast and accurate control of the fuel oil temperature

4.2.2.1 Steam / hot water/ thermal oil heaters

The shell-and-tube design is one of the most common types of fuel oil pre-heaters. The design is simple and it is easy to inspect, clean and repair the heating surface. The shell can be with or without baffles inside. Heaters without baffles may suffer from irregular flow conditions which can result in poor heat transfer.

There are certain disadvantages connected with shell-and-tube heaters:

- Bulky design and need for ambient free space for tube removal during overhaul.
- Slow temperature control due to large volume of oil
- Bad turbulence or even laminar flow may contribute to fouling and slow temperature control.

4.2.2.2 Finned-tube and steam-coil heaters

These types of heaters basically suffer from the same limitations as shell-and-tube heaters.

4.2.2.3 Plate heat exchangers

Plate-heat-exchangers (PHE) are frequently used as fuel oil pre-heaters.
The PHE provides both short retention time and highly turbulent flow.

In the design of the plate heat exchanger a maximum pressure drop of 1 bar should be allowed, typical 0,5 – 0,8 bar is used.

A special type of PHE is the PHE with the corrugated steel plates braised together.

4.2.2.4 Electric heaters

All conventional electric heaters for preheating of oil are mostly of the same basic design; a tube stack of heating elements in a pressure vessel with an electro-mechanical stepwise on-off temperature controller, often combined with manual control.
These heaters are often quite bulky with a large oil volume in the vessel. A large volume of oil in combination with stepwise control of heating results in poor temperature control.
Another factor that limits the suitability of electric heaters is laminar flow distribution of the oil inside the heater. This can result in quiet pockets where the oil is standing still with obvious risk of fouling and coking on the heating elements.

Another type of electric heater has elements with an outer shell of cast aluminium permitting narrow channels between the elements. This ensures small hold-up in the heater, turbulent flow, and that no quiet pockets are formed.

4.2.3 Heat tracing

All the components and pipes comprising the fuel cleaning system should be insulated and heat traced in order to always ensure good pumpability throughout the complete system also during start-up conditions.
It is important that sludge and drain pipes are heat-traced even though intermittently used.

Heat tracing can either be by steam or electrical heating tape.
If electric heating tape is used it should be controlled by a thermostat to ensure that the maximum operating temperature is not exceeded.

4.3 Centrifugal Separators

4.3.1 Task

The fuel oil cleaning system is installed with the purpose to reduce the content of solids and water to a level that does not cause excessive wear or other related problems with the engine.

All solid material contained in the crude oil when fed to the refinery follows the bottom residue all the way through the refinery becoming successively more and more concentrated. It will end up in the residual oil pool from which the final product to the customer will be extracted for final blending to the ordered quality.
Added to the natural solids originating from the crude comes catalyst fines, consisting of Aluminium and Silicon Oxides from cracker units, coke and Asphalteneous material from degradation of the residual oil.

Centrifugal separators have proved to be the most effective means of removing fuel contaminants that are dangerous to the diesel engine. Both water and solids can be effectively removed.
The separation efficiency is strongly influenced by the size and density of the contaminants, and so the centrifugal separator has a natural bias towards removing the most harmful impurities. Thus the centrifugal separators are the most important part of the treatment plant and good results very much depend on correct selection, installation and operation.

4.3.2 Separator sizing

Correct sizing of the centrifugal separators is of utmost importance. When specifying the total required flow rate of the cleaning plant, the fuel consumption of auxiliary engines and boilers, if any, must be included.

The appropriate separator is selected from the capacity tables issued by the separator and engine manufacturers.

If the oil consumption has to be based on the Max Continuous Rating (MCR) of the engines the following formula can be used.

$$Q = \frac{P \cdot b \cdot 24}{\rho \cdot T} \text{ (l/h)}$$

Q = Fuel oil consumption (l/h)
P = MCR (kW or HP)

b = Specific fuel oil consumption (kg/kWh or kg/HPh) specified by the engine supplier.
ρ = Fuel oil density (Presumed to be 0.96 kg/l)
T = Separator daily net operating time (number of hours per 24 hour day)

4.3.3 Type approved performance

The leading classification societies have adopted a test method for type approval of separators. The approval test measures a specific capacity called Certified Flow Rate (CFR), which is considered as a safe level for continuous, efficient separation of heavy fuel oil.

The method for determining CFR has been released by the European Committee for Standardization (CEN) as CWA 15375, (Ref. 4:1).

In the past centrifugal separators have solely been selected according to the “Maximum Recommended Capacity” tables, (MRC), provided by individual separator manufacturers. The MRC-tables have no officially documented reference to the separator performance.

With introduction of CWA 15375 there will be an agreed and well-documented reference to separation performance obtained by a specific test method.

4.3.3.1 Use of CFR

During the purchasing procedure CFR is a tool with which to compare separators of different makes on an equal basis irrespective of which flow rate will be used in the installation.
Running at CFR on real fuel will ensure the user is able to achieve satisfactory separation efficiency under the prevailing circumstances irrespective of the make of separator (Ref. 4:1).

4.3.4 Design

All leading suppliers of centrifugal separators have designs to cope with low-grade heavy fuels with density up to 1010 kg/m^3.
They have a common feature in that they have no gravity disc, but having additional means of controlling the water content and water handling. They all maintain the discharge of sludge at the periphery of the bowl.
Three different principles are applied:

1. Separate water discharge controlled by monitoring the water content by means of a capacitance measurement in the cleaned oil.
   When the water content reaches a set level, water is drained through a separate water outlet, or a sludge discharge takes place.
2. By means of a circulation loop from the outside of the disc stack, a small proportion of the fuel is pumped back to the fuel supply line.
   When the quantity of separated sludge and water increases, the interface moves

inward, and, if water is present, the water content in the circulation loop increases.
When the water content in the loop is so high that the liquid is electrically conductive, this is recorded by means of a conductivity measurement and a quantity of water is drained separately.

3. Based on the density difference between sludge/water and fuel oil. Having reached a certain level in the sludge space, separated sludge and water affect a pressure sensing device and the separated water is discharged together with sludge by opening of the bowl. This separator has no separate water discharge.

All these designs have a common feature in that only a single unit is required. As it is usual to have a spare separator, it is advantageous to use the stand-by separator to improve the cleanliness of the treated fuel.

The suppliers of separators of type 1 and 3 promote parallel operation of the separators, which leads to doubling of the residence time. This must fundamentally give a higher yield of particle removal compared to applying an unaltered residence time as occurs in series operation.

The supplier of separators of type 2 recommends series operation, operating the second machine as a clarifier equipped with automatic sludge monitoring equipment matching the discharge frequency to sludge production. An argument used for series operation is that, if an excessive amount of abrasive contaminants pass through the first separator, the second machine will collect the remaining contaminants. This situation is thought to occur if, due to heavy seas, larger quantities of catalyst fines, slugh and dirt from tank bottom have been disturbed and mixed with the fuel. It is, however, most likely that this problem can be avoided if the settling tank is regularly drained and cleaned.

4.3.5 Installation aspects

4.3.5.1 Clean fuel outlet

Between the outlet of the separator and the service tank, there should be no equipment that influences the separator outlet pressure.

As the throughput of the separators normally is higher than the fuel consumption of the engine(s), provision must be made for the overflow of cleaned fuel from the service tank to the settling tank. The overflow to be drawn from near the bottom of the service tank.

