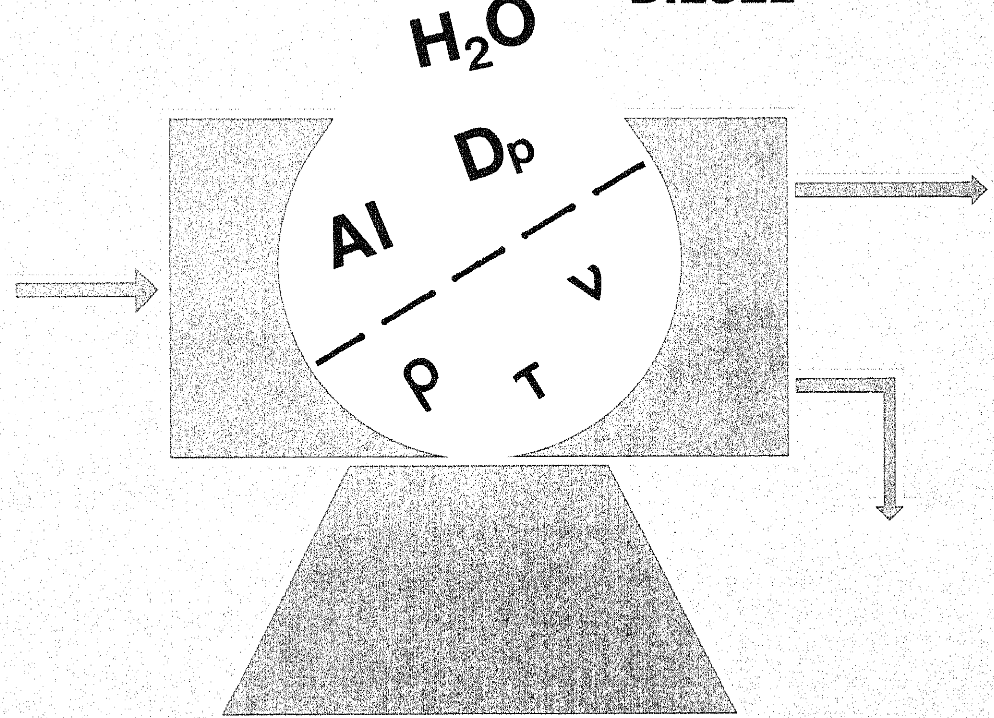
CONSEIL INTERNATIONAL
DES MACHINES A COMBUSTION

INTERNATIONAL COUNCIL
ON COMBUSTION ENGINES

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

RECOMMANDATIONS CONCERNANT LES PROJETS D'INSTALLATIONS DE TRAITEMENT DES FIOULS LOURDS POUR LES MOTEURS DIESEL



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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 universities, research institutes, component suppliers, fuel and lubricating oil suppliers and several other interested parties.

The National Member Associations are listed on page 2 of this publication.

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This document has been elaborated by the Working Group "Future Fuels" and approved by the Permanent Commitee on December 7th 1987.

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Most of the actual work for the Recommendation has been done by the following participants

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Foreword of the President

In the range of fuel-oriented activities, Mr. Wesselo proposed to the permanent committee meeting in June 1983 to start a Cimac Working Group on heavy fuel matters in general.

This working group "Heavy Fuels" worked in parallel with the working group future fuels, chairman Dr. Syassen, which produced in 1985 the "Recommendation for heavy fuel requirements". Already soon, the most important subject was found to be the treatment of heavy fuel.

The activities of the working group were energetic and effective, and altogether 16 international meetings were held.
During 1985 experts from suppliers of equipment such as separators, filters and homogenisers were invited and in 1986, experts on system-engineering were involved. Thus, together with the diesel engine manufacturers and the oil companies, already represented in the group, condensed opinions of all parties involved could be obtained.

The contents of the recommendation are very useful and practical for diesel engine users, engine manufacturers, equipment suppliers and, of course, fuel suppliers.

I believe that the recommendations will be accepted and appreciated all over the world.

Avant propos du President

Dans la succession des études menées par les groupes de travail du CIMAC sur les combustibles lourds pour Moteurs Diesel, Mr. WESSELO a annoncé, lors de la réunion du Comité Permanent de Juin 1983, la mise en place sous sa direction d'un nouveau groupe consacré aux problèmes généraux sur les combustibles lourds.

Ce groupe a fonctionné en parallèle avec celui du Dr. SYASSEN sur les nouveaux combustibles, lequel a publié en 1985 une recommandation sur les «Exigences pour les combustibles lourds». Rapidement le problème du traitement des combustibles lourds est apparu être le sujet le plus important.

Les activités du groupe ont été menées avec énergie et efficacité au prix de 16 réunions internationales.

En 1985 des experts appartenant au domaine de la fabrication des équipements tels que séparateurs, filtres, homogénéiseurs ont été invités à collaborer et en 1986 également des spécialistes des systèmes de traitement. C'est ainsi qu'avec les constructeurs de moteurs et les compagnies pétrolières, déjà représentés au sein du groupe, a pu être obtenu en concensus total entre les parties intéressées.

Le contenu de la présente Recommendation est d'une indiscutable utilité pratique pour les utilisateurs et les constructeurs de moteurs Diesel ainsi que pour les fournisseurs d'équipements et, bien entendu, les fournisseurs de combustibles.

Je suis persuadé qu'elle sera universellement appréciée.

SCOPE

This recommendation presents some guidelines for the design of a modern fuel oil treatment plant for marine and land based installations and some suggestions for its use.

A considerable amount of experience has been obtained with conventional fuel treatment plant and these guidelines describe such installations. However recent changes in fuel quality have adversely affected the performance of conventional plant and so possible modifications and changes which can redress these adverse effects are discussed. These changes present a considerable number of options and the final choice of plant layout can only be made after consultation between future owner, shipyard or contractor, engine manufacturer and equipment supplier.

These guidelines do not contain full technical details necessary for the detail design of a treatment plant and so do not replace either the engine manufacturer or the equipment suppliers' instructions. Their purpose is to promote a clear understanding of the concept design of a fuel treatment plant. Installations have always to comply with the rules of classification societies and with legislative requirements as far as applicable.

As the ideas about heavy fuel treatment are changing continuously, this Recommendation should be considered as a stimulant for further discussions about fuel treatment. The Working Group will be glad to exchange ideas about further developments with those who are interested. As soon as appropriate, CIMAC will publish addenda or a revised edition.

DOMAINE D'APPLICATION

Cette recommandation présente quelques orientations pour l'étude d'une installation moderne de traitement du combustible lourd pour les applications marines ou terrestres ainsi que quelques suggestions pour leur utilisation.

Une quantité considérable d'expérience a été obtenue avec des installations conventionnelles de traitement des fiouls et ces orientations décrivent de tels systèmes. Pourtant, de récents changements dans la qualité des fiouls ont dégradé les performances des installations conventionnelles. Les adaptations possibles qui peuvent redresser les effets néfastes sont présentées. Ces modifications présentent un nombre certain d'options et le choix final de l'installation ne peut être fait qu'après consultation entre le futur utilisateur, le chantier ou l'entrepreneur, le constructeur du moteur et le fournisseur de l'équipement.

Ces orientations ne contiennent pas tous les détails techniques d'une installation de traitement et ne remplacent donc pas les instructions du constructeur du moteur ou du fournisseur de l'équipement. Leur usage est de promouvoir une compréhension claire des concepts de dessin d'une unité de traitement des fiouls. Bien sûr, les installations doivent toujours se conformer aux règles des sociétés de classification et avec les exigences législatives aussi loin qu'elles sont applicables.

Comme les idées sur les traitements des fiouls lourds ne sont pas figées, ces recommandations devront être considérées comme un stimulant pour des discussions futures sur le traitement des fiouls. Le Groupe de Travail sera heureux d'échanger des idées concernant de prochains développements avec ceux qui sont intéressés. Aussitôt que cela sera utile, CIMAC publiera des annexes ou une édition révisée.

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CONTENU

1. FUEL PROPERTIES

1.1. Relationships between fuel properties and system requirements

There are three groups of fuel characteristics:

1) properties that are significant for the correct functioning of the engine, but which are not influenced by the installation (like Conradson Carbon Residue level, Sulphur and Vanadium content)
2) properties that are significant for the correct functioning of the engine, and are influenced by the fuel treatment installation (like salt water content and solid/abrasive content)
3) properties that are not significant for the engine, but only for the treatment installation itself (like viscosity, density, stability and/or compatibility of fuels, pour point and flash point)

The purpose of the treatment system is to reduce the level of contaminants listed in group 2) to such a level that problems with the engine do not occur.

At the same time, problems with the fuel treatment system caused by the properties listed in group 3) should be avoided. It is therefore of interest to review the fuel properties of groups 2) and 3).

1.2. Fuel properties after treatment

The properties of group 2) are of interest because they define the task of the treatment plant. Attempts have therefore been made to obtain an agreement between engine manufacturers about the allowed fuel properties before the engine. These attempts, due to lack of a sufficient number of measurements of fuel quality after treatment, have not yet led to a general result.

It is therefore strongly recommended to arrange for **fuel sampling after treatment** (see also chapter 10 : Sampling) and to collect and analyse these samples regularly during operation. By combining this with a regular check on the operational results, the collection of this data would help to improve the understanding of the interaction of fuel properties and engine behaviour.
The samples could be regularly analysed or be retained and analysed only when irregularities in engine operation have been recorded.

As yet there is no agreement on the required fuel properties before the engine, so no standards can be set.

Accepting the above limitations, an attempt was made to establish some realistic figures for fuel quality **after treatment.** The results are:

For **catalyst fines** most engine manufacturers guidelines come close to 5 – 10 ppm, expressed as Aluminium-content.
It should be noted that these figures are based on experience with centrifuged fuel and so are only valid if the majority of the remaining particles are small, e. g. 3 μm or less.

The use of the Aluminium-content is relatively simple and has been very helpful, but the accuracy is very limited due to the fact that the ratio between Aluminium and total catalytic fine content varies widely (mostly between 3 and 8, exceptionally even more). Therefore work is at hand to obtain a better way of specifying catalytic fines.

