Table 4 of this Appendix shows the final summary of the operating costs and in that the potential for additional income is above 3.5 million US$/year.

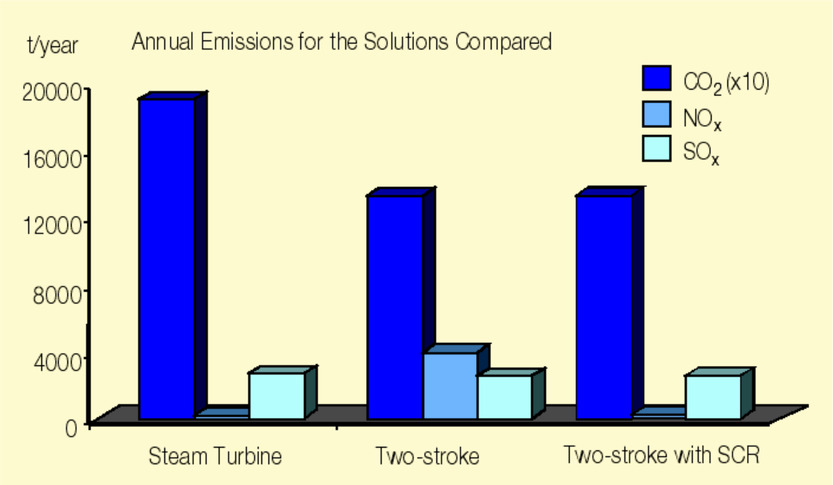
In Fig. the result of the summary in Table 4 is visualized for various sizes of LNG carriers. The additional sale of reliquefied BOG brings the large saving. The savings depends, of course, on the sale price of LNG compared to HFO. Fig. 30 shows the advantage by reliquefaction compared to steam propulsion for a 150,000 m3 LNG carriers as a function of the LNG price compared to the HFO price per energy unit. For guidance, historically price levels of LNG and HFO on some LNG markets are shown.

4.2.3 Investment cost:-

Shipyards that today build LNG carriers have much more experience of installing diesel engines than steam turbines and boilers. The installation of two-stroke diesel engines are therefore already known to the yards and the cost can be kept low. The direct-coupled diesel solution incl. reliquelation plant requires lower investment cost than the steam plant, as far as equipment is concerned. However, the twin-screw solution proposed does represent added cost on the hull side at some shipyards. This could be up to US$ 3-4 million, but the total cost is still comparable to that of the steam plant.

4.2.4 Exhaust Emissions:-

The expected annual exhaust emissions for the solutions is shown in Fig. 31. The CO2 emission is obviously largest for the steam plant due to its low efficiency. The SOx from the fuel sulphur is about the same, as the same amount of fuel is used. This can be reduced by using fuel with low sulphur content for both steam turbine and diesel engine propulsion.



Emissions for the solutions compared

The proposed diesel solution complies with the IMO limits for NOx emissions and is therefore without any NOx abatement. However, the NOx can, if needed, be reduced to any level by Selective Catalytic Reduction.

4.2.5 What’s Special In It-A Comparative Analysis :-

As mentioned in the introduction, the purpose of making electronic engines is focused around the virtues related to “ensuring fuel injection and rate, as well as exhaust valve timing exactly when and as desired”. With respect to the exhaust valve movement, this means changing the ‘cam length’, as illustrated in Fig. by simply changing the point in time of activating the ELVA valve.

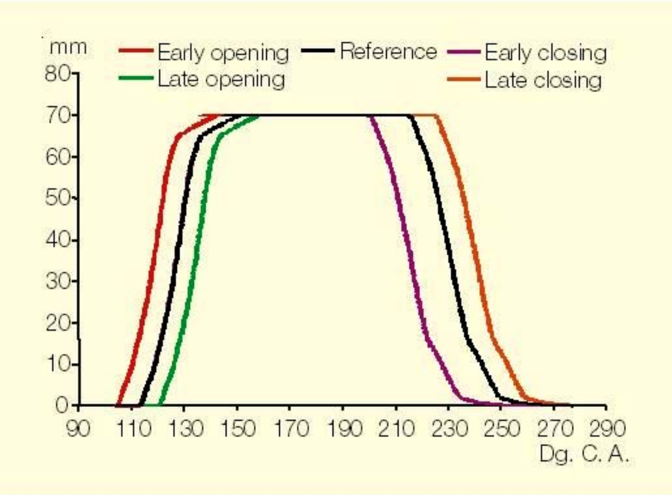


Fig. 24: Exhaust Valve Timing

This can be used to control the energy to the turbocharger, both during steady and transient load conditions.