4.3.5.2 Sludge discharge pipe and sludge tank

For trouble-free operation, the discharge of water and sludge from the separator must take place without any restriction. The discharge pipe should be of large diameter, short in length and preferably vertical. The sludge pipe must end above the liquid level in the sludge tank.
The sludge tank must be sufficiently large and well ventilated to prevent a backpressure building-up against the separator during the discharge of sludge.

The capacity of the sludge tank must be sufficient to prevent the necessity to re-circulate sludge. The contents of the sludge tank should either be disposed of by incineration, delivered ashore or transferred to a sludge treatment system onboard for further treatment, all in accordance with the prevailing anti-pollution regulations (see sec.6).

4.3.5.3 Operating and displacement water

All self-ejecting separators need good quality fresh water for the hydraulic operating system. The same water quality is required for the displacement of oil before discharge.

The separator suppliers state the limits. An example of limits is:

- total hardness: max 180 ppm CaCO3 or 10° dH
- pH: min 6
- solids: max 10 ppm
- chloride ions max 100 ppm

References

4:1 European Committee for Standardization (CEN); CWA 15375, Separators for marine residual fuel – Performance testing using specific test oil.

5 FUEL CONDITIONING SYSTEM

5.1 Introduction

The purpose of the Fuel Conditioning System (FCS) is to treat the heavy fuel oil fed from the service tank to the diesel engine while meeting the requirements for cleanliness, flow rate, pressure and viscosity specified by the engine manufacturer. This ensures fuel efficiency and creates a basis for low costs operation.

A few decades ago a transition from light fuel oils to heavy fuel oils for diesel marine engines began to accelerate in an effort to reduce reliance on light fuel oils.

Fuel conditioning for light fuel oils consisted of a simple atmospheric booster system with an open mixing tube, circulation pumps, heaters and filters. There was also a heater control system most often based on temperature as the controlling parameter. Fuel flowed through the injector pumps at the pressure created by the engine pressure control valve. Excess fuel returned to the atmospheric mixing tube. The daily service tank and mixing tube were level so that gravity caused fresh oil to flow into the system.
Single-stage atmospheric systems are generally now used only when the required fuel injection temperature does not exceed 110°C. This corresponds to a fuel viscosity grade of 180 cSt at 50°C.

This arrangement has two inherent problems. First, as fuel viscosity increased, there was insufficient head from the feed tank to ensure the correct flow rate of fresh oil into the system. Second, cavitation occurred in the circulation pumps due to temperatures in excess of 100°C at fuel injection. As fuel returned to the atmospheric mixing tube, the small quantities of water usually found in the fuel oils mixed with more volatile components in the fuel itself and vaporized after passing through the pressure control valve resulting in violent pressure fluctuations.

Other factors also played a role in advancing fuel-conditioning system technology. Fuel booster systems were large, unwieldy and difficult to maintain and control, despite some minor improvements. Reduced staffing of the engine room raised demand for low maintenance, improved safety and remote control. There was also demand to improve the environmental aspects of fuel treatment and engine operation.

The switch from light fuel oils to heavier low grade oils with a maximum viscosity of 700 cSt at 50 °C and density up to 1010 kg/m^3 prompted the market for conditioning systems capable of handling these types of fuel oils.
This led to the development of the two-stage pressurized booster system.

The two-stage pressurized system eliminates the control difficulties that are frequently encountered with single-stage systems. Two-stage pressurized systems also reduce the occurrence of other problems, such as gasification, that are associated with the high fuel temperatures required for operation using heavy fuel oil.

By introducing a first stage comprising supply pumps, main filter and a closed pressurized mixing tube operating at the low-pressure level around 4 bar, fresh fuel is supplied, maintained at the proper pressure and flow, and mixed with hot fuel returning from the engine. Because the closed mixing tube is kept at a pressure of at least 4 bar, cavitation does not occur. Fuel is then circulated and heated in the high-pressure stage to obtain the required viscosity for injection.

Unlike single-stage systems that use temperature as the primary control parameter, the modern systems use viscosity as the primary control parameter. Two-stage systems are now also used for light fuel oils because these systems offer other benefits, such as greater flexibility for installation. Heavy fuel oils are now the fuel of choice for both main and auxiliary engines.

Viscosity has proven to be an important factor for efficient engine operation. Diesel engine manufacturers specify the fuel injection viscosity that provides optimum combustion. Heavy fuel oils, usually in the range of 380 to 700cSt, are generally heated up to a maximum of 150°C to obtain the required injection viscosity. However, the temperature required to heat heavy fuel oil to a certain viscosity varies. This depends on the origin of the crude oil upon which the heavy fuel oil is based and on the refinery process used. Using viscosity, instead of temperature, as the primary control parameter improves fuel efficiency, while preventing engine damage and reducing maintenance costs.

5.2 Pressurized system

5.2.1 The fuel conditioning process

The two-stage pressurized booster system maintains a pressure of 4 bar during the first, or low-pressure, stage. During the second, or high-pressure, stage, the system maintains a pressure within the range 6 to 16 bar, depending upon the requirements of the engine manufacturer.

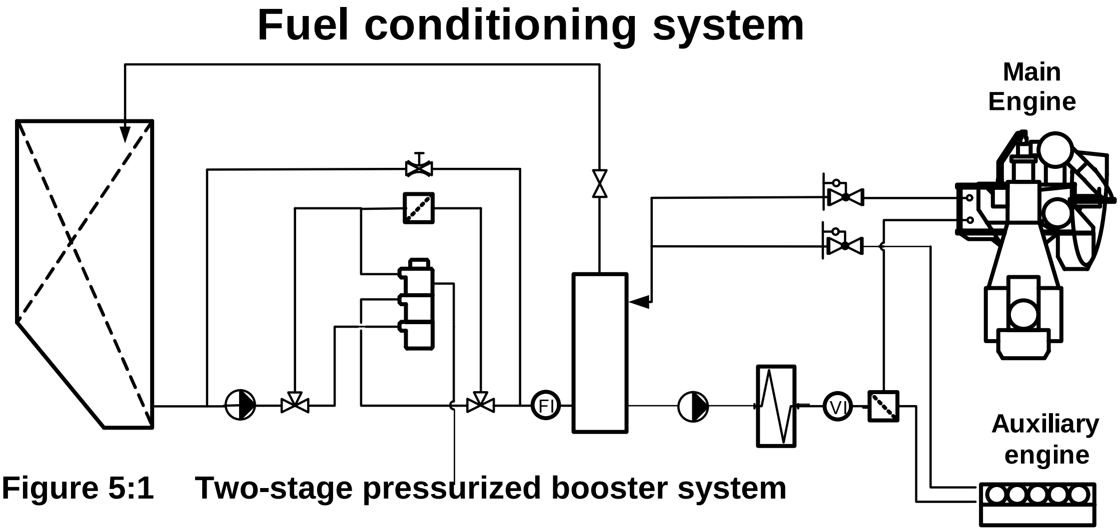


Figure 5:1 Two-stage pressurized booster system

5.2.2 Low-pressure or supply stage

The supply pump takes in fresh fuel from the daily service tank. The fuel oil passes through a three-way valve making it possible to switch over to distillate fuel.
Pump strainers protect the supply pumps preventing large particles from reaching the pumps. In case of supply-pump failure, the system can change over to a standby pump. The supply pump maintains a pressure of 4 to 5 bar. The main oil filter, often of automatic back-flushing type, is placed either between the supply pumps and the mixing tube or in the high-pressure section. The main filters are there to ensure that the fuel oil cleanliness meets the engine specification.