The most probable method will be to determine both Aluminium and Silicon and than to calculate the total catalyst fine content, with the disadvantage that Silicon can also be present in less harmful forms. Another way could be to use a centrifuge method which determines the total content of inorganic particles excluding iron compounds. Even then, the abrasiveness of possible catalyst fines remains an unknown factor. As yet, no decisions have been taken to abandon the Aluminium-based method in favour of an alternative method.

A preliminary figure for inorganic particle content may be of the order of 25 – 50 ppm (again if the particles are small), but this has still to be proved by more information from service.

Due to the properties (density and viscosity) and composition of modern fuels, water shedding characteristics may result in levels of up to 0.5 % **water** after treatment. According to experience up to about 0.5 % seawater, corresponding with 75 ppm Sodium, will not lead to undue turbocharger fouling. Regarding possible corrosion of fuel injection equipment, a limit of 0.2 % would be preferred, but a somewhat higher content may be acceptable for short periods if the seawater is in the fuel as a fine emulsion.

1.3. Fuel properties to be coped with by the installation

The properties of group 3) are of interest for the installation itself.
As long as the **density** ist not higher than 991 kg/m³ at 15 °C the "conventional" system of purifier and clarifier in series can be used. Above this value new treatment methods will be necessary.

For a limited increase (1010 kg/m³) alternative designs of centrifuges are already available, but a large increase in the fuel density could lead to the situation where the removal of the seawater by centrifuging is no longer possible.
However, it is likely that this situation will only occur sporadically in the next few years.

More and more problems occur due to insufficient **stability** and/or **incompatibility.** These terms are often used without much distinction as both concern the increase of sediment, mainly by coagulation of asphaltenes.
If a fuel is **unstable** the amount of sediment increases with time and temperature to a value determined by the degree of instability. Two fuels are **incompatible** if the fuels, each of which may be

stable by itself, when mixed, give an unstable blend. Large amounts of sediment may then precipitate in bunker tanks and settling tanks and the amount of sludge can make it practically impossible to operate the centrifuges.

Reputable fuel suppliers take care that the fuel stability is sufficient to avoid excess sludge formation, and such suppliers will confirm that they take responsibility for the stability of fuel by supplying according to CIMAC Heavy Fuel Requirements. Agreed laboratory methods to define stability are still under development and therefore international standards do not yet give a formal protection. On board testing cannot generally be done before bunkering, so with respect to adequate stability, the engine operator greatly depends on the fuel quality supplied.

The **modified** ASTMD 2781 spot test can be used to give an approximate indication of possible incompatibility. In this test, the fuel or the blend (in the correct proportions) and the filter paper are heated to 70 °C. If the rating is above 2, then the fuel will not be satisfactory as a fuel for diesel engines.
Recently, instruments have become available which are capable of automating this procedure. This makes the spot testing quicker, cheaper and more reliable. Spot testing can be used for mixtures of heavy fuels as well as for blends of heavy fuel and marine diesel fuels.

Compatibility problems can be avoided to a great extent by designing the fuel system in such a way that different fuel supplies are kept separate in bunkers as well as in the treatment installation. The best possible measures to be taken are discussed in chapter 3: "Tanks".

2. GENERAL LAYOUT OF THE SYSTEM

The guidelines begin with the presentation of two possible layout schemes, although some of the arguments for certain choices will be presented in chapters about particular components of the system.

The **first scheme (Fig. 1, page 8)** presents a system with the following features:

- A transfer pump with automatic control to keep the settling tank full.
- A settling tank.
- Feed pumps arranged to adjust the fuel flow to the separator to the wanted rate.
- A modern separator without gravity disc and a spare separator which is normally in use, both separators running in parallel.
  (Piping allowing parallel or individual operation).
- A circulating line for excess separated fuel from the service tank to the settling tank, entering well above the maximum fuel level in order to avoid recirculation in the wrong direction under all circumstances.
- A daily service tank.
- Means are provided to pump back the fuel from the above part of the system in any one of the main bunkers.
- Means are provided to recentrifuge fuel from the daily service tanks.
- A pressurised booster system.
- An automatic self cleaning fine filter as main filter (more positions are possible, see chapter 8).
- A safety filter fitted directly before the engine.
- Though not part of the treatment plant the application of several separate main bunker tanks is strongly recommended.
- It is recommended to make provisions for a metered supply of fuel additives. For the addition of some possible additives a position before the settling tank could be adequate. Because there is no common opinion which additives would be useful no definite views can be presented and the connection is not shown in the diagrams.

The **second scheme (Fig. 2, page 9)** presents a system with the following additions to the system of the first scheme:

- Double settling and daily service tanks to enable fuels to be kept separate as long as possible.
- An arrangement combining one settling and one daily service tank for one fuel and another set of tanks for another fuel to avoid the confusion that could arise due to the complication of the system.
- All four switch-over valves that have to be operated when switching from one set of tanks to the other one are arranged to be operated simultaneously.
- In this case the main filter is located after the booster pump and before the circulating system, according to the ideas developed in 8.3. The choice of this filter location is independant of the choice between single or double tanks

It should be emphasised that both schemes are to be considered as examples only. Some considerations regarding the choice are given in section 3.4. Several additional variations are discussed in the other chapters.

The **third scheme (Fig. 3, page 10)** shows a possible layout for Marine Diesel Oil (MDO) treatment. Though not subject of this Recommendation it is presented because its inclusion completes the fuel treatment system. The layout is partly similar to the single tank heavy fuel system, but only a single centrifugal separator is used. Application of a heater is not always necessary, it is therefore drawn in dotted lines.

