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Preface

When the required vessel power profile has been evaluated and determined, both with regard to propulsion load and electrical load, the next step is to design the engine room configuration so that it will also be optimal with regard to installation, operation and maintenance. MAN B&W Holeby has not only looked at this as an isolated case for the L16/24 type auxiliary engines but, as described in the following, has also looked at it in relation to the MAN B&W two-stroke main engine on board.

The goal is to make the layout of the engine room and the operation and maintenance work in service as simple and effective as possible without jeopardizing the safety on board. A further aspect has been compliance with emission regulations.

The unifuel system is the proof of this where the fuel oil, cooling water and starting air systems are an integrated entity, minimizing the use of components and space, lowering the first cost, and providing simpler operation and maintenance.

In projects where both an MAN B&W main engine and MAN B&W auxiliary engines are ordered, possibly even from the same supplier, the buyer will have fewer contact people, common delivery and stand stronger in the negotiations of the price and extent of delivery. Even if the engines are ordered from different suppliers, there are still all the advantages mentioned in the following chapters of this paper, and the possibility of having the best economical choice of main and auxiliary engines, including the optimum solution in engine layout, power requirements for auxiliary systems, system diagrams, list of necessary capacities and technical advice on systems that deviate from MAN B&W Diesel standard.

For a typical project, with one two-stroke propulsion engine and three auxiliary engines, common installation documentation can be prepared and supplied to the yard and the end-user. In such material, the advantages of choosing both main and auxiliary engines of MAN B&W design will be given in detail, based on project-related engines.

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The MAN B&W Main and Auxiliary Engine Programmes

Two-stroke MC engines

The MC engines have been on the market for thirteen years during which time more than 3,500 engines have been sold. Internationally recognised as *the* prime mover in merchant vessels and power plants, the MC engine does not need many introductory remarks for those involved in either of these two fields. A reference list is given in Fig. 1.

The MC engine programme is constantly being developed and is extremely comprehensive, offering the optimum prime mover for each and every application. This is illustrated in Fig. 2, which shows the engine programme offered to the marine market.

Fig. 3 shows data indicating the evolution in ratings. There have also been substantial component improvements.

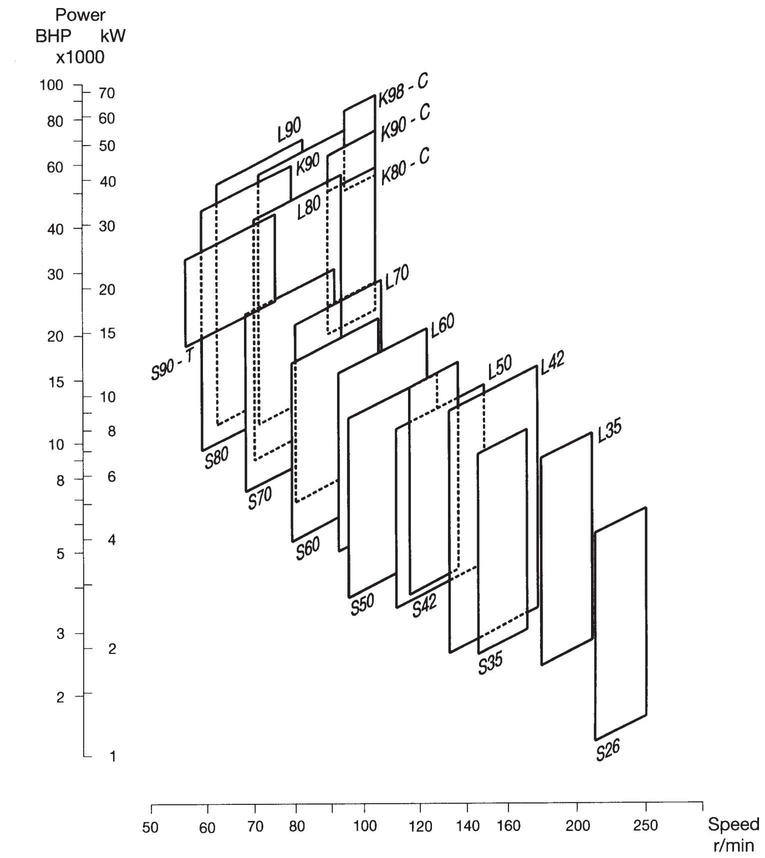

Fig. 2. The MC marine engine programme 1995

	No. of engines	
Type	On order or delivered	In service
90MC	121	71
80MC	339	307
70MC	456	369
60MC	1,046	891
50MC	686	495
42MC	132	106
35MC	634	524
26MC	131	115
Total	3,545	2,878

Total = 52,188,000 BHP ~ 38,384,000 kW

Fig. 1. MC engines on order and in service as at 1st September, 1995

Such improvements in component design, and the subsequent increases in engine ratings, have been possible only due to the extensive amount of service experience gained with the MC engines, and the continuous use of more and more advanced calculation techniques.

The engines in the present MC programme are given Mk V or Mk VI designations, where all engines with a mean effective pressure of 18 bar and above are referred to as Mk VI engines, and all others in the current programme as Mk V engines.

Mk introduced	I 1982	II 1984	III 1986	V 1991
L50MC				
bhp/cylinder	1440	1550	1650	1810
mep	15	16.2	16.2	17
r/min	133	133	141	148
L60MC				
bhp/cylinder	2080	2240	2360	2600
mep	15	16.2	16.2	17
r/min	111	111	117	123
L70MC				
bhp/cylinder	2830	3040	3200	3560
mep	15	16.2	16.2	17
r/min	95	95	100	106
L80MC				
bhp/cylinder	3690	3970	4210	4670
mep	15	16.2	16.2	17
r/min	83	83	88	93
L90MC				
bhp/cylinder	4680	5040	5310	5860
mep	15	16.2	16.2	17
r/min	74	74	78	82

Mk introduced	III 1986	V 1991	VI 1993
K80MC			
bhp/cylinder	4240		
mep	16.2		
r/min	100		
K90MC			
bhp/cylinder	5360	5870	
mep	16.2	17	
r/min	90	94	
K90MC			
bhp/cylinder			6220
mep			18
r/min			94

Mk introduced	III 1986	VI 1993
S50MC		
bhp/cylinder	1780	1940
mep	17	18
r/min	123	127
S60MC		
bhp/cylinder	2550	2780
mep	17	18
r/min	102	105
S70MC		
bhp/cylinder	3490	3820
mep	17	18
r/min	88	91
S80MC		
bhp/cylinder	4560	4950
mep	17	18
r/min	77	79
S90MC-T		
bhp/cylinder		6200
mep		18
r/min		75

Mk introcuced	(III) 1988	V 1991	VI 1993
K80MC-C			
bhp/cylinder	4410	4630	4900
mep	16.2	17	18
r/min	104	104	104
K90MC-C			
bhp/cylinder	5590	5860	
mep	16.2	17	
r/min	104	104	
K90MC-C			
bhp/cylinder			6210
mep			18
r/min			104
Mk introduced			VI 1994
K98MC-C			
bhp/cylinder			7760
mep			18.2
r/min			104

Fig. 3. Design development of the MC engines

With regard to the testing of engines and auxiliary components, the various MAN B&W departments exchange test results on a regular basis. This gives the other sectors of our organisation access to the accumulated experience and to the latest technology.