A pressure relief valve allows fuel to recycle within the low-pressure section so that the flow of fresh fuel entering via the three-way valve precisely matches the fuel consumption of the engine. A pressure transmitter at the oil outlet is used to ascertain the correct pressure and maintain the supply pump stand-by function.

5.3 Mixing tube

The mixing tube acts as a system buffer to obtain stable viscosity or temperature control and, to some degree, to smooth the transition when changing over from DO to HFO, or vice versa.
The mixing tube should be insulated and heat-traced. It has to be approved for operating pressure up to 6 bar.

The mixing tube is equipped with a level switch that presents an alarm or a signal to the control system when air or gases accumulate in the tube, indicating the need for de-aeration that either can be done manually or automatically. Air and gases are vented back to the service tank.

Experience to some extent shows that a mixing tube is not optimal as a pressure damping vessel, but if - in special cases - this should be necessary, separate damping devices can be introduced - as an example by introduction of damping vessels connected with T-pipes to the inlet and outlet fuel supply line to the engine.

The size, volume and working pressure of the mixing tube have to be in accordance with the engine maker specification.

5.4 Supply pumps

The recommended type of supply pumps is three-spindle screw-pumps. These pumps are available specifically designed for transfer of heavy fuel oils at elevated temperature. Pumps housed in nodular cast iron with magnetic drive or shaft seal located on the suction side to minimize leakage are preferred. Durability is further enhanced with double shaft seals, a hard metal type and a lip seal.

Two supply pumps in parallel are recommended, one in operation and one on standby. Strainers should be installed before each supply pump to protect any large particles from entering the pump. Non-return valves are mounted after the supply to prevent fuel oil from entering the pump on standby.

Standard pumps are equipped with two-pole electric motors that operate at a speed of 3000/3500 RPM. Built-in safety relief valves are standard. Pumps with four-pole electric motors are available on the market if requested.

The supply pumps should be sized for a flow rate of about 1.5 times the required flow rate at MCR. The over-capacity, relative to the instantaneous fuel consumption fed to the mixing tube, is re-circulated to the suction side of the supply pump via a pressure control valve.

5.4.1 Pressure control valve

This valve controls the pressure at the engine inlet by re-circulating fuel to the suction side of the circulation pumps. The valve should provide nearly constant pressure under all operating conditions - from engine stop to maximum engine consumption. When the engine is idling or stopped and most (or all) of the fuel is re-circulated the temperature may increase beyond acceptable limit. A cooler, e.g. air fin cooler, can be used to limit the temperature. The cooler should be installed after the pressure control valve.

5.4.2 Flow transmitters

A flow transmitter of good precision has to be installed to monitor fuel consumption by measuring the volumetric or mass flow rate that is transferred to the mixing tube. Because flow transmitters are sensitive to contaminants, they should be installed on the pressure side of the supply pumps, and after the main filter, if the filter is located on the cold side.

5.5 Filters

5.5.1 Task

The centrifugal separators remove the bulk of contaminants in the fuel oil. However, to protect the engine, it is standard practice to fit a filtration unit as the final stage in the fuel treatment system. The filter is there not to remove sludge but rather as a safety measure to stop remaining big particles reaching the engine

Filtration presents a logical supplementary step in the treatment system because of the risk that some particles, particularly of low-density material, escape the centrifuge. Experience shows that filters always collect some material most probably coming from the service tank.
In addition, the filter serves as an indicator of the performance of the cleaning system up-stream and in the case of an unstable or incompatible fuel.

There must always be a main filter installed between the service tank and the engine. The filter should be capable of handling relatively large quantities of contaminants.

It is also recommended to install a safety filter immediately before the engine. The more piping and equipment there is between the main filter and the engine, the more reason there is for it to be included. Even if the main filter is very close to the engine, the safety filter is a safeguard against possible faults occurring during repair or maintenance of the main filter. Several engine manufacturers therefore include a safety filter in the engine supply.

It is recommended that the safety filter be provided with a magnetic trap because ferrous particles can present an acute risk.

5.5.2 Design

The main parameter when sizing a filter is the mesh size, meaning the size of the openings in the filter mesh. There are two prevailing expressions in use regarding mesh size – Absolute mesh size and Nominal mesh size.

Absolute mesh size is defined as the size of a spherical particle that will just pass through the mesh. (“larger” particles may pass if they are oblong).
This definition gives a virtual understanding of the mesh openings.

Nominal mesh size is the size of those particles of which 90 % are retained in practical use.
This definition, which is purely empirical and depending on the particle shapes, does not give a clear understanding of the filter mesh geometry, which allows a flexibility from the filter manufacturers side.

The nominal mesh size is always smaller than the absolute mesh size. The ratio between the two depends on the wire structure, the mesh size and on the particle shape and size distribution.
In the range of 5 to 50 micron the size ratio absolute/nominal mesh is in the order of 2.5/1.

The selected mesh size depends on the requirements of the engine supplier and on the expected reliability and cleaning efficiency of the separators. The nominal mesh size of the main filter must be at most 25 micron (absolute 50 micron), but there is a tendency towards smaller values. A nominal mesh size of about 10 micron (absolute 25 micron) is already quite common and some new designs of 5 micron nominal mesh size have been introduced.

Under the prevailing conditions of temperature and shear effects, the amount of insolubles can increase largely by coagulation of Asphaltenes and hence the mesh size of the safety filter must be at least twice that of the main filter.

The conventional design is a duplex type of filter with a differential pressure indicator to monitor the increase in flow resistance during service. In this case, either surface filtration (generally with stainless steel elements that can be hand-cleaned) or depth filtration (applying disposable cartridge elements of synthetic felt) can be applied. This can be considered as the minimum recommended requirement.

The normal recommendation today is automatic back-flush filters.
One type of such a filter works so that the cleaning depends on the differential pressure across the filter element. At a preset pressure difference back-flushing is achieved through one filter elements at a time in a cyclic sequence. A cleaning cycle counter warns when the frequency exceeds a preset value.
Another type of automatic back-flush filter has disc formed filter elements divided in a number of sectors, which are back-flushed continuously one at a time while the rest of the filter sectors are in operation.

5.5.3 Position in the system

Normally, the main fuel filter is installed in the circulating system, after the circulation pump and heater. In this position, as close as possible to the engine, the risk of dirt being present in the system or entering after the filter is at its lowest. On the other hand, due to the temperature history of the fuel, there is a risk of Asphaltene coagulation, which can cause severe clogging of the filter elements by organic matter. This can happen with unstable fuel, particularly during changes from heavy fuel to distillate fuel or vice versa.
An option is to place the main filter directly before the circulating system, between the supply pump and the mixing tube. In this position, the fuel entering the filter has a temperature between 70 and 98°C. At this temperature, considerably less ageing occurs, reducing the risk for clogging.
Although the viscosity of the fuel is higher than in the circulating system, the resistance of the filter is similar for a given filter area, because the flow is only about 1/3 of that in the circulating system.
More important, however, is the less exposed position of the filter, with lower fuel temperature, lower pressure and less pressure peaks.
The trend appears to be towards placing the main filter before the mixing tube. However, the rather long distance from the filter to the engine with the piping and the equipment in between may cause a risk of intrusion by contaminants.
Accordingly, in particular the installation position of the fine filter (including depth filter) should be agreed upon and decided by both the supplier and the customer in consideration of the risk and the benefit.