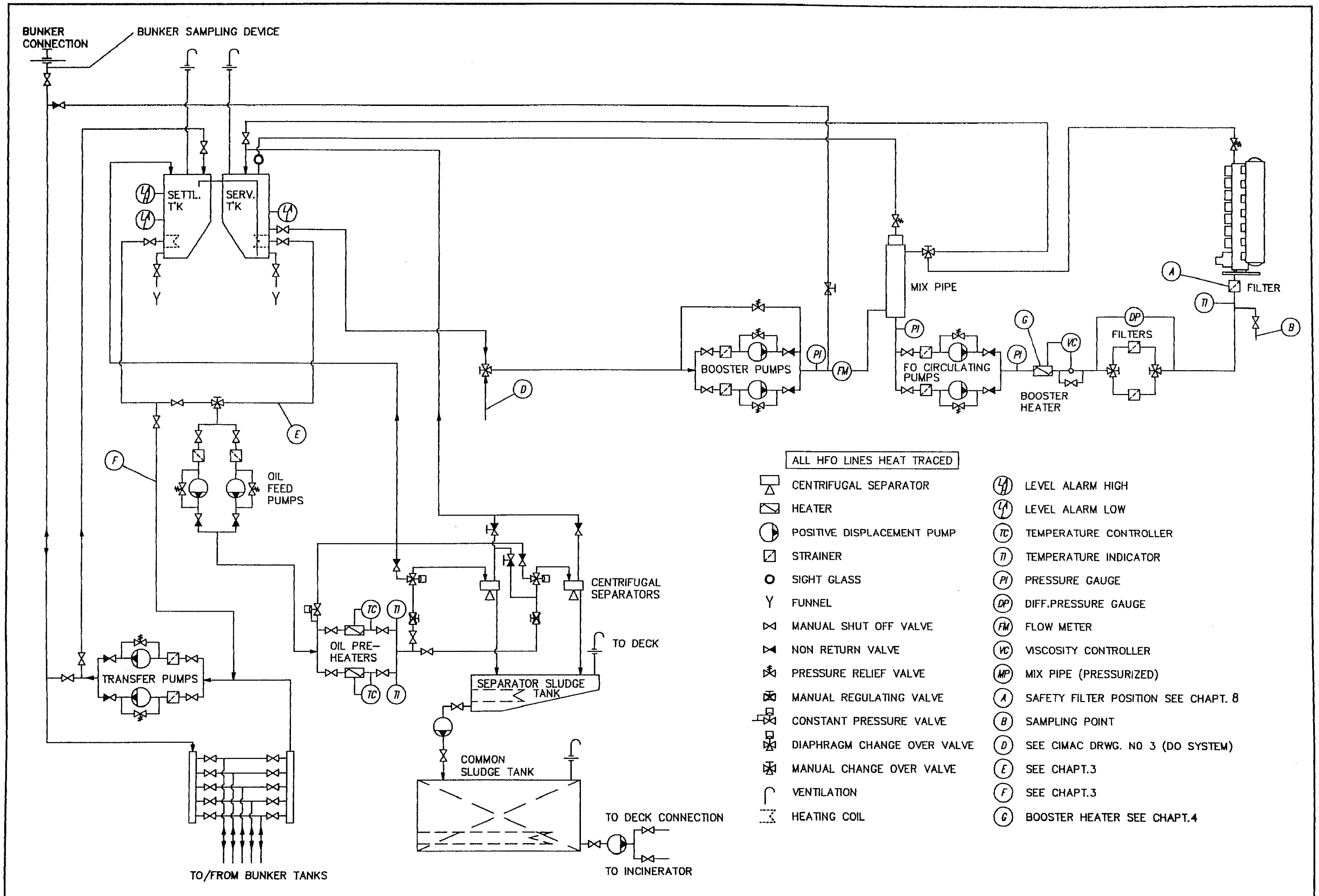


Fig. 1: SINGLE TANK SYSTEM

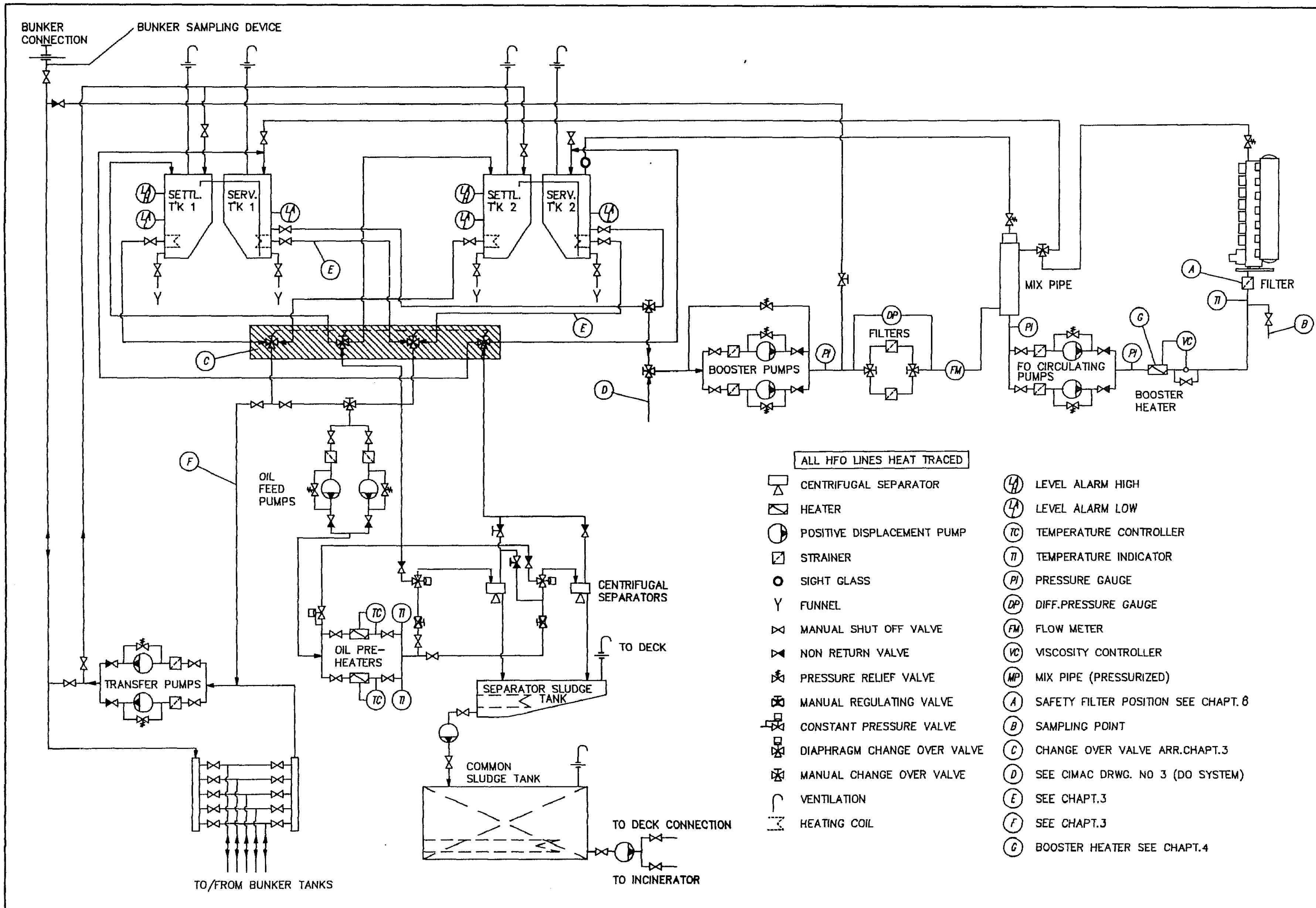


Fig. 2: DOUBLE TANK SYSTEM

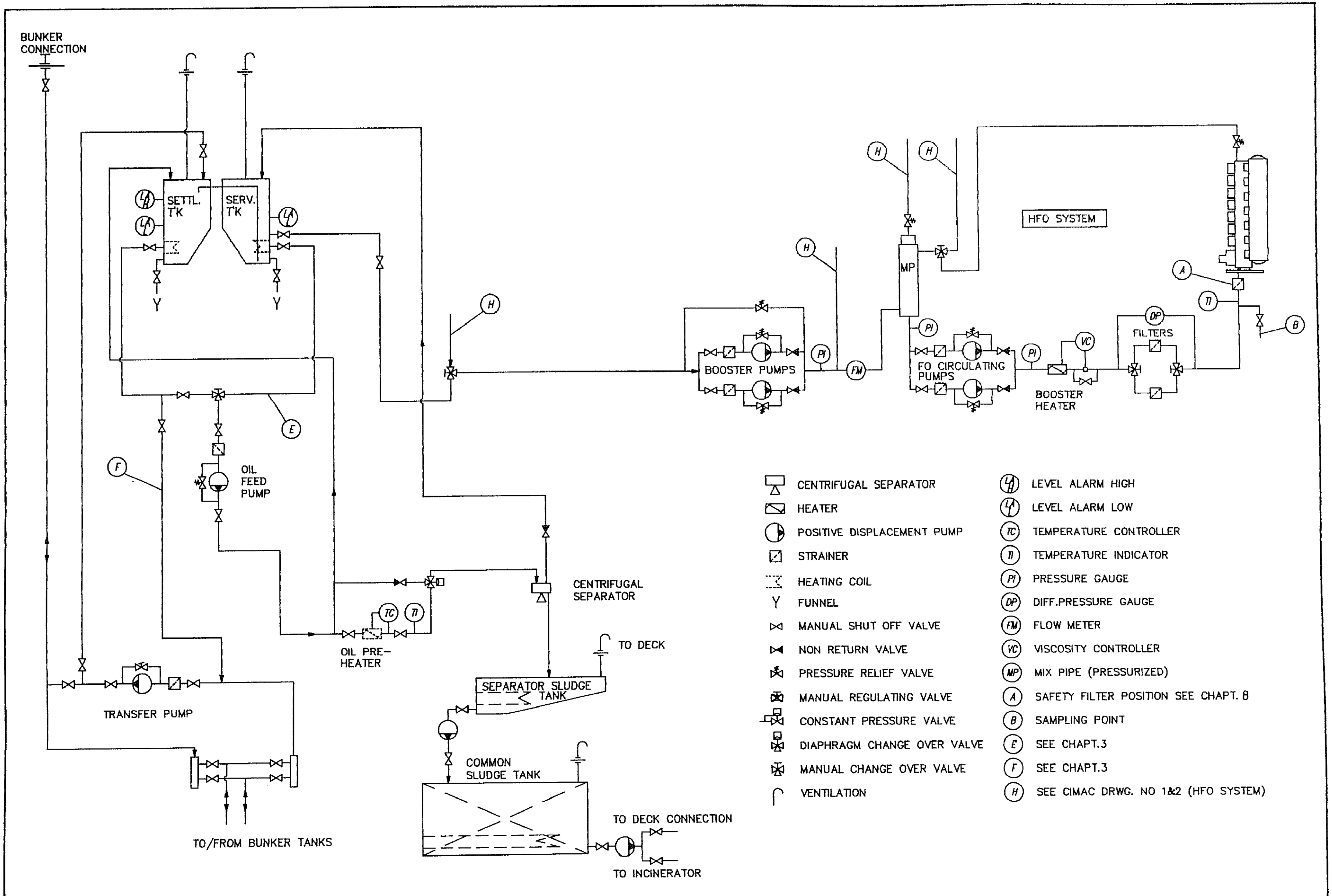
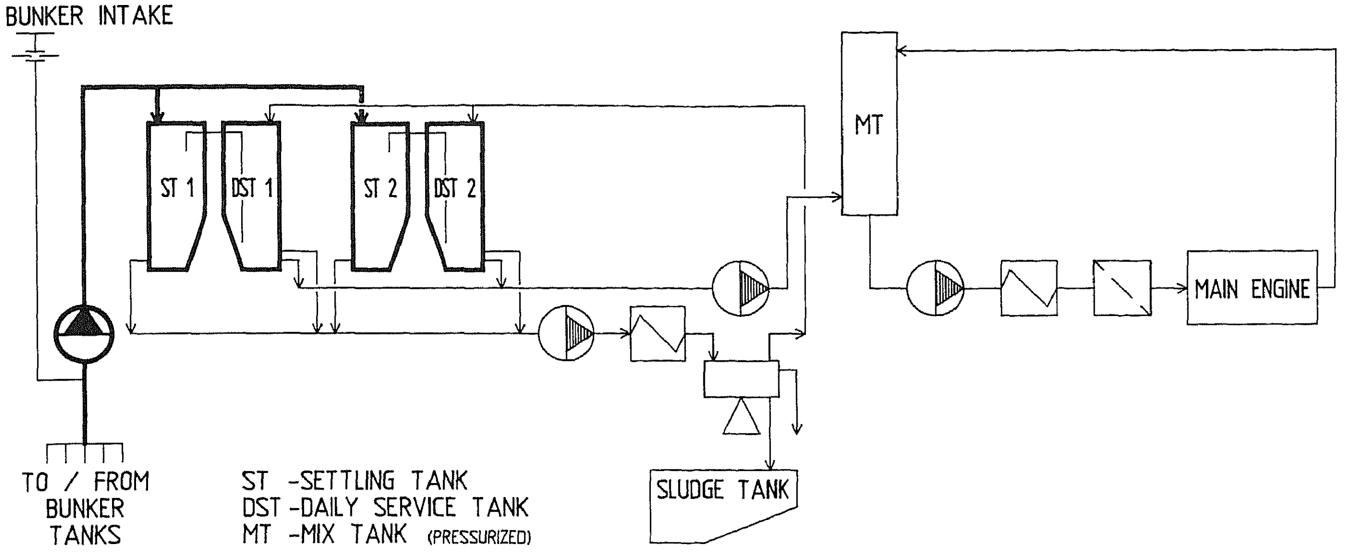


Fig. 3: DIESEL OIL



3. TANKS

3.1. Bunkers

From the foregoing, it is clear that the main fuel bunkers should be arranged such that mixing of newly bunkered fuel with remaining fuel can be avoided. The finer the total capacity is subdivided into separate bunkers, the greater is the freedom to maintain this principle under all types of operating conditions.

The problems associated with the use of higher pour point fuels and fuels in the upper viscosity range, should be countered by the provision of adequate tank heating coils, transfer line trace heating, self draining bunker and transfer lines; and possibly transfer line air or steam blow-through facilities.

In cases when bunkers of the highest viscosity grades are taken aboard it is recommended to use cross-bunker tanks if possible. The use of tanks in the double bottom may entail difficulties in keeping the fuel pumpable, owing to the cooling effect from the hull.

During transfer from the bunker to the settling tank the temperature should be sufficiently high to obtain the required pumping viscosity, and be kept at least 10 °C above the pour-point. Because the fuel can become stationery in the pipes when no fuel is consumed, and high fuel velocities should be avoided anyway (guideline: max. 1 m/sec for suction, max. 2 m/sec for discharge pipes) there is always the risk of wax precipitation. Therefore no transfer should take place without trace heating.

To avoid emulsification with water, gentle treatment of the fuel is important. Therefore the transfer pumps should be of the positive displacement type, e. g. screw-type pumps.