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Four-stroke GenSets

MAN B&W Holeby have produced GenSets for about 75 years. The number of engines sold of the current Generating Set programme appear from Fig. 4.

The L16/24 GenSet covers a lower power range than the existing L23/30H, which means that the total programme will cover a larger range.

The output ranges of the engine programme are shown in Fig. 5 and, as will be seen, they are able to cover the power needs of practically all ships in the merchant fleet today.

Type	No. of engines On order or delivered	In service
L23/30	1,166	923
L28/32	795	677
V28/32	51	
Total	2,012	1,600

Total = 4,054,291 BHP ~ 2,981,931 kW

Fig. 4. Auxiliary engines on order and in service

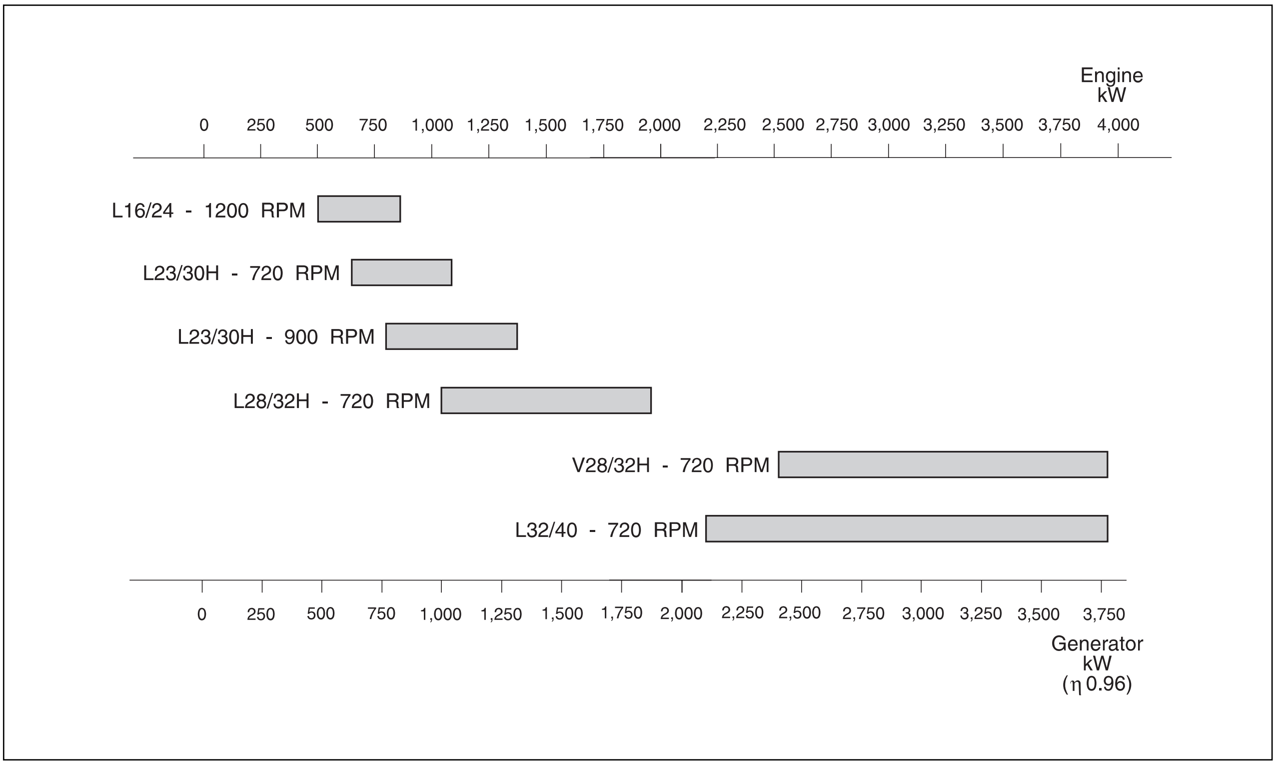

Fig. 5. Four-stroke layout areas

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In order to find the auxiliary power requirement for different ship types, we have evaluated data available from Lloyd's and other sources (see Fig. 6). The L16/24, which is the first in a new series, will cover the auxiliary power requirement of different ship types up to approximately 3,700 bhp. The auxiliary power in excess of this level will be covered by the larger engines coming in the same family.