5.5.4 Operation

The filter must be properly maintained in order to allow detection of deficiencies in the fuel treatment before significant damage to the engine occurs. Cleaning of the filter elements should be carried out on a regular basis and with the correct equipment to avoid damaging the filter elements, gaskets and seals.

Frequent clogging of the filter (identified by a rapid increase of the differential pressure or by short intervals of the automatic cleaning cycles) can either be caused by Asphaltene coagulation or if significant amounts of inorganic matter is found, due to a deterioration in performance of the centrifuges. In either case immediate action is necessary.

5.6 Circulation Pumps

The comments in 5:4 supply pumps are also applicable to circulation pumps.
The specification of the circulation pumps must of course include the higher operating temperature in the high-pressure section of the fuel system.
The sizing of the circulation pumps has to meet the demand from the engine maker regarding pressure and flow rate.
The needed pressure varies from 3.5 to 10 bar and is typically from 5 to 9 bar. To maintain this pressure, a pressure control valve is installed in the re-circulation pipe between the engine and the mixing tube.
The circulation flow rate is typically 2.5 - 4 times the fuel consumption at MCR.

5.7 Heaters

5.7.1 Task

The Fuel control system (FCS) must provide flexibility for heating fuel oil to the required viscosity or temperature. It should have two heaters, one in operation and one on standby. The heaters have to be properly sized to specific requirements based on flow rate, oil temperature in the mixing tube and oil temperature to the engine. A margin for fouling should not be forgotten.

5.7.2 Design

Shell-and-tube heat exchangers (S&T) for either steam or thermal oil are the most common type of heater despite they are bulky and require significant service space.

Plate heat exchangers (PHE) offer a compact, lightweight solution suitable for steam heating. They are flexible and easy to modify by adding or removing plates, according to the specified duty. Narrow channels provide higher efficiency for heat transfer at high temperatures. Their small hold-up volumes enable quick response at changing load conditions.

Electric heaters (EH) provide an alternative to S&T and PHE for heating of all types of fuel oils.
When sizing EH’s much attention has to be paid not to over-load the electrical elements. Normally the specific load should not exceed 1 W/cm^2. Certain types of EH can be operated up to 2.5 W/cm^2,

The EH needs a power unit that feeds electrical power to the heater to ensure that the oil outlet temperature meets the preset parameter values of viscosity or temperature. The power unit should continuously supply variable power between zero and 100 percent, providing accurate control.

5.7.3 Position in the system

The heaters are positioned in the high-pressure section of the FCS after the circulation pumps.

5.8 Viscosity transmitters

5.8.1 Task

The task of the viscosity transmitter is to deliver a signal directly proportional to the viscosity of the fuel oil at the injection temperature and which is suitable for further control actions.
Viscosity is the best possible fluid parameter for control of the injection properties of the fuel.

5.8.2 Design

Viscosity transmitters in common use in FCS for diesel engines are of two different types, based on different physical principals – the capillary tube and the oscillating rod.

The capillary tube transmitter comprises a calibrated capillary tube, a positive displacement pump and a differential pressure transmitter.
Through the capillary tube oil is pumped at constant flow rate determined to give laminar conditions in the tube.
The differential pressure transmitter measures the pressure difference between the inlet and the outlet of the capillary tube. The pressure drop is directly proportional to the dynamic viscosity of the oil.
The accuracy is claimed to be better than 2 %.

The oscillating rod transmitters are all using a rod vibrating longitudinal or torsional.
The vibration is driven by a piezo-element.
This type of transmitters has no moving parts.
The measured signal is the damping effect from the viscous oil on the vibrating rod.
The damping effect is proportional to the viscosity. The accuracy is claimed to be in the range of 1.5 to 2.5 %.

5.8.3 Position in the system

The viscosity transmitter should be placed as close to the engine as possible. The recommended place for installation is immediately before the safety filter.

5.9 Homogenisers

5.9.1 Task

It is claimed that homogenisers reduce the size of agglomerates of Asphaltenes and thoroughly disperse them throughout the fuel. This is useful in cases where Asphaltene coagulation occurs, which can happen with unstable fuels or by blending incompatible fuels. Homogenising will create a fuel of uniform structure and

consistency and thus helps to prevent deposits in fuel injection equipment or clogging of filters.
If the chemical and physical conditions are such that precipitation of sludge is promoted, coagulation will generally continue after the homogeniser. Therefore the treated fuel must be used at once.

If water is present in the fuel this will be dispersed into a stable emulsion, despite fresh or saline water.

No manufacturer claims explicitly any effect on catalytic fines.

5.9.2 Design

The required treatment can be achieved by a combination of shear, turbulence, vibration and cavitation. There are several types of equipment in which one or more of these effects may be utilised, and some of them are roughly described below in the order in which the amount of energy exerted on the fuel increases.

5.9.2.1 Colloid mill

Homogenisers utilizing the principle of the colloid-mill (as used for paints) work with rotating toothed surfaces passing each other with a very small wedge-shaped clearance, through which the fuel passes from the widest to the narrowest part. The minimum clearance is in the order of 50 micron. They are claimed to break down agglomerated Asphaltenes to a size range between 2 and 20 micron.

5.9.2.2 Roller mill

Homogenisers with mechanical rollers running on a cylindrical wall. They are claimed to break down agglomerated Asphaltenes to some 5 micron or less.

5.9.2.3 Ultra sound homogeniser

Ultrasonic waves not only attack hydrocarbon agglomerates, but also their adhesion to metal surfaces. For the latter reason ultrasonic generators are installed in combination with a surface filter to keep the wire elements clean. To-date, this is their only application.

5.9.2.4 Jet homogeniser

Homogenisers forcing the fuel through a specially designed adjustable area orifice by means of an integrated high pressure pump. This type is claimed to break down coagulated Asphaltenes to very small particles. Water in the fuel is emulsified to droplets of about 1 micron.

5.9.3 Position in the system

Homogenisers perform the same function as emulsifiers, but in addition, they break down precipitated Asphaltenes. Homogenisers do not break down hard abrasives and therefore cannot replace centrifuges. No homogeniser supplier recommends fitting a homogeniser without a centrifugal separator in the system.

In very unstable fuels, the Asphaltenes precipitate very quickly, so the fine dispersion obtained by homogenising requires that the fuel be used immediately, before re-agglomeration occurs. Based on this requirement it can be installed in several possible positions in the treatment system but not before the separators.

5.9.3.1 Before the main filter

The most appropriate position for the homogeniser is before the main filter, so that it prevents clogging due to coagulating Asphaltenes in the main filter, the safety filter and the engine. This is only valid if the residence time of the fuel between the homogeniser and the engine is short, regardless if the main filter is installed on the low-pressure side or the high-pressure side. In view of the required throughput, the homogeniser could be placed before the fuel conditioning system but after the service tank or after the supply pumps but before the main filter and the mixing tube.
Mild homogenisers are certainly sufficient when filters with a nominal mesh size of 25 micron are installed. When smaller mesh sizes (nominal 10 or even 5 micron) are installed, mild homogenisers will probably be adequate, but the use of a strong homogeniser may give the best conditions for reducing the risk of filter blockage.