3.2. Settling tanks

Considerable thought is being given to the design of settling tanks and as a consequence, there are a range of possibilities:

3.2.1 The **conventional** settling tank has always been considered an important item because excess water (together with sludge and abrasives) can be removed in the tank by gravitational effects.

To give the settling process sufficient time, these tanks normally have a capacity equivalent to 24 hours fuel consumption. The fuel should be in a still condition and therefore the effect of the supply and return pipes should be minimised by directing them against the tank wall. Thermal insulation of the settling tanks is useful to avoid thermal losses and will contribute to the stillness by eliminating convection currents.

As a constant temperature and even temperature distribution are important, a heating coil of large dimensions and a moderate temperature is desirable. The coil should be fitted near the bottom but not too close to it. A high temperature is favourable to encourage the settling process, but too high a temperature would promote ageing of the fuel. The recommended temperature is about 70 °C.

The settling tank should be provided with a high and a low level alarm (in a relatively high position – the tank should be nearly full) and a thermometer to control the heater and the high temperature alarm.

3.2.2 The first departure from the conventional settling tank is due to the fact that much of the water in modern fuels is present as a rather fine emulsion and, due to the higher fuel densities, hardly settles out.

Also, the amount of sludge and abrasives removed by settlement is considerably less than the amount removed by the separator. Consequently, it is **usual** to specify a smaller tank capacity (10 – 20 hours comsumption), which only has a buffering function. In this tank, hot recirculating fuel from the centrifuge mixes with fresh fuel from the bunkers. The tank then contains fuel at a constant temperature, ready for final pumping, heating and centrifuging.

3.2.3 To be able to keep different fuels separate, it is useful to have two settling tanks, allowing immediate switching to the other tank at the occurrence of a severe sludge problem. In the case of large, conventional settling tanks, duplication allows them to be used in turn with the tank in use being emptied, and the other tank left full and still for 24 hours for optimum settling.
Usually two smaller tanks are used and a reduction in the settling effect accepted. By accepting some fuel movement the temperature variation can be reduced by frequent topping up, either manually of automatically, so that both tanks are normally full. To avoid fuel ageing, switching from one tank to the other should be done every one or two days.

Due to the fact that all the proven design features of a conventional settling tank are maintained, this system still allows very good settling with moderate density fuels, which is useful if the fuel contains slugs of water.

Double settling tanks are a **recommended alternative** giving a high degree of flexibility.

An alternative philosophy regarding the double tank system is that one settling tank is considered as an auxiliary. This tank would be empty during normal operation and could have a smaller and simplified design which makes it easier to try fuels shortly after bunkering (see 3.4.).

3.2.4 In ship's operation, where bad weather can disturb sludge and abrasives which had accumulated at the bottom of bunkers and of settling tanks, overloading of separators and filters can occur. A **new idea** has been put forward to prevent this phenomenon in settling tanks by deliberately inducing a given amount of **fuel movement.** This would also distribute possible slugs of water, improving water removal by the centrifuge. The tank capacity can be made even smaller, but to distribute the accumulated material stirred up in the bunkers over an acceptable time, a minimum capacity (6 hours or so) should be maintained.

3.3. Day tanks or Service tanks

New developments, partly comparable to those in settling tanks, have taken place in the operation of day or service tanks.

3.3.1 The **conventional** day tank or service tank provides a large buffer quantity of clean, heated fuel. The capacity has traditionally been for about 24 hours engine operation. Most of the service tank design features are similar to those of the settling tank.

The tank is provided with an overflow line to the settling tank and it is recommended that fuel is drawn by means of an internal pipe from near the bottom of the service tank. The return fuel which has by-passed the engine should not be fed to the service tank because the resulting higher temperature would result in fuel degradation and an increased tendency to deposit formation. Instead, the return fuel should be fed to a separate mixing tank (see chapter 6).

The fuel treatment system must be provided with the capability to re-clean the fuel in the case of centrifuging failures leading to contamination. In that case it is useful to extract the fuel from the daily service tank on a lower level than the normal outlet, but higher than the bottom drain.

3.3.2 With the improved effectiveness of modern generation centrifuges, it is **usual** to specify a smaller tank capacity. Therefore the traditional "day tank" can be replaced by "service tank".

A capacity of about 10 hours is considered a normal value. The minimum is determined by the time that separators may be out of service due to servicing and therefore capacities down to a few hours fuel consumption are possible, and have been used.

In a modern service tank, regular draining by hand is considered to be a burden and also difficult to judge how much to drain off. There are several possibilities to supplement this operation or to reduce the frequency of it. These are:

1. Drain a specified quantity of fuel automatically at regular intervals, and return it to the settling tank. This could be done at short intervals, by means of a separate pump and pipe connection, or by draining into the double bottom tank, the contents of which is then pumped to the settling tank by means of the transfer pump.
2. Recentrifuge the service tank contents regularly, drawing the fuel from the bottom of the service tank. This can be done every time the vessel is in port for marine installations and every night or every week-end in power stations, or it can be done continuously with a small proportion of the fuel. To that end a flow control valve should replace the change-over valve on the suction side of the oil feed pump.

3.3.3 As for the settling tanks, there are good reasons for specifying double service tanks. Pumping back a problem fuel, or a fuel which is contaminated due to faulty centrifuging, would cause interruption of engine operation, whereas double service tanks allows an immediate change to the other tank.

Again regular switching from one tank to the other is recommended to reduce possible ageing in the "sleeping" tank and also avoids separation of water and sludge.

As normally the total capacity of the two tanks is available, a small capacity can be used for each service tank.

Again, double service tanks are a **recommended alternative** offering a high degree of flexibility.

As before one tank could be of smaller capacity and kept empty during normal operation, making it easier to try new fuels shortly after bunkering. The smaller tank should have its own automatic level control, but could be simpler in other respects (e. g. no low level alarm). In this case, the volume of the single remaining service tank determines the quantity of treated fuel normally available.

3.4. Choice of tank configuration and operation

3.4.1 Double or single tank system

The choice between the two alternatives depends on what probability the user will receive unsuitable fuel with regard to incompatibility, instability, poor filterability or engine operating problems. If due to the region in which the ship will operate, or due to arrangements with fuel suppliers of land-based installations, the risk of bunkering such fuels is low, the single tank system is perfectly adequate. If this risk is high, the double tank system, due to its flexibility, is preferable because of its ability to cope with potential handling problems.

In this respect there is a difference between settling and service tanks. Double settling tanks are particularly important when fuels are unstable.
In that case, it may be benefical to pump back the contents of the settling tank to the bunker and then it would be difficult to prepare enough centrifuged fuel. Double service tanks, however, are useful in nearly all cases of fuel problems. A system with a single settling and double service tanks is therefore a possible option.

A double tank system requires some extra attention and special measures. Switching from one system to the other can impose problems. The connection shown in diagram 2 to couple 4 different change-over valves, which can probably be achieved by means of electrical control, makes operation easier to understand. In the case of unsuitable fuel, the bunker location should be indentified before pumping the fuel back to it. Also the ship's trim and stability can restrict the freedom to select which fuels to use and in which sequence.

3.4.2 Second tanks full or empty

A double tank system is of no use if the good fuel has been consumed at the time the next fuel appears to be causing trouble. Therefore it is recommended to **try a new fuel** shortly after it has been bunkered. If both circuits are full, this is only possible after consuming or pumping back the fuel from one circuit. To avoid this, it could be considered to leave the tanks in one circuit empty in the normal condition. This implies that it would not be possible to switch immediately to another fuel because some fuel must pass through the treatment installation and be collected in the service tank first. However, the necessity to change fuels should occur less often because most problems will appear when the new fuel is tried after bunkering.
If it is intended to operate with the tanks in one circuit empty, a small capacity could be specified for those tanks to give a main and auxiliary fuel circuit. In multi-engine (particularly land-based) installations risks can be further reduced by trying a new fuel first in one engine.

3.4.3 General remarks

The new ideas presented in this chapter are the result of discussions between a group of experts from throughout the industry. All the proposals entail arrangements that are additional to proven systems, but the risks are considered to be small. They have not all been proven in practice, but CIMAC have decided to publish the ideas as a contribution towards the improvement of fuel treatment systems.

4. HEATERS FOR HEAVY FUEL SYSTEMS

The storage and preparation of heavy fuel oil for combustion in diesel engines demands careful attention to the design of the heating arrangements in order to avoid operational problems and to minimise the energy consumption of the heaters.

4.1. Bunker Heating

Bunker heating is usually provided by steam, hot water, thermal oil or electric coils running through the tanks. There should be sufficient heating capacity to raise the bulk temperature of the highest viscosity fuels likely to be encountered to at least 45 °C, or that temperature which gives a maximum pumping viscosity of 1000 cSt. It is important to arrange the layout of the heating coils such that the contents of the tank are evenly heated and, in the case of steam, that the control of the steam to the heating coils is regulated to maintain the desired storage temperature.

Too high a storage temperature may lead to ageing (thickening during long term storage), carbon deposition on the heating surfaces, and excessive energy consumption. The type of fuel to be bunkered, the size, layout, and likely heat losses from the bunker tank should all be taken into consideration when designing the tank heating system.

4.2 Outflow or Line Heaters

Outflow or line heaters are required to increase the temperature of the bunker fuel to facilitate the handling of the fuel. To avoid degradation of the fuel, the metal surface temperature should not exceed 170 °C. Experience has shown that this is achieved if the electrical output does not exceed 1.0 Watt/cm^2. However, there are some types of electric heater on the market which, because they are designed to ensure that turbulent flow over the heater section takes place, exceed the usual power loading of 1.0 Watt/cm^2 by a significant margin.

These heaters are used at several places in the fuel system, and the temperature of the fuel should be regulated to that required by the next piece of equipment downstream of the heater.

Control of line heaters can be either by monitoring the temperature and regulating the input of heat energy to maintain the set temperature, or alternatively by measuring the viscosity of the fuel by means of a Viscometer. The Viscometer measures the viscosity of the fuel and produces a signal that is proportional to the viscosity which is then used to modulate the input of heat energy to the heater.