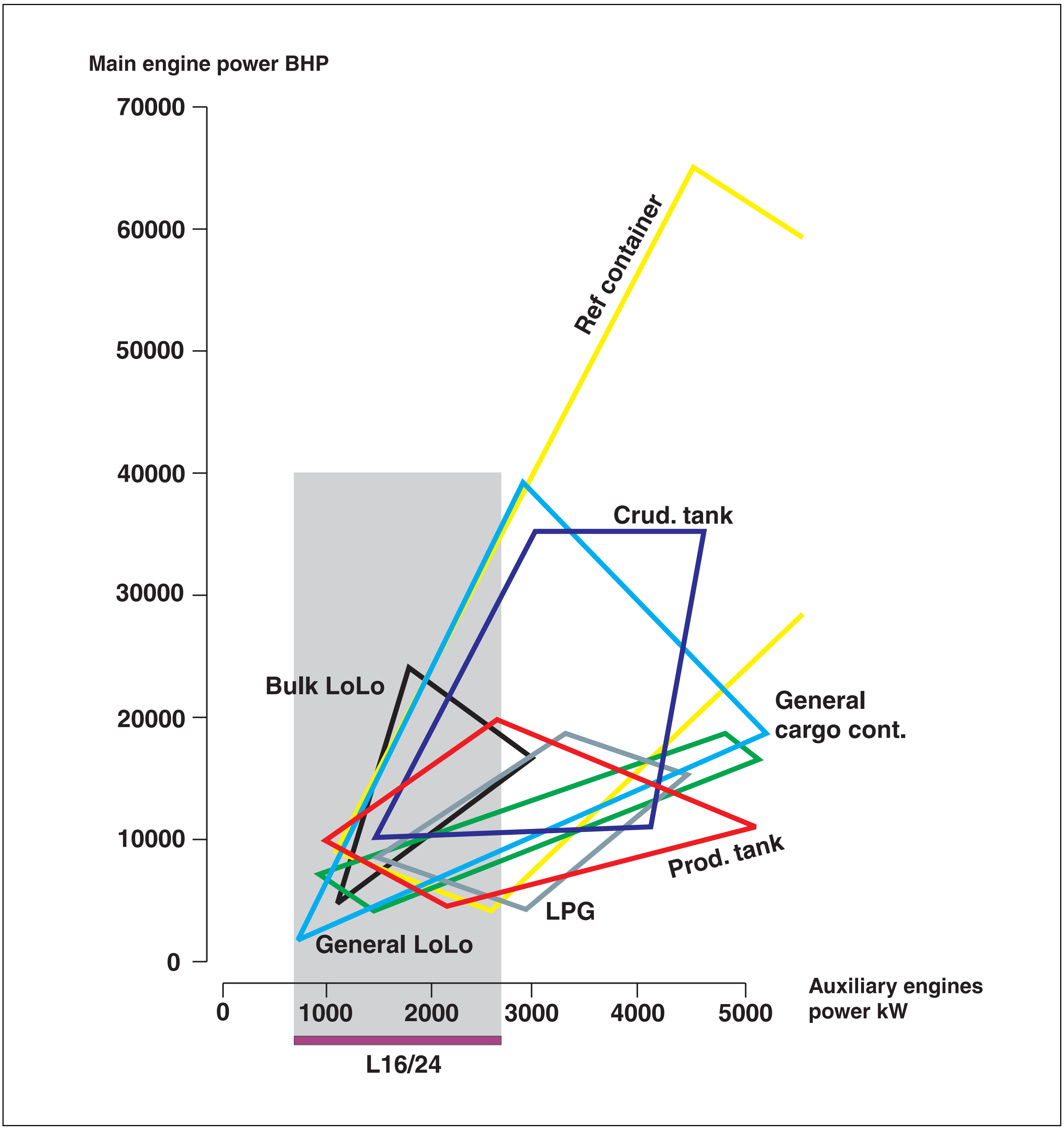

Fig. 6. Power requirements for auxiliary machinery for different ship types

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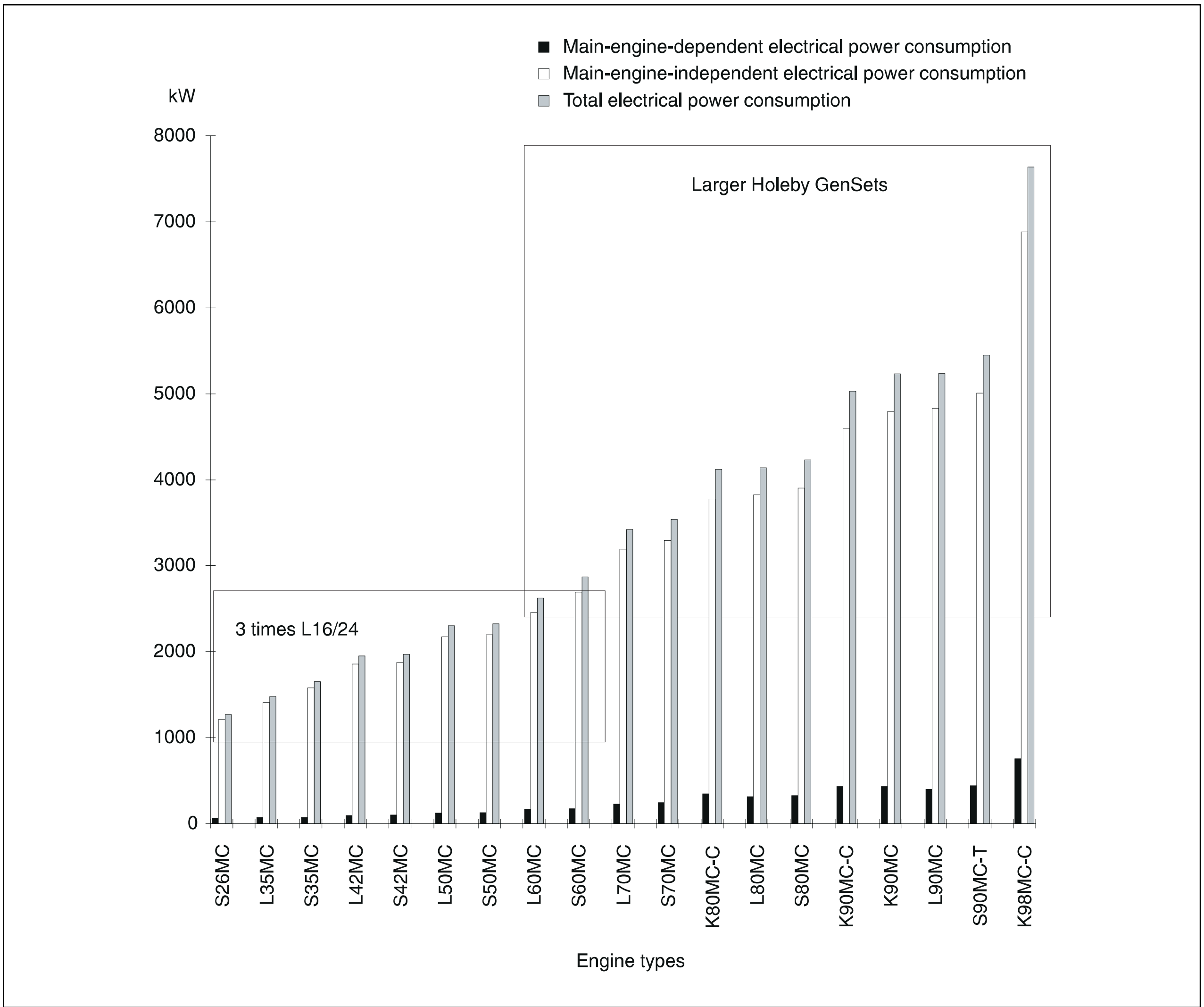

Fig. 7. Electrical power requirements for tankers and bulk carriers equipped with MC engines

In Fig. 7 we have calculated the electrical power requirement for the MC engines in tankers and bulk carriers.

The requirement for auxiliary power is very individual, however, our calculations are based on examples of data obtained from shipowners and yards. In the column for engine-dependent electrical power consumption, we have included all standard auxiliary systems, including auxiliary blowers.

For the ship-dependent electricity consumption, we have calculated with the following consumers: bow thrusters (300 - 1500 kW depending on ship type/ size), ventilation, air condensing, separation equipment, etc.

We assume that during manoeuvring the electrical consumption is twice that for calm sea operation and that two auxiliary engines running at 80% load are capable of delivering the entire electrical power requirement during manoeuvring.

**Fuel Oil System
- the 'Unifuel' system**

MAN B&W Diesel's two-stroke low speed diesel engines and MAN B&W Holeby four-stroke diesel GenSets are designed to operate in accordance with the unifuel principle, i.e. with the same fuel for both main and auxiliary diesels.

For guidance on purchase, reference is made to ISO 8217, BS6843 and to CIMAC recommendations regarding requirements for heavy fuel for diesel engines, edition 1990. From these, the maximum accepted grades are RMH 55 and K55. The mentioned ISO and BS standards supersede BS MA 100 in which the limit is M9.

Based on our general service experience, and as a supplement to the above-mentioned standards, we have prepared a guiding fuel oil specification, shown in Fig. 8.

Density 15°C	kg/m³	991 *
Kinematic viscosity		
at 100°C	cSt	55
at 50°C	cSt	700
Flash point	°C	≥60
Pour point	°C	30
Carbon residue	%(m/m)	22
Ash	%(m/m)	0.15
Total sediment after ageing	%(m/m)	0.10
Water	%(v/v)	1.0
Sulphur	%(m/m)	5.0
Vanadium	mg/kg	600
Aluminium+ silicon	mg/kg	80

Equal to ISO 8217/CIMAC - H55

* 1010 provided automatic modern clarifiers are installed

Fig. 8. Guiding fuel oil specification

On heavy fuel oil research we have, in Copenhagen and on board ship, run several tests with modified injection equipment to establish a basis for experience and confirm development within injection equipment, fuel treatment before injection, and emission. In 1995, a representative from MAN B&W Diesel has been elected chairman of the CIMAC Heavy Fuel Oil working group.