5.9.3.2 Before the safety filter

Another useful position for a homogeniser is before the safety filter. Without this provision, experience has shown that the mesh size of the safety filter should be clearly larger than that of the main filter to avoid clogging due to precipitated Asphaltenes built up in the high-pressure side.
By breaking down these conglomerates, a smaller mesh size can be applied in the safety filter, about similar to that of the main filter.
This would lead to a better protection of the engine against hard abrasives, which is particularly useful in installations where the main filter is installed on the low-pressure side, making the safety filter more important.

5.9.3.3 Homogenisers before the centrifuges

Recently, some homogeniser manufacturers have suggested that a homogeniser should be installed upstream the fuel cleaning system.
The result of doing so is claimed to be a reduction of the amount of sludge from the centrifuges to a minimum. The potential reduction is typically in the magnitude below 0,1 % of the fuel consumption.

The practice is that fuel is ordered from an oil company according to the ISO 8217 standard or the CIMAC Recommendation No. 21. This practice depends on the assumption that the centrifuge works at an optimum and delivers clean oil with a quality suitable for injection to the engine. The three major centrifuge manufacturers have an obligation to secure optimal cleaning.

The reason why the centrifuge manufacturers strongly advise against the above idea is that such a system configuration may lead to a low separation efficiency of both water and particles.

- Both freshwater and seawater will be emulsified; i.e. the water droplets will be too small to be removed by centrifugal separation.
- Some contamination particles like catalytic fines are hydrophilic. The particles will then create non-separable aggregates together with emulsified water. This state is also valid for low water levels.
- Samples that have been received from installations using homogenisers support the above statements. In the cleaned fuel, the content of Water, Sodium, Aluminium, and Silicon are generally higher with the homogeniser in operation than without.
  In tested cases, the cleaning system has not been able to bring down the contamination level. This is due to the homogenising effect. As a reference, the untreated bunker has been tested with a spin test in order to simulate the effect as if the oil had been treated in a separator without homogenising.
- Samples analysed show that the loss of separation efficiency cannot be compensated for by the use of 10-micron fine filters.

6 SLUDGE TREATMENT SYSTEM

6.1 Task

The sludge treatment system shall reduce the amount of sludge to a minimum by removing as much water as possible and recover all useful oil for further use. Remaining concentrated sludge to be sent ashore.

6.2 Amount of sludge

About 1 - 1.5% percentage of the fuel consumption will be discharged as sludge. The fuel separators and automatic self-cleaning fuel filters will produce the oily sludge.

6.3 Composition of sludge

The sludge will consist of 40-90 % water with soluble salts, fuel oil, 1-4 % abrasive solids, Asphaltenes, etc.
The volume of fuel oil reporting to the sludge tank is in the normal case a minor part of the total volume of sludge.

6.4 Design

The sludge can be treated by using a sludge separator or by using a decanter centrifuge.

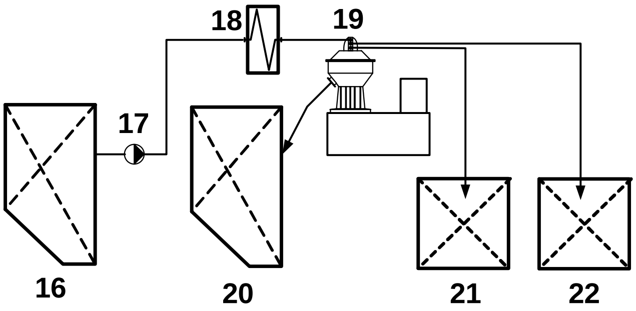
6.4.1 Sludge Separator

The system consists of:

- Feed pump
- Heater
- Centrifugal separator of concentrator type with separate outlets for oil, water and concentrated sludge and solids
- An automatic control unit
- Concentrated sludge tank
- Recovered oil tank
- Bilge water tank

Sludge is pumped from the separator sludge tank via the heater to the sludge separator.
The separation temperature should be kept at 95 deg C to maintain high separation efficiency.
As an option to enhance performance of the system it is possible to inject a

demulsifier before the feed pump.
Normal dosing rate of the demulsifier could be in the order of 250 to 500 ppm.
Fig. 6:1 below gives an example of the installation.



Legend

16. Sludge tank
17. Separator feed pump
18. Separator pre-heater
19. Sludge separator
20. Concentrated sludge tank
21. Recovered oil tank
22. Bilge water tank

Figure 6:1 Oil recovery and sludge treatment system

6.4.2 Decanter centrifuge

The system consists of (see fig. 6:2):

- Sludge tank with oil skimmer unit
- Feed pump
- Chemical dosing unit
- Treatment/settling tank with heater facilities
- Bilge water tank
- Decanter centrifuge. The decanter separates the dewatered sludge in super sludge/solid, and clarified oil
- An automatic control unit
- Super sludge reservoir

The decanter is specially designed for removal of solid matter from the oily sludge. Sludge is pumped from the sludge tank via the skimmer unit to the treatment/settling tank where the sludge will be heated to about 50 deg C. After 24 hours the water is to be drained to the bilge water tank. As an option to enhance water settling it is possible to inject a demulsifier before the treatment/settling tank.
The dewatered sludge is transferred to the decanter. The decanter rotates at a speed of about 3,000 rpm, resulting in a centrifugal force of approximately 2,000 g. The centrifugal force causes solid matter (super sludge) to be deposited on the inside wall of the rotating cylinder, where it is propelled by a conical conveyor screw to the discharge ports, and from here to the super sludge reservoir. The media temperature in the decanter will be 50-80 deg C. Super sludge part of the oily sludge will be 2-4

%. The super sludge is to be taken ashore.

From the other end of the decanter the clarified oil will be transferred to the oil fired boiler for burning.