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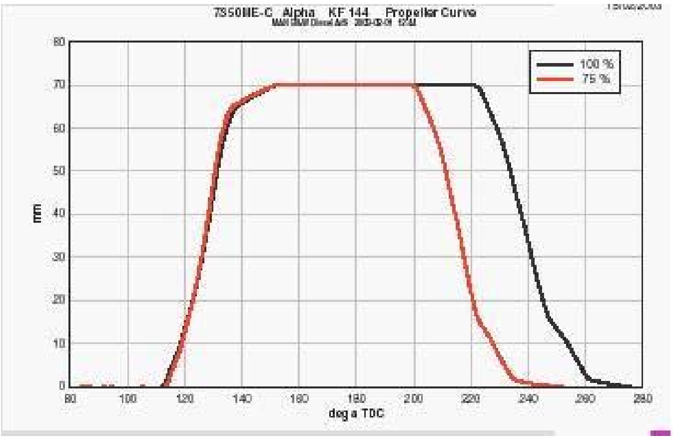


Fig. 25: Exhaust Valve Closing Time

Smoke-free acceleration is a natural benefit apart from SFOC optimization at any load. Fig. 25 gives an illustration of how already a ‘different cam length’ was implemented on the 7S50ME-C engine in Frederikshavn for 100% load vs. 75% load

Thanks to the multitude of possibilities with the ELFI, the proportional valve controlling the servo oil pressure to the fuel oil pressure booster, not only the fuel oil ‘cam length’, but also the ‘cam inclination and angle’ and even the number of activations per stroke can be varied for the fuel oil injection. Fig. 26 illustrates different profiles demonstrated during testing of the 7S50ME-C.

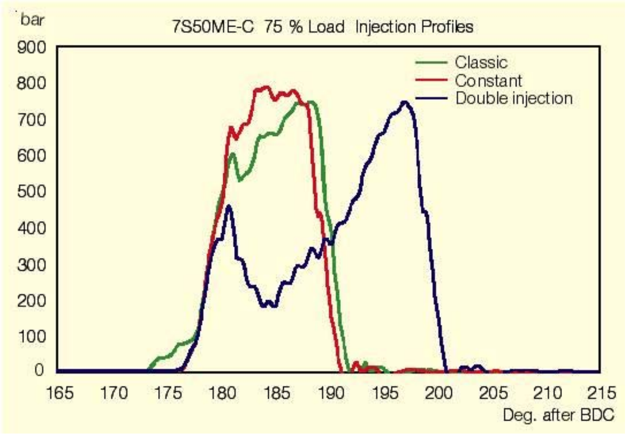


Fig. 26: Injection Profiles

The double injection profile is specially tailored for a significant reduction of NOx emissions as referred to later (see Fig. 32). Fig. 27 shows the selected injection rate on that engine at 75% load, compared with what it would have been with a fixed cam.

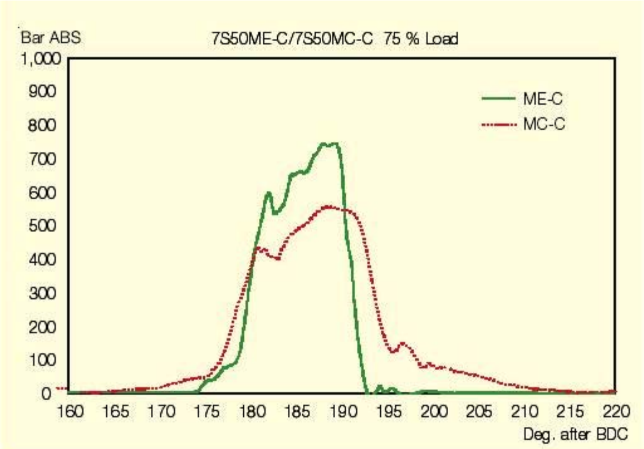


Fig. 27: Injection at 75% load, ME-C versus MC-C

The resulting heat release, see Fig. is the reason for selecting a more intensive injection.