Control of the temperature of the fuel at the inlet to the centrifuge is critical as the fuel temperature must not exceed 98 °C or the water seal in the conventional purifier will not be maintained. Difficulty is often experienced with maintaining the temperature accurately due to the inaccuracies of commercially available sensors and thermostats. A PI controller should therefore be used to sense the fuel temperature and modulate the heat input to maintain the set temperature for the correct operation of the centrifuges.

4.3. Trace Heating

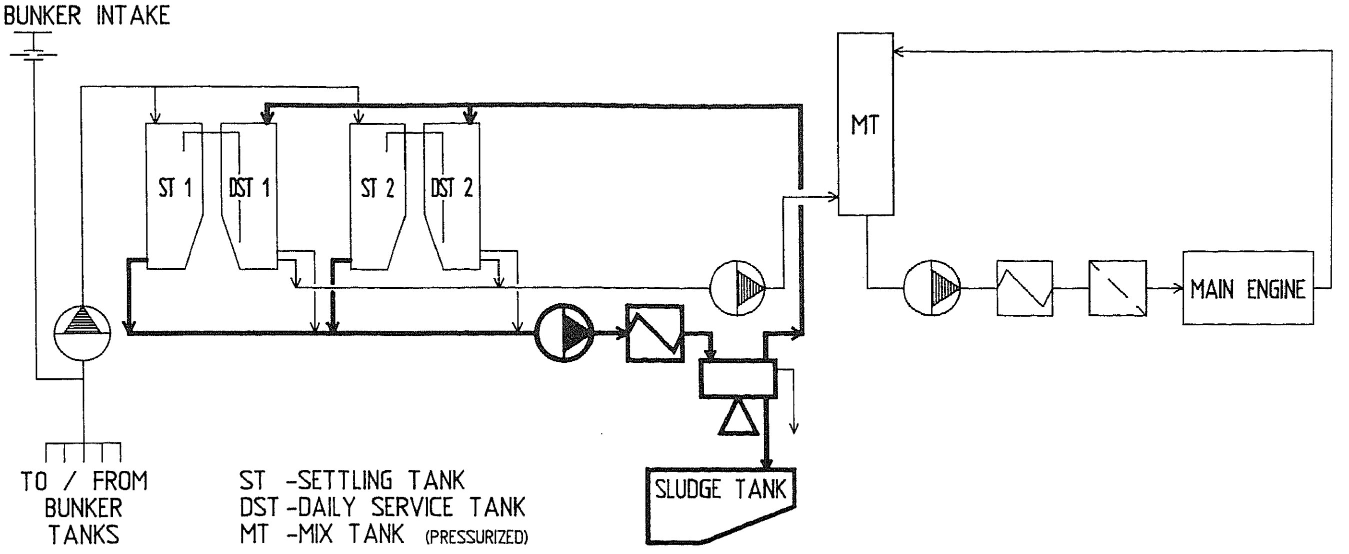
All the pipes connecting the various components of the fuel system should be trace heated and insulated in order to maintain the fuel passing through them at the correct temperature.

Trace heating can be either by steam or electrical heating tape. If electric heating is used, then it should be thermostatically controlled.

It is also important to trace heat both sludge and drain pipes, even though are only used intermittantly.

4.4. Electric Tank Heating

If electric immersion heaters are to be used, then they should be of the sheathed type (so that the elements can be changed without draining the tank) and the heat rating should be restricted to 1.0 Watt/cm^2 to avoid carbon deposition on the sheath. The heaters should be positioned uniformly around the bottom of the tank to ensure that the heat input is evenly distributed.



5. CENTRIFUGAL SEPARATORS

A. *High speed principle*

5.1. Task

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.

5.2. Design

5.2.1 Conventional systems

The generally accepted system consists of two separators, purifier and clarifier. The purifier has a continuous water discharge and an intermittent sludge discharge.
In order to maintain the hydraulic balance between the oil and the water in the separator bowl, the purifier is equipped with a gravity disc. This gravity disc must be correctly specified in relation to the fuel density in order to keep the oil/water interface in the correct position. The interface position is of the utmost importance in order to obtain good separation of the contaminants from the fuel.

The clarifier has no continuous water discharge. The water is intermittently discharged with the sludge from the periphery of the separator bowl. The clarifier has no gravity disc.

From general experience (as well as special tests, particularly with respect to catalyst fines) the commonly accepted mode of operation has become that of a purifier followed by a clarifier in series. The safety margin provided by the clarifier is very important because the risk of running the purifier with an incorrect gravity disc can have serious consequences on the engine.

Although this risk has been reduced by designs employing a larger radial distance between the periphery of the top disc and the other discs, (so that one gravity ring covers a wider gravity range), faults cannot definitely be excluded. What happens in that case is the following:

> If the gravity disc is chosen for a lower density than the actual fuel density, the interface between the fuel and the water moves outward and the water seal is broken resulting in oil losses which will trip the alarm. If the gravity disc is chosen for a higher density than the actual density, the interface moves inwards. When the water reaches the disc stack, the vertical fuel distribution is restricted to the lower part of the disk stack causing a drastic reduction in separation efficiency, which may occur unnoticed.

The layout of the system should be such that the separators (generally in purifier mode) can also be used in parallel operation to improve the sludge handling capability in case of excessive amounts of sediment in the fuel.

This "conventional" system will safely handle fuels which have, according to existing standards (BS MA 100-1982 and ISO 8217-1987), a specified density up to 991 kg/m^3 at 15 °C. Acceptable results have been reported with slightly higher densities, but there is a pronounced risk of hydraulic instability leading to the selection of too small a gravity disc.

5.2.2 Modern systems

To cope with lower quality and higher density fuels, a new class of centrifuges has been introduced. They have a common feature in that they can be considered as clarifiers, having no gravity disc, but having additional means of controlling the water content and waterhandling. They all maintain the discharge of sludge at the periphery of the bowl. Three different principles are applied:

1) A separate water discharge controlled by monitoring the water content by means of a capacitance measurement in the clean oil. When the water content exceeds a set level, the sludge discharge takes place and when the desludging frequency becomes too high, water is drained through a separate water outlet.
2) By means of a circulation pipe 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 sludge and water increases, the interface moves inward, and the water content in the circulation pipe increases sharply. This is recorded by means of a conductivity measurement and a quantity of water is removed separately.
3) A centrifuge without separate water discharge. As before, the water content of the clean oil is continuously measured by means of electrical capacitance and the separated water is discharged together with sludge by partial opening of the bowl.

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 it to improve the cleanliness of the treated fuel.

The suppliers of machines of type 1) and 3) promote parallel operation of the separators, which leads to duplication of the residence time. This must fundamentally give a higher yield of particle removal compared to applying twice the residence time with complete mixing in between, as occurs in series operation.

The suppliers of machines of type 2) recommend series operation, operating the second machine normally as a pure clarifier equipped with automatic sludge monitoring equipment matching discharge frequency to sludge production. They claim that the longer discharge intervals will lead to a lower total sludge production. Of course, with series operation the second machine will yield some further reduction in the abrasive content.
Another argument used for series operation, is that if an excessive amount of abrasive contaminants pass through the first machine, the second machine will collect them. This situation is thought to occur if, due to heavy seas, larger quantities of dirt (collected in bunker bottoms) have been disturbed and mixed with the fuel. It is, however, probable that this problem can be prevented if the (conventional) settling tank is regularly drained, or by other measures (see: 3.2.: "settling tanks").

Although operating experience is still being accumulated, it has been predominantly aimed at confirming the fundamental advantages of the new class of centrifugal separators.

The maximum allowable fuel density for satisfactory water removal is about 1.010 kg/m^3. Higher densities will reduce the efficiency of the water removal but, in contradiction to the conventional purifier, the separating efficiency for sludge and abrasives cannot be impaired. Also, the separation efficiency cannot be impaired by faults that disturb the correct position of the interface. As a consequence, they are less demanding with respect to the skill of the operator. As the inside of the bowl and disc stack remain cleaner, they require less maintenance. In conclusion, the selection of separators of the modern type is **recommended.**

5.3. Operation

Conventional system

In conventional installations the selection of the correct gravity disc, as explained under "Design", is of paramount importance.

A conventional cleaning system should always comprise two separators; a purifier and a clarifier in series. With the clarifier following the purifier, additional improvements to the separation efficiency are obtained. With this arrangement, the clarifier acts as a "safety net" if the interface of the purifier has moved into the disc stack. This additional security provided by the clarifier is important, since cleaning of heavy fuel oil means operation close to the limit of the purifier's performance.

In cases of excessive sludge in the fuel oil, both separators should be operated in parallel at half the feed rate, thus employing maximum sludge handling capacity. This mode of operation requires close supervision to ensure safe operation and selection of the correct gravity discs.

When a spare separator is available, it should be operated in purifier mode and run in parallel with the main purifier (both with half the feed rate). The outlet from both purifiers is then fed to the clarifier.

Modern system

Operation has already been discussed under the section "modern system" of 5.2.

5.4. Installation aspects

Size

Correct sizing of the centrifugal separators is of utmost importance. When specifying the total required flow rate ot 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.

Fuel feed arrangements

Gentle treatment of the fuel is important in order to avoid water emulsification. It is recommended that separate positive displacement pumps are used, (e. g. screw-type or slow-running gear pumps) and that they are installed as close to the settling tank as possible to avoid throttling in the fuel pipe, especially in the suction line.

It is important to maintain a constant flow rate to the separators, particularly when using high density fuels. The flow rate should be set for the engine's "normal" fuel flow and should not be regulated according to short term variations in fuel consumption. To this end, a pump of the required capacity and without any control is the simplest and safest solution. Controllable pumps should be used when pumps of the required capacity are not available or when large changes in engine power (due to operational requirements or economic circumstances) are required.

The temperature of the fuel in the separator should be as high as possible but not exceeding the maximum specified inlet temperature for the machine. To avoid boiling-off existing water, 98°C is the practical and recommended limit for all heavy fuels. For lower viscosity fuels lower temperatures are acceptable. Separator manufacturers will supply tables of recommended temperatures.

It is very important to keep the fuel temperature constant. For purifiers, the allowable tolerance is plus or minus 2 °C. This can only be achieved by means of a special preheater with a fast thermal response and a control circuit with a PI controller (with an accuracy of at least plus or minus 2°C). For clarifiers and modern centrifuges without gravity discs, the maximum acceptable tolerance is approximately plus or minus 5 °C, but 2 °C is preferable.