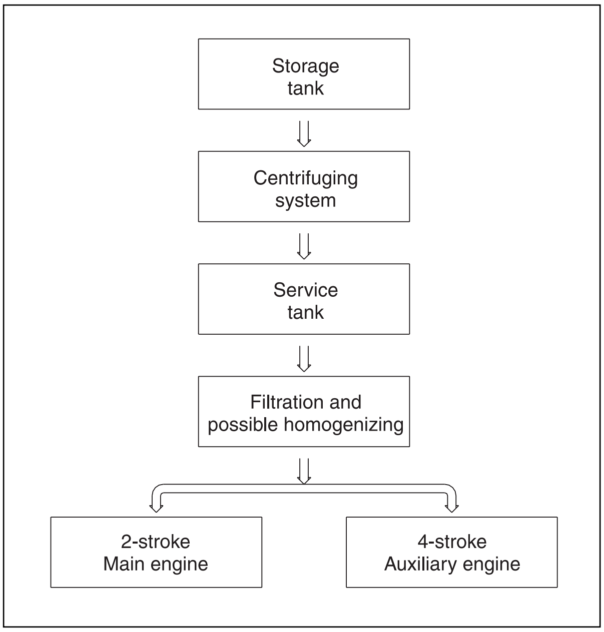

Fig. 9. Heavy fuel oil treatment concept

The common system covers the entire fuel oil flow from storage tank to injection into the engine cylinders.

With regard to centrifuge recommendations, fuel oils should always be considered as *contaminated upon delivery* and should therefore be thoroughly cleaned to remove solid as well as liquid contaminants before use. The solid contaminants in the fuel are mainly rust, sand, dust and refinery catalysts. Liquid contaminants are mainly water, i.e. either fresh water or salt water.

Impurities in the fuel can cause damage to fuel pumps and fuel valves, and can result in increased cylinder liner wear and deterioration of the exhaust valve seats. Also increased fouling of gasways and turbocharger blades may result from the use of inadequately cleaned fuel oil.

Effective cleaning can only be ensured by using a centrifuge.

Results from experimental work on the centrifuge treatment of today's residual fuel qualities have shown that the best cleaning effect, particularly in regard to the removal of catalytic fines, is achieved when the centrifuges are operated in series, i.e. in purifier/clarifier mode.

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This recommendation is valid for conventional centrifuges. For more modern types, suitable for treating fuels with densities higher than 991 kg/m^3 at 15°C, it is recommended to follow the maker's specific instructions.

In view of the fact that some fuel oil standards incorporate fuel grades without a density limit, and also the fact that the traditional limit of 991 kg/m^3 at 15°C is occasionally exceeded on actual deliveries, some improvements in the centrifuging treatment have been introduced to enable the treatment of fuels with higher density.

With such equipment, adequate separation of water and fuel can be carried out in the centrifuge, for fuels up to a density of 1010 kg/m^3 at 15°C. Therefore, this has been selected as the density limit for new high density fuel grades.

Thus high density fuels are fully acceptable for our engines provided that appropriate centrifuges are installed. They should be operated in parallel or in series according to the centrifuge maker's instructions.