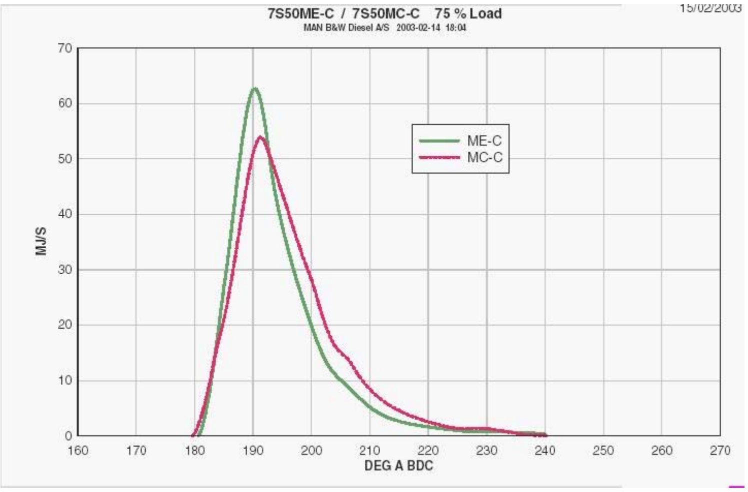


__Fig. 28: Heat Release at 75% load, ME-C versus MC-C__

A better heat release mirrors a better fuel consumption, also because the pmax is higher, see Fig. Such data could of course also be realised on a

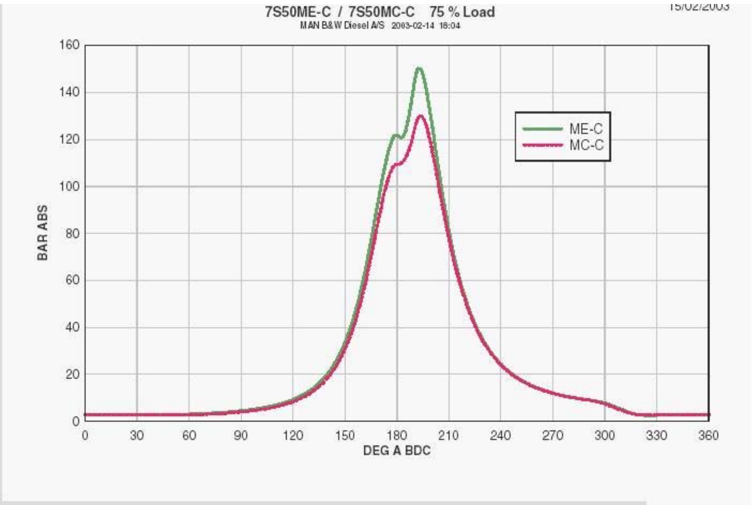


__Fig. 29: Cylinder Pressures at 75% load, ME-C versus MC-C__

mechanical engine, but not while at the same time maintaining the ability to perform at 100% load. In the low end of the load scale, the possibility for controlling the timing and rate of injection gives the possibility to demonstrate stable running down to 10% of MCR-rpm, i.e. 13 rpm against a water brake only. This could be even more stable against a propeller eliminating the need for stop-and-go operation through channels and canals and making ME engines particularly suitable for shuttle tankers and lightering vessels, as well as for vessels with greatly varying load profile. General performance curves for the ME-C and MC-C engines are shown in Fig. 30. The lower part load fuel consumption is achieved by raising the pmax over the whole load range.