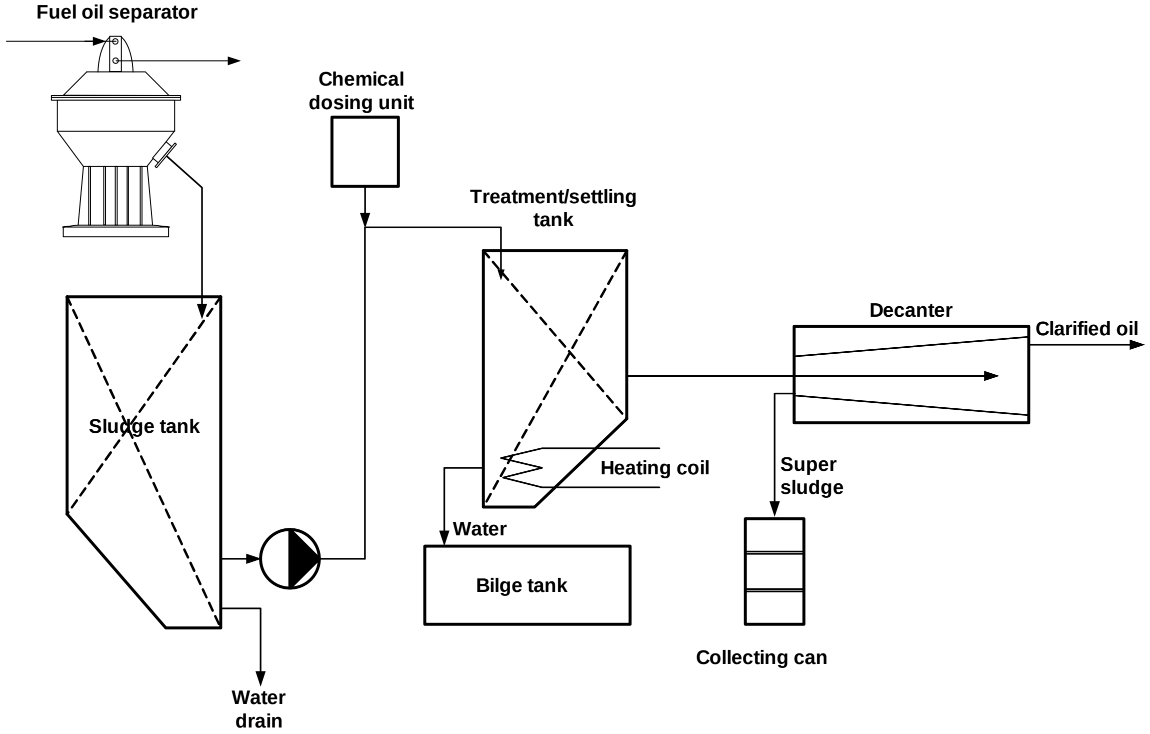


Figure 6:2 Decanter system for sludge treatment

7 CHEMICAL FUEL TREATMENT

Modern diesel engines operating on CIMAC Recommendation Regarding Requirement for Heavy Fuel for Diesel Engines (CIMAC Volume 21, 2003) or ISO 8217 specification class fuel and treated properly in the on board physical/mechanical treatment plant, do not usually need chemical fuel oil treatment to perform satisfactorily.

7.1 Need for chemical treatment

Fuel additives are used in most commercial distillate fuels today ranging from aviation fuel to petrol and gas oil. Residual fuel as bunkered is not fit for use in an engine without first being cleaned and mechanically treated, otherwise operational problems may occur, which might lead to catastrophic failure of the engine. Careful handling, cleaning and conditioning with the on board equipment described in this CIMAC document can solve or alleviate many of the potential problems.

However, operating engines on residual fuel can sometimes be made difficult by fuel-instability and/or incompatibility, high temperature corrosion, deposit formation etc. Such problems may be reduced by the proper use of a chemical additive. In general, older engines are more sensitive to fuel problems than modern ones and - with regard to ignition and combustion properties - medium speed engines are more sensitive than slow speed engines.

Residual fuel additives are often called "fuel oil treatments". This could be misleading and must not be interpreted in a way suggesting that chemical fuel oil treatment can replace or partly replace the on board treatment plant.

Unlike the distilled products, which are blended to uniform formulations, residual fuels have varying properties and can be an unfinished product when it leaves the refinery. While it is possible and common practice to treat the commercial distillates with additives in the refinery or by the supplier, this is not so with residual fuel. Here it is the end user who decides whether he wants to treat his bunker chemically or not, and if so, it is he who adds the treatment products to the fuel.

Additives are used to maximize the engine-, turbine- and boiler performance and to a certain degree increase fuel efficiency, or to prevent specific problems. The additives used for residual fuel could roughly be divided in three categories:

- additives for pre-combustion application
- additives for combustion application
- additives for post-combustion application

7.1.1 Pre-combustion additives

Pre-combustion additives are usually Asphaltene dispersants/stabilizers that are dosed into the fuel as early as possible to prevent fuel-handling problems.
An Asphaltene dispersant/stabilizer inhibits or strongly reduces the risk of instability of the fuel and agglomeration of Asphaltenes that precipitate and form sludge in bottom of tanks and/or overload centrifugal separators and filters.

Asphaltenes naturally exist in a crude oil as electro statically charged micelles stabilized by natural resins. Refinery processes change the structure of the natural resins and can reduce their natural ability to act as Asphaltene dispersants. Additionally dilution of a residual fuel with a paraffinic type cutter stock to obtain the required viscosity can lead to instability and incompatibility (See sec.2.2.3).

Asphaltene dispersant/stabilizers have the same affinity for the polar Asphaltene molecule as the natural resins, and thereby maintain stability/compatibility of the fuel. Certain pre-combustion additives are also extremely oil soluble and solubilize Asphaltenes into the fuel oil by reducing the surface tension of the Asphaltene molecules, while they at the same time increase the interfacial tension between the oil and the water, thus acting as emulsion breaker as well.

Other pre-combustion additives that will improve and facilitate fuel handling are emulsion breakers (demulsifiers) and biocides. The use of emulsion breakers enhances separation of excess water in settling tanks and lowers the load on the centrifugal separators. Biocides are more commonly used in distillate fuels where microbiological infection is a well-known phenomenon. Standard dip slide test methods can be used to test for infections.

7.1.2 Combustion improving additives

Combustion catalysts or combustion improvers are used to maximize fuel utilization during combustion and to avoid or minimize unburned carbon.

A combustion catalyst is an oil soluble organo-metallic compound that contains Fe, Ce, Ba, Ca and/or others metals.

Large molecules like Asphaltenes, but also smaller aromatic molecules with high C/H ratio present in the residual oil and in the cutter stock, which are stable and slow-burning constituents, reduce the burnability of the fuel. The intended function of a combustion catalyst/improver is to accelerate the main combustion by lowering the energy level needed for complete carbon burnout but also to form radicals that enhance complete combustion. Combustion catalysts also lead to cleaner and more effective turbochargers and they limit negative effect of soot deposits the exhaust system.

7.1.3 Post-combustion additives

Post-combustion additives are mainly used to:

- inhibit or reduce hot corrosion related to the fuel's V/Na content
- minimize cold corrosion related to sulphur content in the fuel
- reduce soot derived from incomplete combustion.

Additives used to minimize hot corrosion are usually organo-metallic compounds such Mg, Ca and Si which will increase the melting/stiction temperature of ashes containing vanadium, sodium and other metals. By increasing the melting/stiction temperature of these very aggressive ashes, they will remain in a solid state and are expelled from the engine with the exhaust gases avoiding deposit build up and hot corrosion on exhaust valves and turbochargers. Mg and Ca, used in fuel additives, will also to a certain extent neutralize sulphuric acid to minimize cold corrosion.