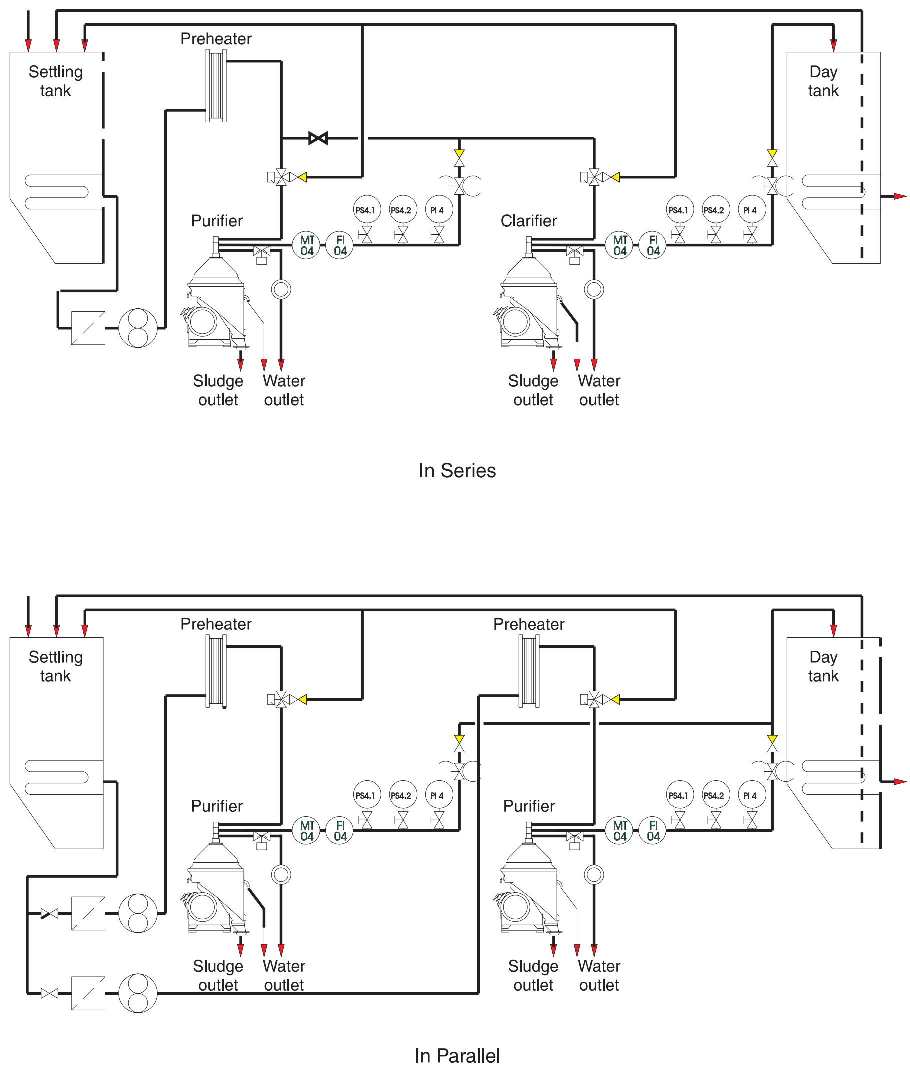

Fig. 10. Fuel oil centrifuges - series and parallel operation

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Fuel oil system

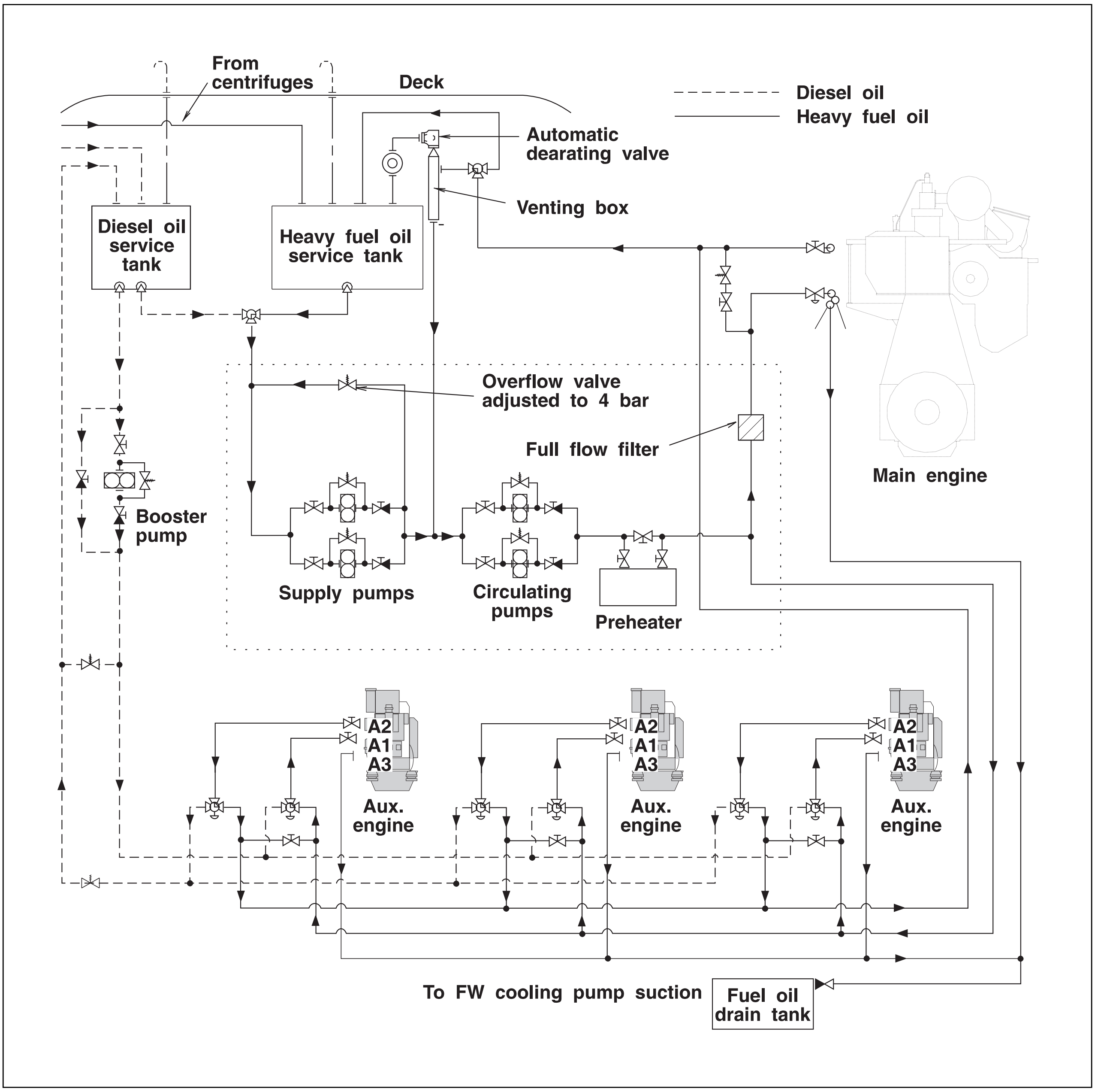

Fig. 11. Fuel oil system

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Design features and working principle

The fuel oil system is a common, pressurised system in which both heavy fuel oil and diesel oil can be used. The purpose of pressurisation is primarily to avoid boiling and cavitation in the system, which may occur when the heavy fuel oil is heated to achieve the viscosity of 10-15 cSt required for injection.

Operation at sea

The fuel from the bunker tanks must be treated in centrifugal separators before entering the service tanks. From the service tanks, the fuel enters the supply system.

In the supply system, the fuel is pumped by the supply pumps, into a circulating system at a pressure of 4 bar. The supply system may include a fine filter. All overflow from the supply pumps is recirculated in the by-pass piping, which incorporates the overflow valve shown in order to keep the inlet pressure in the circulation loop constant, irrespective of the actual consumption.

The pumps in the circulation loop, raise the pressure of the fuel oil from the supply system to a constant inlet pressure of 7-8 bar before the engines. The inlet pressure is maintained at the specified level by a spring-loaded overflow valve located on the main engine. The temperature or viscosity controlled preheater heats the heavy fuel oil until it reaches the necessary viscosity. To safeguard the injection system components on the main engine, a full-flow 50 μ filter, must be installed as close to the main engine as possible. Such a filter is already built onto the auxiliary engines.

Excess fuel oil supplied to the engines is recirculated via the venting box, where gases, if any, are released by a deaerating valve, to avoid cavitation in the system.

The flexibility of the system makes it possible, if necessary, to operate an auxiliary engine on diesel oil by means of remote controlled 3-way valves, which should be located close to the auxiliary engines.

A separate booster pump supplies diesel oil from tank 2 to the auxiliary engines and returns any excess oil to the tank. In order to ensure operation of the booster pump in the event of a black-out, the booster pump must have an immediate possibility of being powered by compressed air or by power supplied from the emergency generator.

A 3-way valve is installed immediately before each auxiliary engine for change-over between the pressurised and the open MDO (Marine Diesel Oil) supply system.

In the event of a black-out, the 3-way valve at each auxiliary engine will automatically change over to the MDO supply system. The internal piping on the auxiliary engines will then, within a few seconds, be flushed with MDO and be ready for start up.

Operation in port

During operation in port, when the main engine is stopped, but power from one or more auxiliary engines is still required, the supply pump should be running. One circulation pump should always be kept running when there is heavy oil in the piping.

The by-pass line with overflow valve between the inlet and outlet of the main engine serves the purpose of by-passing the main engine if, for instance, a major overhaul is required on the main engine fuel oil system. During this by-pass, the overflow valve takes over the function of the internal overflow valve of the main engine.

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Central Cooling Water System