Clean fuel outlet

Between the outlet of the separator and the service tank, there should be no piece of equipment that influences the separator outlet pressure. In particular the purifier is very sensitive to a varying back pressure.

As the throughput of the separators is normally 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.

Sludge discharge pipe

For trouble-free operation, the discharge of water and sludge must take place without any restriction. The discharge pipe should be of large diameter, short in length and preferably vertical.

The sludge tank must be sufficiently large and well-ventilated to prevent a back pressure building-up against the machine during the discharge of sludge. The capacity of the sludge tank must be sufficient to prevent the necessity to recirculate sludge. The contents of the sludge tank should either be disposed of by incineration or delivered ashore, all in accordance with the prevailing anti-pollution regulations.

Manoeuvering and displacement water

All self-ejecting separators need good quality fresh water for the hydraulic manoeuvering system. The same water quality is required for the replacement of the water seal in purifiers after discharge, and when displacement of oil is made by water before discharge.

The limits are stated by the separator suppliers. An example of limits is:

– total hardness	max 180 ppm $CaCO_3$ or 10° dH
– pH	min 6
– solids	max 10 ppm
– chloride ions	max 100 ppm

B. ***Low speed principle***

A horizontal shaft centrifuge operating at moderate speed is known as a "decanter". If specified, it is installed before the high speed centrifuge and removes sludge in a continuous way. It will remove some water, but its main advantage is a large sludge handling capacity. This is useful in cases where the sludge content of the fuel is so high that the efficient operation of the high speed centrifuge tends to be impaired, and where the prior removal of part of the catalytic fines content is required.

Experience with decanters indicates that they are capable of removing significant amounts of sludge and catalyst fines, and require very little maintenance. A reduction in purifier maintenance has been observed in installations with conventional centrifuges. Application of a decanter could be considered in single and double tank systems. To install a decanter into the system requires additional equipment and a possible layout is presented in **Fig. 4.**

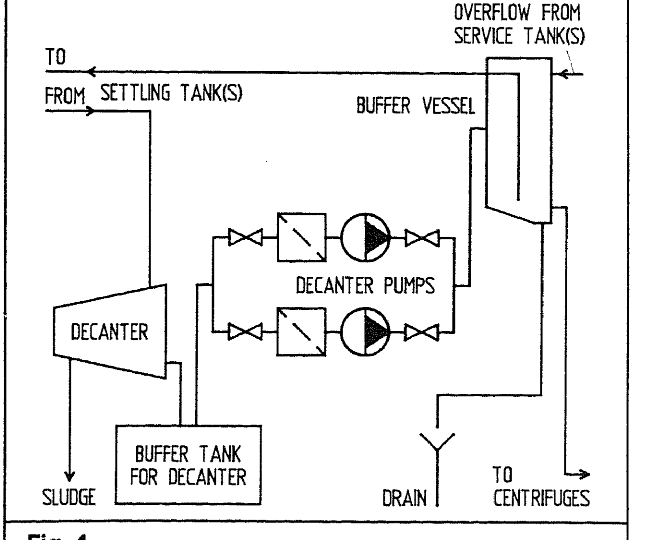
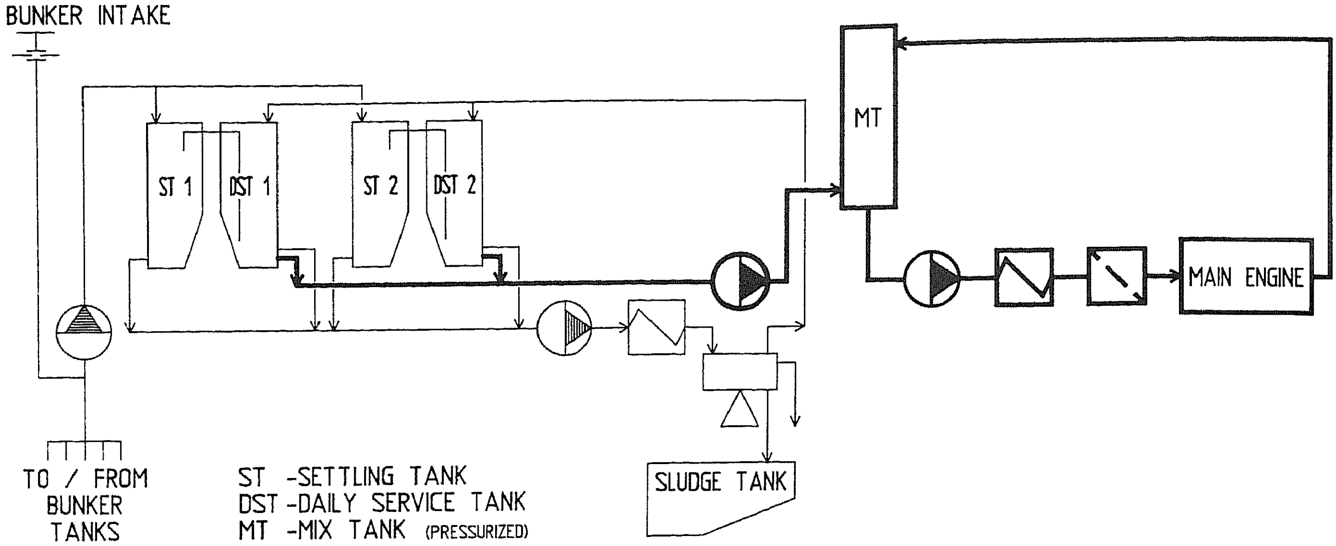


Fig. 4



6. MIXING PIPE AND BOOSTER SYSTEM

6.1. *Introduction*

The main function of the booster system is to supply the fuel to the injection pumps at the required temperature and pressure. Because the fuel supply is always greater than the maximum fuel consumption, excess fuel is recirculated and mixed with the freshly supplied fuel in the mixing pipe. In the conventional system the mixing pipe was operated at atmospheric pressure, but this is no longer recommended.

6.2. *Pressurised booster system*

At the high temperatures required by modern high viscosity fuels, excessive vapour from the remaining water and volatile components in the fuel has to be prevented by maintaining a pressure of at least 3.5 bar in the booster system including the mixing pipe. The pressurised booster system incorporates a booster pump installed before the mixing pipe and a circulation pump after the mixing pipe.

The booster pump is installed with a pressure control valve mounted in the overflow line to the suction side of the pump. The circulating pump maintains a flow of about three times the maximum fuel flow to the engine in the circulating system. The required pressure in the fuel rail should be specified by the engine manufacturer. This pressure depends on the type of fuel and on the fuel injection pump, and varies from 3.5 to 9 bar, but usually is between 5 and 7 bar. This pressure can be controlled by a regulating valve or by a diaphragm after the engine.
The required pressure after the booster pump is at least 3.5 bar. It is possible to raise the fuel rail pressure to the required level in one step, in which case the circulation pump would only circulate the fuel, and the pressure relief valve after the engine would be omitted.

6.3. *The mixing pipe*

It is not possible to keep different fuels separate in the booster system and the mixing pipe is the largest volume in which the fuels can meet.
To reduce the time that the two fuels are together to a minimum, the mixing pipe should obviously be as small as possible.

The ultimate aim is not to use a mixing pipe but to utilise a simple junction. The engine manufacturer, however, may specify a certain minimum capacity to reduce the thermal shock effect when changing from heavy fuel to marine diesel fuel or vice versa.

The de-aeration valve in earlier systems was often mounted on the mixing pipe, but is now usually fitted in a high position in the booster system. The ventilation pipe need not be heated as normally only air escapes. In the case of a failure, volatile or liquid fuel could escape and hence the ventilation pipe should be fed to the service tank.

7. BLENDERS, EMULSIFIERS, HOMOGENISERS

7.1. Task

This category of equipment may perform one or more of the following three functions:

1) Mixing fuels of different quality and/or viscosity.

2) Emulsifying the water which may be present in the fuel. This is useful if, after treatment, small slugs or large droplets of water are still present, which can cause irregular combustion. Water, emulsified to droplets smaller than 5 μm will generally do no harm to the combustion process and can even improve it. The sodium content of the fuel (caused by the presence of seawater) is of course not reduced, and so still can cause deposits in the combustion space or fouling of the turbochargers. There may be some reduction in corrosion of the fuel injection system due to the emulsification, but even a fine emulsion can be detrimental particularily when the engine is stationery.

3) Reducing agglomerates of asphaltenes in size and thoroughly dispersing 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. Because coagulation generally starts again immediately after homogenising, the treated fuel must be used at once.

The techniques used to achieve the above functions are described in more detail in the following sections.

7.2. 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 described below roughly in the order in which the amount of energy exerted on the fuel increases.

1) Blenders of static design (employing the energy of the fuel transfer pump) generate sufficient turbulence to create a homogenous mixture of two fuels, but do not emulsify water sufficiently or break down coagulated asphaltenes.

2) Static emulsifiers, applying a separate pump which forces the fuel through an orifice at 20 bar pressure, causing intensive shear between fuel layers in the mixing chamber. This method can create a water-fuel emulsion with droplets sizes of 3 – 5 μm, but has been found to be inadequate as a true homogeniser.

3) Dynamic emulsifiers, utilising a centrifugal pump in which a defined clearance between the rotor and the housing creates a shear effect. A water-fuel emulsion with droplets of about 5 μm can be made, but the merits as a true homogeniser are not known.

4) Homogenisers utilising the principle of the colloid-mill (as used for paints). Rotating toothed surfaces pass each other with a very small wedge-shaped clearance through which the fuel passes from the widest to the narrowest part. They are claimed to break down agglomerated asphaltenes to a size range between 2 and 20 μm.

5) Homogenisers with mechanical rollers running on a cylindrical wall. They are claimed to break down agglomerated asphaltenes to some 5 μm or less. The rollers can crush solid particles of soft material but catalyst fines remain unaffected.

6) Homogenisers forcing the fuel through a specially designed adjustable area orifice by means of an integrated high pressure pump. This type breaks down coagulated asphaltenes to very small particles. Water in the fuel is emulsified to droplets of about 1 μm.

The designs mentioned under 4), 5) and 6) have all been used with some success in heavy fuel treatment plants. As far as it is possible to judge, type 4) could be classified as a mild homogeniser, while types 5) and 6) could be classified as strong homogenisers.