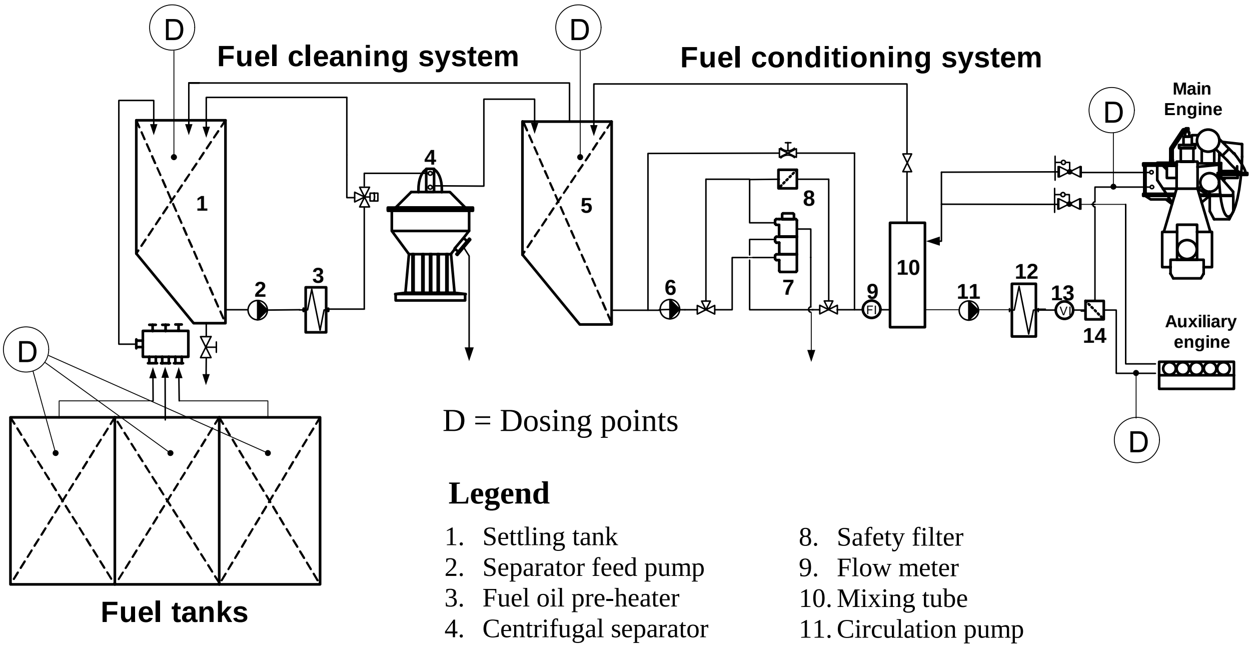
7.2 When is chemical treatment necessary

Fuel oil should be treated chemically only when necessary. The fuel supplier provides a fuel specification. There also is a variety of on-board fuel test kits on the market. Once the fuel properties are known it becomes evident what can be expected during the consumption of the fuel and if one or more parameters are out of specification or at a border limit, it may be of advantage to dose an additive.

Fuel oil additives should be dosed into the fuel at different locations according to type and application (See figure 7:1)

For good distribution into the fuel they should be dosed proportional and at a dosage rate as required by the severity of the respective problem. Some additives are best dosed into the storage tanks or into the settling tank during transfer, while others can be metered into the booster line.

Engine manufacturers' possible restrictions should be taken into account in case fuel additives are planned to be used, especially during the warranty period of engines.



D = Dosing points

Legend

1. Settling tank
2. Separator feed pump
3. Fuel oil pre-heater
4. Centrifugal separator
5. Service tank
6. Fuel oil supply pumps
7. Main filter
8. Safety filter
9. Flow meter
10. Mixing tube
11. Circulation pump
12. Heater
13. Viscosity transmitter
14. Safety filter

Figure 7:1 Locations suitable for dosing of additives of different application

8 SAMPLING

8.1 Sampling of fuel as bunkered

Drawing a truly representative sample from a fuel oil delivery is not an easy task. In theory this is best achieved using an automatic flow-proportional sampler to draw a sample throughout the entire bunkering, but the cost of these devices and the careful maintenance required, preclude their routine use in the bunker industry. The most commonly used alternative is the manual continuous-drip sampler fitted to the bunker line where this is carrying the full flow of oil, i.e. not in a bypass leg or in a dead-leg in the pipe work. It is important that the sampler extracts fuel from across the full pipe diameter, not just from the side wall or the top/bottom of the pipe line.

Careful design of the sampling location is important. The flange to which a sampler is to be connected should lie in a vertical plane, and should have adequate space around it to install a sampler and to allow easy access and coupling for the delivery hose. It must have adequate space to allow a drip-tray to be placed under the sampler, and therefore should not be placed too close to the ship/barge rail. Figure 8:1 shows a photograph of an ideal arrangement of a ship’s bunker manifold; Figures 8:2 – 8:3 show examples where the location or design of the bunker manifold would prevent a drip sampler being installed in a safe manner.

Figure 8:1 Proper drip sampling

Figure 8:2 Bunker manifold unsuitable for sampling

Figure 8:3 Bunker connection too close to rail

However contractual or commercial agreements or even governmental regulations may require that samples be taken in a specific position. In such cases it is important that the parties involved prior to the bunkering, in order to identify and agree on the correct sampling position, have clarified these conditions. Some examples are discussed below.

From a purely practical point of view, the choice of location of the sampler is governed by several considerations. Either end of the bunker hose may be suitable, in order to meet the criterion of “seeing” the full fuel flow. The version of the ISO Technical Report (TR13739) current at the time of writing specifies that the sampler can be fitted at either end of the delivery hose, the exact location to be agreed contractually between the parties.

As noted above, in some jurisdictions the sampling location is specified in local regulations. Supplier’s Terms sometimes specify that samples should be drawn on the bunker barge. The sampling guidelines of IMO’s 1997 Protocol to MARPOL Annex VI, require that provided practicable a regulatory sample is taken at the ship’s manifold, to demonstrate compliance with the requirements specified in Annex VI. These include fuel quality requirements and limitations on the sulphur content of the fuel oil. Finally, many commercial contracts specify the exact location of custody transfer, and it is sometimes inferred that samples must be drawn at this same location. The technical justification, and the legal precision, does however cause some discussion.

In Singapore the receiving ship’s end of the delivery hose is the location specified in the mandatory Code of Practice CP60, unless physical limitations at the bunker manifold of the receiving vessel make sampling at that point impossible. In such cases the samples should be taken at the bunker barge. A few other ports are implementing their own procedures based on Singapore’s CP60. Often contractual terms will specify a sample location, e.g. BIMCO’s latest Standard Terms specify a location “mutually agreed ….., closest to the receiving Vessel’s bunker manifold”.

Given the varying and sometimes conflicting requirements, and in the absence of an unambiguous legal obligation the choice should generally be made taking into account the following:

- the location of suitable well-maintained sampling equipment;
- safety considerations, particularly concerning the need for personnel to transfer between vessels;
- the ability to implement effective spill prevention measures around the sampler;
- the convenience for all parties, and the visibility and transparency of the sampling process to achieve a single, representative sample of the fuel actually delivered to the vessel that is accepted by the parties involved.

In general, most laboratories wish to see a sample size of approximately half to one litre to cater for the full suite of tests, plus some fuel specimen left for re-test if necessary. A sample of 4 – 5 litres will therefore need to be drawn, to allow it to be subdivided among the three or four parties (owner, charterer, supplier, and surveyor) with an interest in the delivery. Note that the mandatory sample under MARPOL Annex VI (for which a minimum amount of 400 ml is required) must be retained on board until the fuel has been substantially consumed, but in any case not less than one year from the date of delivery. This is to facilitate inspection by the relevant authorities such as Port State Control, and the said sample will not be available for general routine quality monitoring. However, provided 4 – 5 litres of sample is drawn at the ship's manifold, there should be sufficient to provide separate sub-samples to meet the requirements of both MARPOL Annex VI and routine quality monitoring.

The sub-division must be carried out with care so that the individual sub-samples remain representative of the original sample taken. Before sub-division, the 4 - 5 litres sample should be thoroughly shaken and then be poured into the individual 1 litre sample containers, making 3 or 4 passes to fill each container in turn.

Finally it should be noted that before starting a bunker transfer operation and sampling process, proper precautions should be taken to prevent oil spill and risk to personnel.