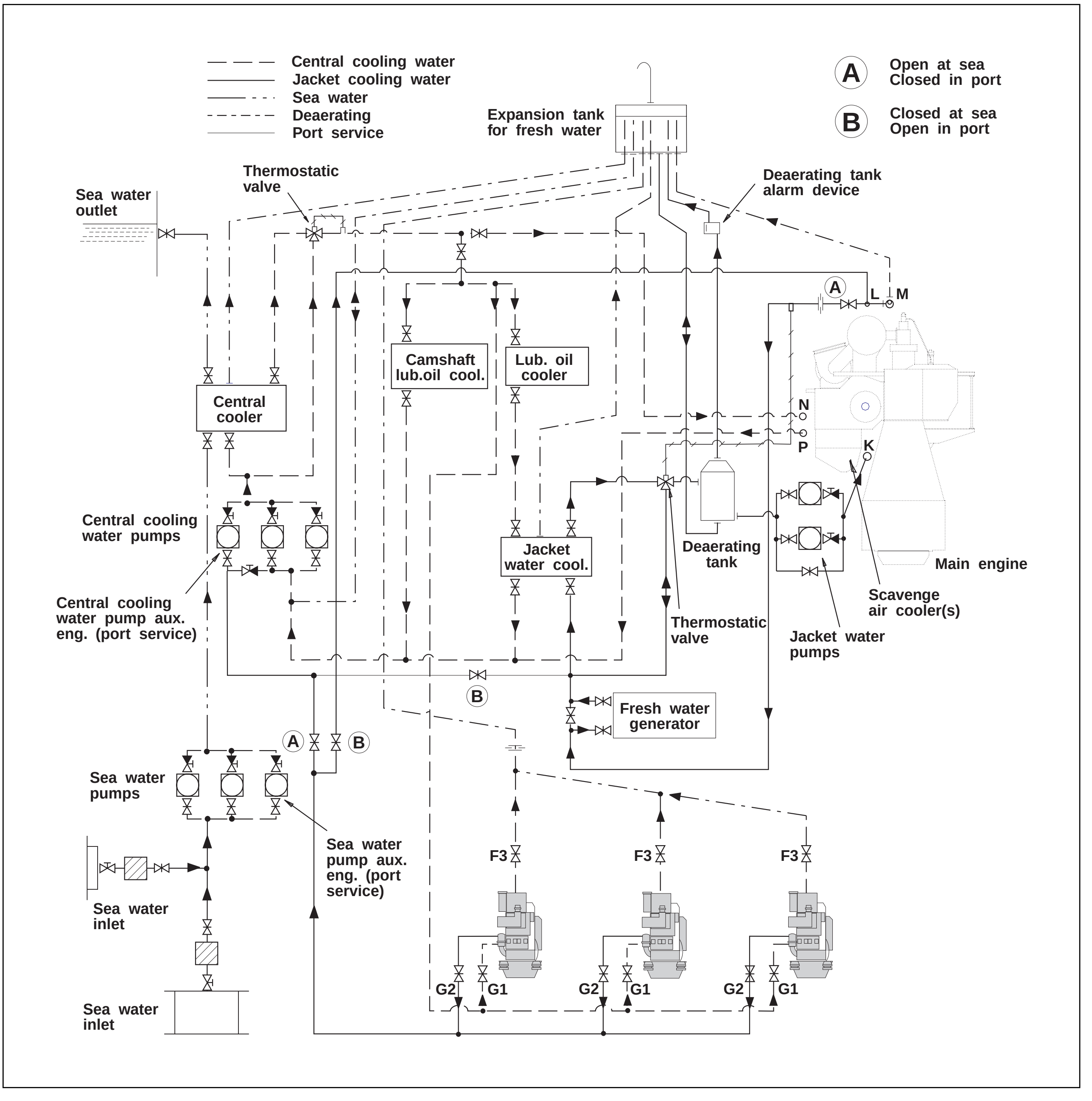

Fig. 12. Central cooling system

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Design features and working principle

The central cooling system is an alternative to the conventional seawater cooling system, based on the same design principles with regard to cooler locations, flow control and preheating, but with a central cooler and one additional set of pumps.

Maintenance work is minimised by the use of a central cooler, as this is the only component that is in contact with seawater. All other parts of the system use inhibited freshwater in accordance with MAN B&W's specifications.

The low and high temperature systems are directly connected to gain the advantage of preheating the main and auxiliary engines during standstill.

As all fresh cooling water is inhibited and common for the central cooling system, only one common expansion tank is necessary for deaeration of both the low and high temperature cooling systems. This tank accommodates the difference in the water volume caused by changes in the temperature.

To prevent the accumulation of air in the cooling water system, a deaerating tank is located below the expansion tank. An alarm device is inserted between the deaerating tank and the expansion tank so that the operating crew can be notified if excess air or gas is released, as this signals a malfunction of engine components.

Operation at sea

The seawater cooling pumps pump seawater from the sea chests through the central cooler, and overboard. Alternatively, some shipyards use a pumpless scoop system. On the freshwater side, the central cooling water pumps circulate the low-temperature freshwater, in a cooling circuit, directly through the lubricating oil coolers of the main engine, the auxiliary engines and the scavenge air coolers.

The jacket water cooling system for the auxiliary engines is equipped with engine-driven pumps and a by-pass system integrated in the low-temperature system, whereas the main engine jacket system has an independent pump circuit with jacket water pumps, circulating the cooling water through the main engine to the freshwater generator and the jacket water cooler.

A thermostatically controlled 3-way valve at the jacket cooler outlet mixes cooled and uncooled water to maintain an outlet water temperature of 80-85 °C from the engine.

Operation in port

During operation in port, when the main engine is stopped, but one or more auxiliary engines are running, valves A are closed and valves B are open. A small central water pump will circulate the necessary flow of water for the air cooler, the lubricating oil cooler, and the jacket water cooler of the auxiliary engines. The auxiliary engine-driven pumps and the above-mentioned integrated loop ensure a satisfactory jacket cooling water temperature at the auxiliary engine outlet.

The main engine and the stopped auxiliary engines are preheated by the operating auxiliary engine(s).

Starting Air System

Design features and working principle

Two air compressors, with automatic start and stop, maintain a starting air pressure of 30 bar in the starting air receivers.

The main engine is supplied with 30 bar starting air directly from the starting air receivers. Through a pressure reduction station, compressed air at 7 bar is supplied as control air for the engine manoeuvring system, and as safety air for the emergency system.

Starting air and control air for the auxiliary engine(s) is also supplied from the same starting air receivers, via reducing valves that lower the pressure to a value suited to the actual type of MAN B&W four-stroke auxiliary engines chosen.

An emergency air compressor and a starting air bottle are installed for redundant emergency start of the auxiliary engines.

If high-humidity air is sucked in by the air compressors, an oil and water separator will remove moisture drops present in the 30 bar compressed air. When the pressure is subsequently reduced to 7 bar, as for the main engine manoeuvring system, the humidity in the compressed air will be very slight. Consequently, further air drying is considered unnecessary.

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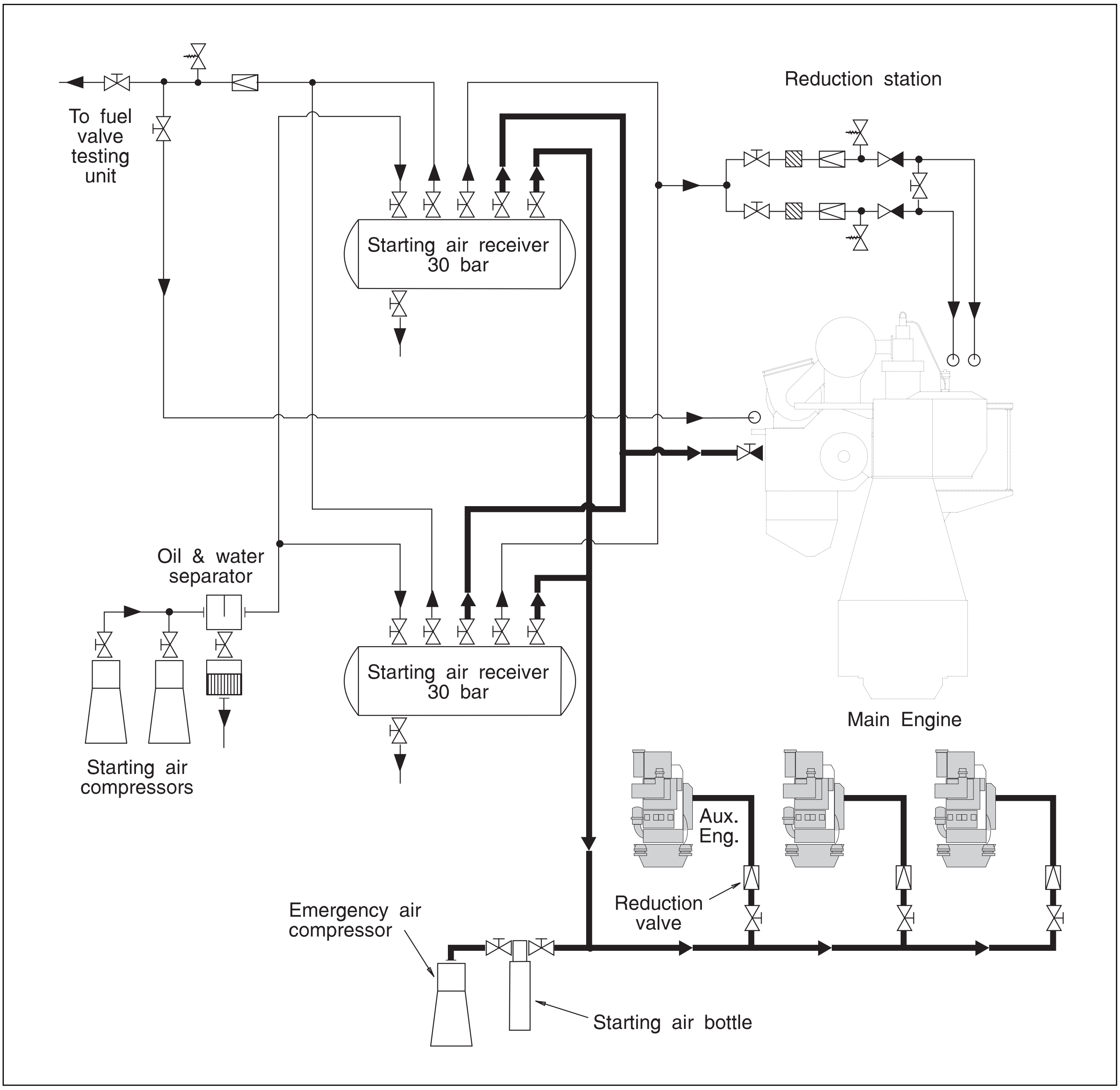