Ultrasonic waves not only attack hydrocarbon conglomerates, 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.

7.3. Position in the system

1) *Blenders*

The effect of blending is well known and the postion of a blender, if applied, should be between the service tank and the mixing pipe.

2) *Emulsifiers*

An emulsifier can be useful in cases where non-dispersed water is not removed by the treatment plant, thus preventing water from impairing fuel injection and combustion. The effect of seawater corrosion, however, is limited, particularly when the engine is not stationery. Also the deposition of sodium based deposits in the engine and turbocharger can still occur. The emulsifier should be installed after the service tank. If it is fitted before the main filter, possible problems there may also be avoided.

3) *Homogenisers*

Homogenisers perform the same function as emulsifiers, but in addition they break down coagulated asphaltenes. Because they do not break down hard abrasives, homogenisers cannot replace centrifuges.

In very unstable fuels, the asphaltenes coagulate very quickly, so the fine dispersion obtained by homogenising requires that the fuel must be used immediately, before new coagulation occurs. Based on this requirement it can be installed in several possible positions in the system.

a) 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, and so if the main filter is installed in the booster system or just before the booster system. In view of the required throughput, the homogeniser could be placed before the booster system in both cases. Mild homogenisers are certainly sufficient when filters with a nominal mesh size of 25 µm are installed. When smaller mesh sizes (nominal 10 µm or even 5 µm) are installed, mild homogenisers will probably be adequate but the use of a strong homogeniser may give the greatest likelihood of minimising the chances of filter blockage. Experience tends to show a reduction in filter problems. There have been cases of severe fuel instability where the fuel filter functioned only because the homogeniser had dispersed the agglomerated particles in the fuel.
Also the effect of water will be less severe when emulsified.

b) Another useful position for an 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 coagulated asphaltenes built up in the high temperature boost system.
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 intalled before the circulating system, making the safety filter more important. In the case b) a "mild" homogeniser is quite probably sufficient.

8. FILTERS

8.1. Task

The bulk of the contaminants in the fuel oil must be removed by the centrifugal separators.
However, to protect the engine, it is standard practice to fit a filtration unit as the final stage in the fuel treatment process.

Filtration presents a logical supplementary step because generally some of the larger particles, particularly those of light weight material, escape the centrifuge.
Experience shows that filters always collect some material (e. g. catalyst fines, abrasives) and in addition, the filter serves as an indication as to the performance of the separators up-stream.

There should always be a main filter installed between the separator and the engine (see 8.3.), capable at 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 occuring during repair or maintenance of the filter. Several main engine manufacturers therefore include a safety filter in the engine supply.
It is recommended that the safety filter is provided with a magnetic trap because ferrous particles can present an acute risk.

8.2. Design

Mesh sizes are defined as the **nominal** mesh size, which is the size of those particles of which 90 % are retained (the generally used definition) and the **absolute** mesh size, which is the size of an equivalent spherical particle that will just pass through the mesh. (Larger particles may pass if they are oblong)
After some build up of dirt smaller particles are retained and hence the nominal mesh size is always smaller than the absolute size. The ratio between the two depends on the wire structure, but also on the mesh size, the finer the mesh size, the higher the ratio.

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 μm (absolute about 50 μm) but there is a tendency towards smaller values. A mesh size of about 10 μm (absolute 25 μm) is already quite common and some new designs of 5 μm nominal mesh size have been introduced.
Under the prevailing conditions of temperature and sheer 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 finer the mesh size, the more care has to be taken to avoid clogging of the filter elements.
The conventional design is a duplex type 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.

There is a tendency towards automatic backflush filters, whose cleaning depends on the differential pressure across the filter element. A cleaning cycle counter warns when the frequency exceeds a preset value. Measures have to be taken to avoid disturbances due to the back flush operation. One way is to clean only a limited and alternating part of the total filter surface, allowing a continuous fuel flow through the remaining part. In this case only surface filtration is possible.
Designs of this type can be considered as the normal **recommendation.**

Another way to avoid clogging is the application of ultrasonic waves, acting on the filter surface. This simultaneously leads to the breakdown of organic particles and can be considered as homogeniser and filter integrated into one unit. Cleaning, when necessary, is carried out using the backflush principle. This design allows a nominal mesh size of 5 μm. Due to its relatively high cost, it is predominantly used for auxiliary engines and for propulsion engines of smaller ships. It is designed to be installed between the booster pump and the mixing pipe.

Recently a second filter of 5 μm nominal mesh size has been introduced for application to main engines. To keep the filter surface clean, the fuel rotates around the filter element so that the heaviest particles are kept away from the filter and collected in a drain. This design utilises an integrated nozzle homogeniser. The filter is designed for installation between the booster pump and the mixing pipe.

These recommendations apply primarily to the main filter. Safety filters which should normally collect much less dirt, are still often hand-operated duplex filters. In view of the increasing degree of automation on-board, and particularly if the main filter position is before the circulating system (see 8.3.), the application of an automatic backflush safety filter may be considered.

For all filters applying surface filtration, the tendency to clog can be reduced and the ease of cleaning improved by the application of elements with wires of a rectangular section arranged to offer the narrowest area flush with the external surface.

All filters must be capable of being heated and be designed to cope with heavy fuel oil up to viscosities of 700 cSt at 50°C (55 cSt at 100°C), which necessitates a working temperature of aproximately 160°C maximum.

8.3. 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 fuels, particularly during changes from heavy fuel to distillate fuel or vice versa. One way to prevent this is by the application of a homogeniser before the filter.

An alternative option is to place the main filter directly **before the circulating system,** between the booster pump and mixing pipe. In this position, the fuel entering the filter has a temperature between 70 and 90°C. At this temperature, considerably less ageing occurs, reducing the risk of clogging. Although the fuel viscosity is higher than that in the circulating system, the resistance of the filter is similar or not much higher (for a given filter area) because the flow is only about ⅓ of that in the circulating system.

More important, however, is that the lower fuel velocity through the filter mesh contributes to a further reduction in the risk of clogging, already achieved by the lower temperature. Engine manufacturers accept the installation of main filters in this position reluctantly, because of the greater number of sources of dirt after the filter. In any case, close attention should be paid to the thorough cleaning of pipes and equipment before installation.

A second advantage of this location is that the flow meters, which are becoming more widely used and are very sensitive to dirt, can be installed directly after the main filter.

A third possible position, **before the service tank,** has been promoted as a safeguard against the effects of maloperation of conventional separators (i. e. use of the wrong gravity-ring). It involves a major disadvantage in that a large part of the system is after the main filter, leading to increased risk of contamination.
It is also more complicated because the filter has to be equipped with a buffer tank and pump to give an unrestricted fuel flow after the centrifuge. Therefore it is not recommended to install the filter in this position.

8.4 Operation

The filter must be properly maintained in order to be able to detect 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 rapid asphaltene coagulation or, particularly if much inorganic matter is found, by the deterioration in performance of the centrifuges. In either case, immediate action is necessary.

9. FUEL BLENDING

Fuel blending in this context is defined as the controlled mixing of two fuel components by means of an in-line blender.

For example, by diluting the residual fuel oil (HFO) generally used in the main engine with Marine Diesel Oil (MDO) or Marine Gas Oil (MGO), a fuel results which is cheaper than MDO and has a lower viscosity than HFO. The resultant blend may be suitable for use in the auxiliary engines.

The required ratio of the blending components, in relation to their known viscosities at the same temperature, can easily be determined from a blending chart by connecting two points with a straight line. An example is given in **Fig. 5.**