8.2 Sampling of fuel before and after treatment

In addition to the sample taken during the delivery, it is strongly recommended that samples of the treated fuel are taken at regular intervals (at least twice a year), or when using fuels for which the analysis results obtained on the delivery sample indicate special care is needed. The analysis results of these samples should verify that the fuel entering the engine has been properly cleaned, and that the levels of water and catalyst fines are reduced to an acceptable level according to the engine manufacturers' specifications.

Early detection of a possible relationship between abnormal engine behaviour, wear or damage, and the fuel quality at the engine inlet is critical. The lack of this kind of information has often delayed the understanding that might have led to corrective measurements being taken. Hence, the ships crew should be instructed to take notes and log any observed deviations from normal operation of engines or treatment plant, and check any possible link to the quality of the fuel being used.

The fuel treatment system should be provided with sampling cocks located in convenient positions e.g. at the transfer pump from the bunker tanks, before and after the centrifuges and after the service tank. Please see the below figure (8:4) for guidance. The sampling procedures and instructions should be made as simple as possible in order to encourage regular sampling.

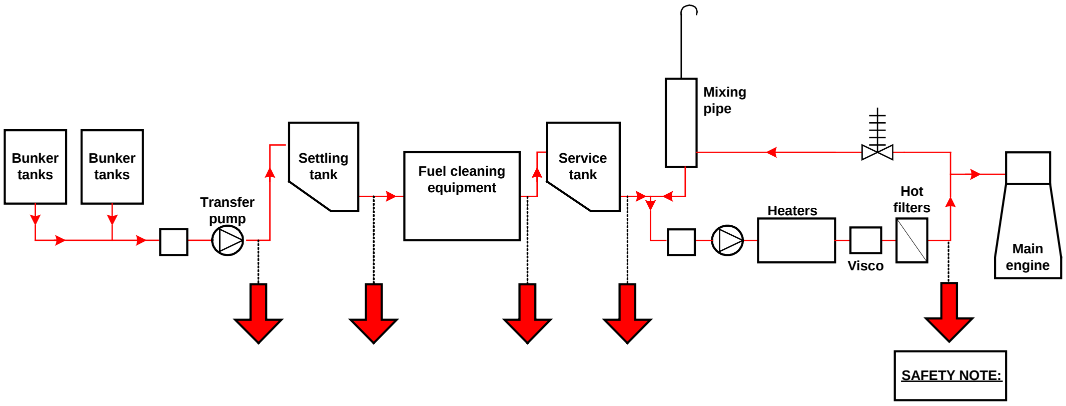


Figure 8:4: Fuel treatment system and sampling positions

Safety Note: For safety reasons it is not recommended to take samples from the booster system. Safety precautions should be observed if such samples nevertheless are to be drawn because the fuel at this point has an elevated temperature (130-145 °C) and is kept under a relatively high pressure (5-8 bar).

When samples are being taken before and after the centrifuges, the conditions should be allowed to stabilize after adjustments have been made to e.g. the oil flow rate, before drawing samples. The before/after centrifuges samples should preferably be taken at the same point in time. Time for sampling should be the discharge interval, divided by two. For instance, if discharge interval is set to two hours, the samples should be taken one hour after discharge. First the centrifuge inlet sample is taken, and immediately after that, the centrifuge clean oil outlet sample.

Fuel samples taken at the transfer pump between a bunker tank and the settling tank, or between bunker tanks during circulation of oil, should be drawn as a continuous drip sample over a period of time sufficient for ascertaining that the sample is representative of the oil being pumped through the system. This may require that the sample is taken over the whole period for transfer of the entire tank contents.
The transfer pump should be operated for a time period sufficient to ensure fuel from the relevant bunker tank is being sampled.

8.3 Tank Samples

Tank samples may be drawn to:

1) Establish the quality of the fuel oil in the various tanks or
2) To assess the system performance when examined in conjunction with other samples from further down the treatment chain.

Such samples can be taken in different ways depending on the access to the tanks and the equipment available.

Some preferred procedures for obtaining representative samples (in order of priority) are:

- a sample taken via the tank top or manhole as either a composite sample by combining spot samples taken at different levels in the tank (zone sampler) e.g. top, middle, and lower; or
- a continuous running sample whilst the sampling vessel is being lowered or raised through the bulk of the oil; or
- a spot sample taken at a given sampling position/sampling cock; or
- a transfer sample taken during circulation of the oil between tanks (for which see figure 8:4)

Note: Samples drawn from a sampling cock or drain cock near the bottom of a static tank are almost certain to be non-representative of the tank contents, due to the accumulation of water and sediment near the bottom of the tank.

8.4 Sampling Devices

An example of a recommended device for continuous sampling of fuel during bunkering or transfer is shown in Fig. 8:5 below:

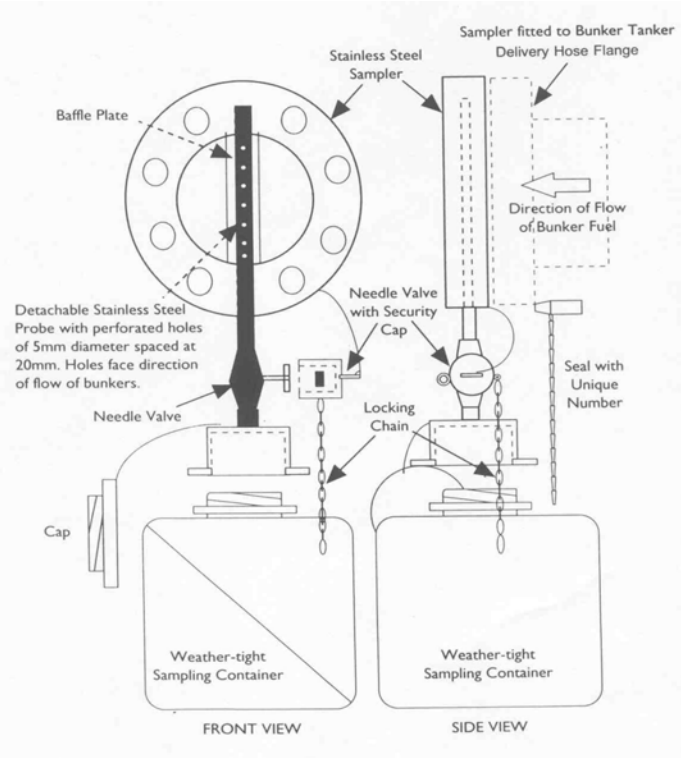


Figure 8:5 Recommended sampling device (Source: Singapore CP 60 Code of Practice for Bunkering by Bunker Barges/Tankers)

ACKNOWLEDGEMENT
By endorsing this document, CIMAC acknowledges the work accomplished by the CIMAC Working Group "Heavy Fuels" through its worldwide membership.

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No. 5 Recommendations for Supercharged Diesel Engines, 1971
Part I: Engine De-rating on Account of Ambient Conditions
Part II: Engine Acceptance Tests

No. 6 Lexicon on Combustion Engines, Technical Terms of the IC Engine and Gas Turbine Industries, 1977

No. 7 Recommendations regarding Liability - Assured Properties, Publications and Fuels for Diesel Engines, 1985

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No. 13 Guidelines for the Lubrication of Medium Speed Diesel Engines, 1994

No. 14 Standard Method for the Determination of Structure Borne Noise from Engines, 1994

No. 15 Guidelines for the Lubrication of two-stroke Crosshead Diesel Engines, 1997

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