Fig. 13. Starting air system

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From the starting air receivers, a special air line leads to the valve testing equipment.

Lubricating Oil System

The lubricating oil systems cannot be combined, and different grades of main lubricating oil may have to be used, as the auxiliary engines operate without stuffing boxes, and their combustion chamber is thus not completely isolated from the oil sump. The lubricating oil for the auxiliary engines therefore has to have a higher TBN to obtain the appropriate neutralisation of sulphuric acid formed during combustion. An initial TBN level of at least 20 is recommended for GenSets, whereas two-stroke main engines use TBN 5.

CoCoS – Computer Controlled Surveillance

CoCoS is a software program package for helping the engine room crew. CoCoS consists of four modules that can be used individually or together. The modules can help in fault finding, work planning, managing ship's stock and handling spare parts orders. An electronic version of the instruction book will also be included in the complete package.

CoCoS has been developed within the MAN B&W Diesel group and, in the programming, both MAN B&W Diesel's main engine and auxiliary engines have been considered.

The development work is being performed as an inter-company project, involving MAN B&W Diesel in Copenhagen (MBD-K), Alpha Diesel (MBD-F), Holeby Diesel (MBD-H), MAN B&W Diesel in Augsburg (MBD-A) and Pielstick in France. The engine diagnostics part is being developed on the basis of the experience gained with MBD-K's CAPA, MBD-A's Modis and MBD-H's HGM and will, when finished, be able to replace these products. The three other modules include areas that are new to us.

CoCoS modules

The system consists of four modules:

- CoCoS-EDS - Engine Diagnostics System
- CoCoS-MPS - Maintenance Planning System
- CoCoS-SPC - Spare Parts Catalogue
- CoCoS-SPO - Stock and Parts Ordering System

CoCoS-EDS is a system in which data from the engine is processed. Data can be collected directly from sensors located on the engine. Data can also be keyed into the system manually.

What can CoCoS be used for? Well, values can be processed and compared with the values they ought to be. On this basis a trend (tendency) is calculated, for example, how the various parameters will develop/change with time. All this can be used to find out whether something is wrong. If something abnormal is observed, it will be analysed/diagnosed, and the result will be a diagnosis. One can make the comparison with a doctor who makes a diagnosis and prescribes medicine. The medicine which the system will prescribe here is a job of work. The work will be ordered in the CoCoS-MPS module.

A Beta-version of CoCoS-EDS has been in operation in a container vessel since July 1994, and the crew has expressed great satisfaction. CoCoS-MPS, CoCoS-SPC and CoCoS-SPO became available for Beta-testing in 1995.

CoCoS-MPS is used primarily for planning the inspection and maintenance work that must be performed after a certain number of service hours or calendar days. Jobs are listed and presented visually. In this way, the user can see when and what should be done, choose jobs and make work schedules that suit the sailing schedule. CoCoS-EDS can be used to specify personnel, work tools and spare parts that should be employed to make work go without a hitch.

CoCoS-EDS also contains a reporting function for the recording of jobs that have been completed. Historical data concerning the different jobs can be logged, so as to retain valuable work experience.

The instruction book will also be included in this module, not only in the form of text and graphics but, in future versions, also in the form of video clips of the various jobs considered relevant. With video clips incorporated in CoCoS-MPS, the user need not view an entire film to get information, but can make do with just those sequences which are actually needed.

CoCoS-SPC is an electronic catalogue that can be used to identify spare parts. Components can be found in three ways: by using a search word; by clicking on a drawing (by this means one can zoom in on specific areas or parts of drawings, simply by clicking on them with the mouse, so that individual parts and components can be examined in more detail); and a further possibility is a systematic breakdown of the Plate / Item parts list, for example, to find a piston.

CoCoS-SPO is a combined inventory and spare parts ordering system which can be used to obtain all information about the size, weight, location on board ship of an individual component, how many there are in stock, etc. It will also be possible to follow-up historically on large components.

The ordering part of the system gives the crew an administrative tool for ordering spare parts from the shipowner or supplier and, at the same time, keeping check of all orders.

Joint Services – Main and Auxiliary Engines

Main and auxiliary engine spare parts

Spare parts for the Holeby GenSets are produced in accordance with the same demanding specifications that are valid for the GenSets themselves.

The worldwide operation of Holeby GenSets is backed-up by a spare parts stock containing over 15,000 different items. The fastest possible delivery of these parts depends on our receiving complete and accurate forwarding details.

To enable the fastest processing of marine spare parts orders, contact is to be made to Diesel Service in Copenhagen, or one of our local offices, giving them all details.

Because the same departments in Copenhagen are involved with spare part orders for the main engine, the same contacts, the same systems, the same high quality of spare parts are available for the Holeby GenSets. Accordingly, the newly introduced unit concept of cylinder covers, complete with valves, etc., being forwarded for parts exchange/reconditioning purposes to MAN B&W Diesel in Copenhagen or one of our service centres will be treated in the same way.

Common tools

In order to simplify overhaul, as well as to save investment, space and stocks, the MAN B&W two-stroke engines and the Holeby GenSets can share a number of common tools.

The following tools are normally the same for the MAN B&W Diesel main engine and the auxiliary engines:

- Air driven high pressure pump for hydraulic tools
- Manual high pressure pump
- Eye screw for lifting of piston
- Shackle for lifting of piston
- Torque spanner
- Max. pressure indicator
- Pressure testing pump for fuel valve.

Emission Control and Compliance

Emission rules and emission control techniques are being discussed and developed internationally, nationally and regionally, particularly as regards NO_x and SO_x.

Fig. 14 shows the internationally applicable target levels proposed by IMO – the International Maritime Organisation.