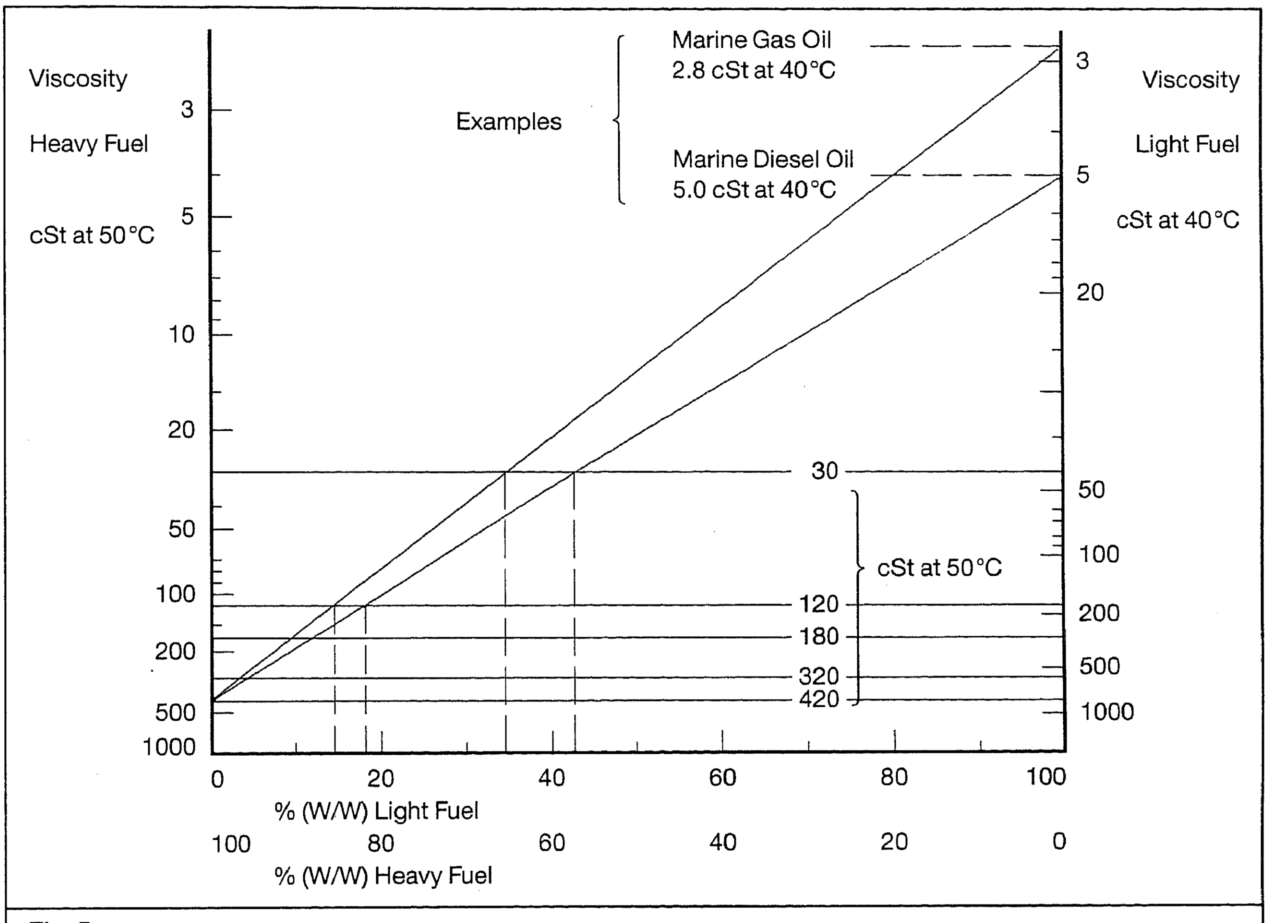


Fig. 5

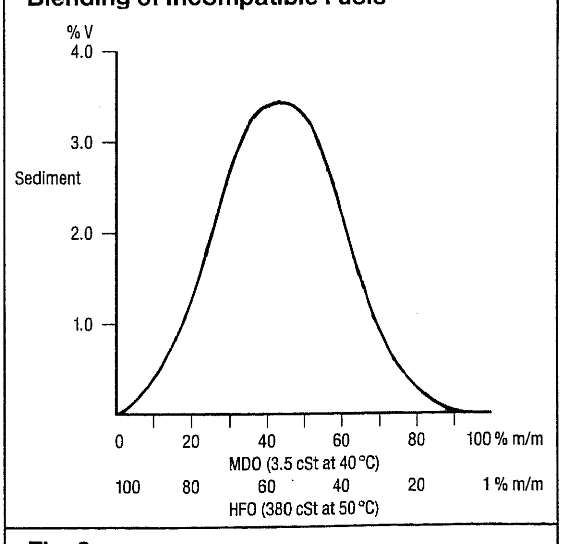


Fig. 6

When blending different fuel components, there is always a risk of incompatibility and consequent sludge formation. Incompatibility depends on particular properties of the component fuels employed, such as the solvent power of the diluent, the stability reserve of the residual fuel oil and the degree of dilution.

As illustrated in **Fig. 6,** with any specific blend there is a critical blending range with a tendency for maximum sedimentation. In the example illustrated, the range is from about 40 to 60 percent proportion of HFO to MDO. It is essential to be aware that the heavy fuel component is generally already a blend of residual oil cut back with a diluent to a marketable viscosity. The degree of diluent which can be tolerated by the heavy fuel depends therefore on the nature of the diluent (paraffinic or aromatic), and the stability reserve of the HFO.

Incompatibility can be evaluated by a number of laboratory tests, but these are not practical for shipboard application, with the exception of the modified ASTM spot test (see introduction).

A number of blending units are available on the market which are designed for use onboard ships. The blending should be achieved by a continuous process with in-line blending of the two components, automatically controlled to assure consistent viscosity. It is recommended to check that the settings or indicating instruments of the blender represent true values of the desired viscosity (or proportion of the fuel components respectively).

As time and temperature enhance the settling out of a blend, which often is unstable, the blended fuel should be fed directly into the engine and certainly not be kept in a tank.

The modern trend is to avoid blending, resulting in the "one fuel ship". There are several reasons for this trend:

1) Lack of stability is one of the dominating problems of todays fuels, and mixing it with the most common types of MDO is the greatest challenge for a fuel regarding compatibility. Heavy fuels that show reasonable compatibility with many other heavy fuels may become unstable if blended with MDO.

2) Because the most important fuel characteristics (like carbon residue, sulphur, vanadium) have a linear relationship to the applied ratio, a considerable reduction can only be obtained by using a large amount of MDO. This is expensive and increases the compatibility problems.

3) To obtain the required viscosity a smaller percentage of MDO is required. However, the required injection viscosity can also be obtained by heating. In all cases where the required temperature is acceptable, it is generally more attractive to heat the fuel than to run the risks associated with blending.

10. SAMPLING

10.1. Fuel as bunkered

Because the engine operators have little control about the way the "retained" sample is taken by the fuel supplier it is important for them to collect their own samples of the bunkered fuel.
The only correct way to do this is to drain some fuel continuously or at regular intervals during the whole bunkering period directly from the fuel feed. Three similar samples should be obtained, one for testing by one of the international fuel quality services, one for the fuel supplier and a sealed sample to be retained by the operator.

It would be a positive development if this "delivery sample" would replace the customary "retained sample". The first prerequisite to be fulfilled to that end would be for the supplier to watch the sampling procedure and to sign the samples as being representative of the delivery.

10.2 Fuel after treatment

It is strongly recommended that samples of the treated fuel are taken regularly (at least once a week). Analysis of this fuel is essential to ensure that the fuel treatment is effective.
Just as important however is to be able to detect any relationship between possible abnormal engine behaviour, wear or damage, and the specific properties of the fuel it burned. Lack of this kind of information has often delayed the understanding that could lead to the right measures being taken.

The fuel treatment system should be provided with a cock located in a convenient place (as close as possible to the engine). The sampling procedure should be made as simple as possible in order to encourage regular sampling.

10.3 Sampling method

(sample drawn from treated fuel)

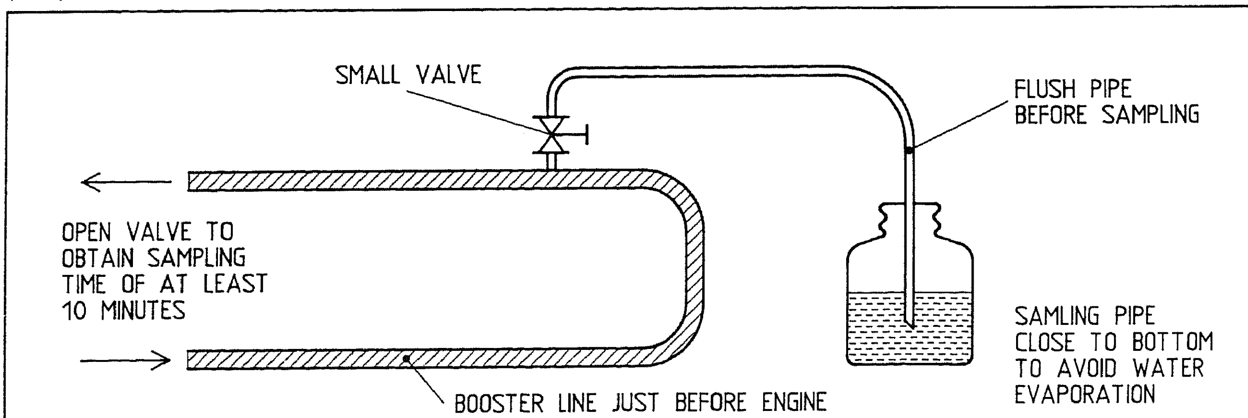


Fig. 7

11. SUMMARY

The key elements of this recommendation are listed in the following summary:

1. Design the fuel handling system such that different fuel supplies can be kept separate.
2. Apply trace heating to all transfer lines.
3. Settling tanks can be smaller than the conventional 24 hour capacity – 10 hrs seems sufficient –, and even less may be possible.
4. Service tanks can have a capacity of 10 hours or less.
5. Depending on the risk of obtaining incompatible, unstable or otherwise poor fuel, duplication of settling tanks and service tanks may be considered in order to keep fuels as separate as possible.
6. Careful design and location of heaters is important. Surface temperatures of more than about 170°C should be avoided.
7. Centrifuges are the key element of the fuel treatment. Selection of one of the types mentioned under "modern system" gives the freedom to use fuel with a density up to about 1010 kg/m^3 (15°C).
8. Install correctly sized centrifuges to obtain the required low throughput.
9. The fuel supply pumps should be positive displacement pumps, fitted close to the settling tank. The flow rate should be constant over long periods.
10. The clean fuel outlet should be subject to a constant back pressure.
11. The sludge discharge pipe should be of large area, straight and vertical.
12. A pressurised booster system avoids several problems associated with high viscosity fuels.
13. An emulsifier reduces the potential risks associated with non-dispersed water passing through the separator. A homogeniser performs the same function and in addition reduces the amount of filter clogging that can be caused by unstable fuels (which can be important in emergency situations). It should be positioned before the main filter or additionally before the safety filter.
14. Installation of a fine main filter is a logical and necessary supplement to the centrifuge.
15. It is recommended that automatic self-cleaning filters with partial backflush are utilised. Modern types with a very fine mesh and special provisions to keep the elements clean are worth consideration.
16. The more piping and equipment there is between the main filter and the engine, the more reason there is to apply an extra safety filter immediately before the engine.
17. There is no common opinion about the position of the main filter in the system.
18. Fuel blending by operators is risky and may not be very economic. If carried out, on-line blending directly before the engine should be used.

PREVIOUS PUBLICATIONS

1. Recommendations for Internal Combustion Acceptance Test —1961* (out of print)
German version is available
* Contents of these CIMAC recommendations is more or less completely adopted in ISO 3046, part 1—5

2. Recommendations for Gas Turbine Acceptance Test —1968 (English and French version)
Price £4.50 (plus postage)

3. Recommendations for the Measurement of the Overall Noise of Reciprocating Engines—1970 (English and French version)
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4. Recommendations for SI Units for Diesel Engines and GasTurbines—1975 (English and French version)
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5. Recommendations for Supercharged Diesel Engines*
Part I—Engine De-rating on account of Ambient Conditions
Part II—Engine Acceptance Tests
(English version only)(*not printed—photocopies)
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6. Lexicon on Combustion Engines, Technical Terms of the Internal Combustion Engine and Gas Turbine Industries—1977
(in Dutch, English, French, German, Italian, Spanish)
Price £10.00 (plus postage)

7. Recommendations regarding Liability—assured properties, publications, fuels for Diesel Engines (English version)
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11. Recommendations regarding Fuel Requirements for Diesel Engines
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12. Exhaust Emissions Measurement (Recommendations for reciprocating engines and gas turbines)
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The publications can be ordered (subject to availability) from:

1) The National Member Associations
2) The Secretary General of CIMAC, Mr E. Peter Davies, The Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, London SW1H 9JJ, United Kingdom.
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