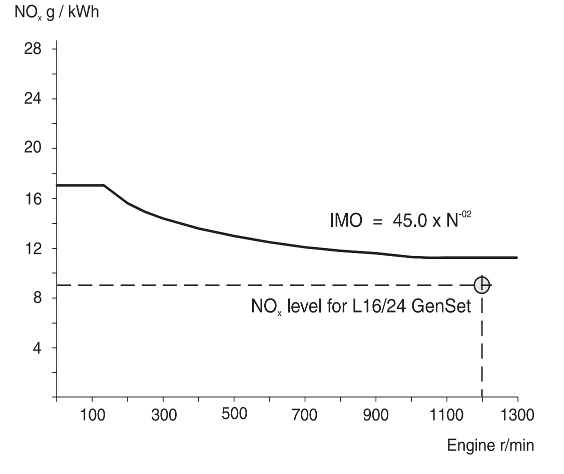

Fig. 14. Proposed IMO emission limits

Another proposed rule is that of the EPA (Environmental Protection Agency) for the west coast of the USA based on a user fee penalty, depending on the actual NO_x emission level.

These two sets of rules represent two very different approaches. Most other bodies seem to be taking a wait-and-see attitude until these proposals have been fully discussed and developed.

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While chemical methods and washing/scrubbing processes to remove SO_x from the exhaust gas are known, the most pragmatic and economical approach would probably be to control the fuel oil sulphur content. From the legislation and control points of view this is the simplest approach.

As far as diesel engines are concerned, a reduction in the fuel oil sulphur content from the current maximum of 5% to a realistic lower value would involve no technical complications. Consequently, efforts are being concentrated on NO_x control methods.

It is realised that, irrespective of the rules, policing of compliance will be difficult. The California EPA will generally give economical favours to those with lower NO_x, as illustrated in Fig. 14, making policing more demanding.

Owners are already starting to specify emission measurements as part of shop-testing. Verification of engine performance by testbed running will in future be meaningless without corresponding emission measurements.

The technical possibilities for NO_x reduction in low speed diesels include both primary (internal) methods and secondary (external) methods.

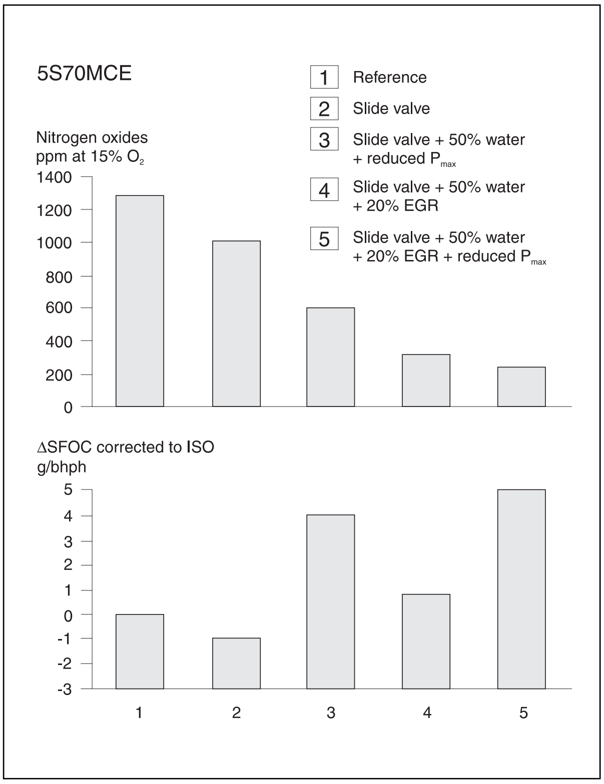

Fig. 15. NO_x reduction potential shown with primary methods

Obviously, the market favours primary methods of meeting requirements like those proposed by the IMO and, indeed, this is the most practicable approach.

Fig. 15 shows that with primary methods an 80% reduction has been achieved on an S70MC engine in test conditions.

The IMO proposal – assuming a reasonable and pragmatic formulation – can be met with our main engines using primary methods of NO_x control, whereas the generator set engines already meet IMO.

When using water emulsification (i.e. water emulsified into the heavy fuel) or primary methods of reducing the NO_x to the IMO level, the fuel injected into the auxiliary engine will also have water added when the unifuel system is being used.

This, however, is only an advantage since the relatively low NO_x level for the L16/24 engine will be reduced further, with no disadvantage on engine performance.

Fig. 16 shows the expected NO_x levels at different loads for the L16/24 GenSets.

If further NO_x reduction to an extent calling for secondary methods will be required, this can be done by SCR (Selective Catalytic Reduction). The two-stroke engine will require its own catalyst, but the L16/24 auxiliary engines can operate on a common catalyst. For the L16/24, primary methods have great potential, and catalysts are not foreseen.

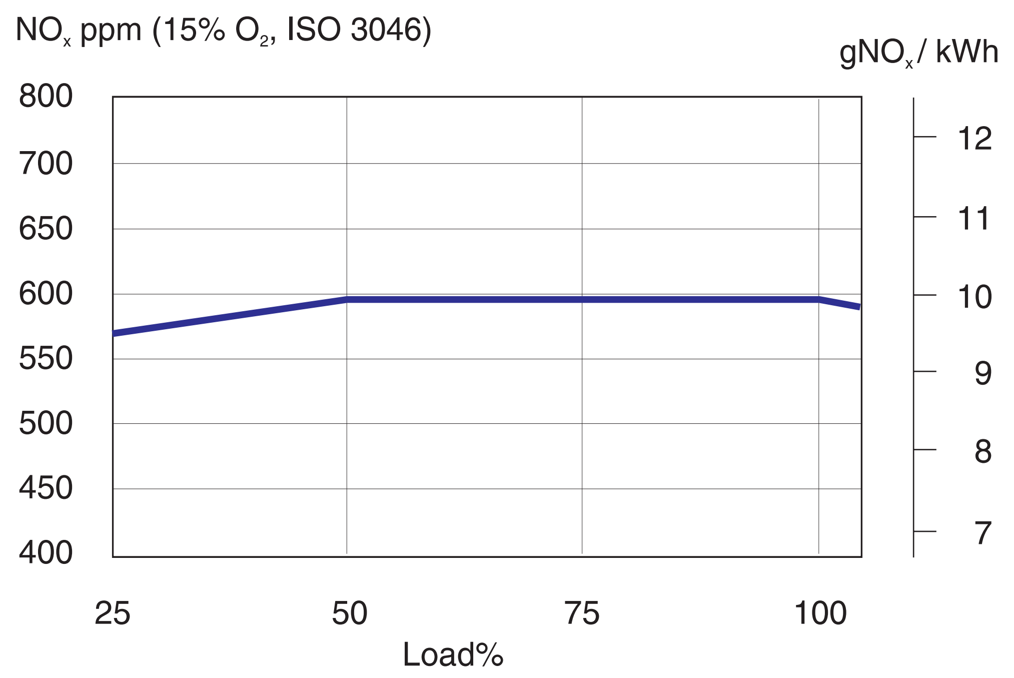

Fig. 16. Expected NO_x level for the L16/24 type engine

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Note!

All our product ranges are constantly under review, being developed and improved as needs and conditions dictate.

We therefore reserve the right to make changes to the technical specification and data without prior notice.