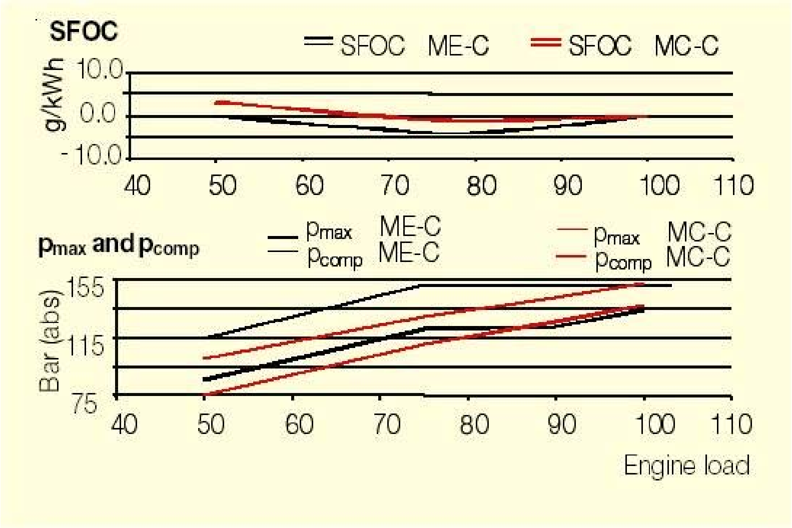


__Fig. 30: Performance Curves, ME-C versus MC-C__

In order to avoid too high difference between pmax and pcomp, also this pressure is raised by timing control. As also illustrated, the lower SFOC comes at a price in that the NOx increases. For this reason, the first two modes to be incorporated in the control system of the ME engine, as standard, are the 'fuel economy mode' and the 'low-NOx' mode. Fig. 31 illustrates the coagency between SFOC, NOx, and pmax/Pcomp for the two modes.

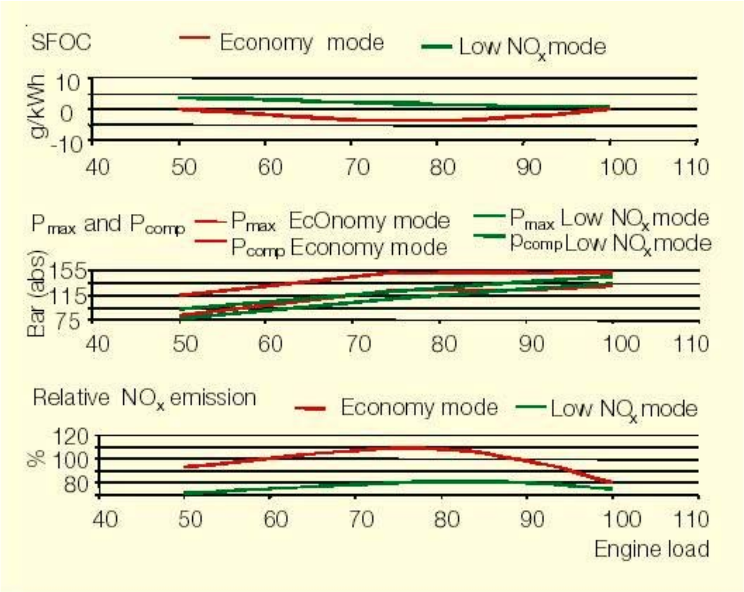


__Fig. 31: Performance Curves, Economy versus low-NOx__

It goes without saying that an ME-C engine will comply with IMO's NOx cap also in the fuel economy mode.

The low-NOx mode is intended for areas where lower than IMO NOx limits do or will apply. The change from one mode to the other is a matter of seconds only and, of course, is done while running, as illustrated in Fig.

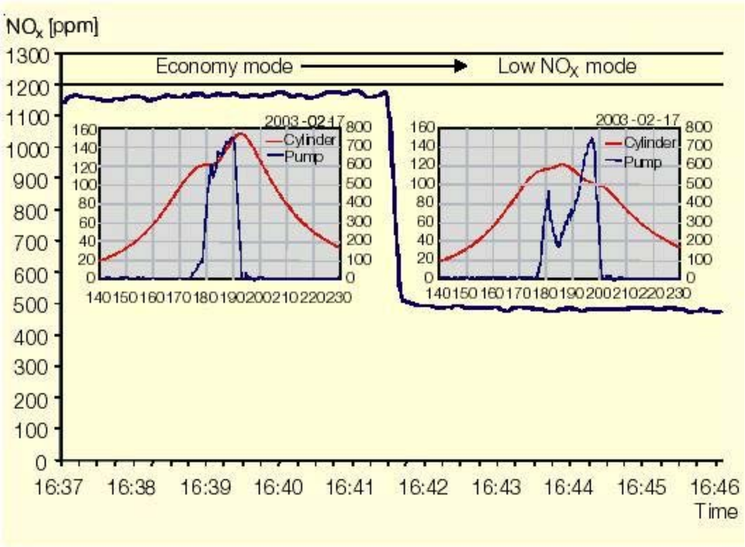


Fig. 32: 7S50ME-C – 75% load

4.2.6 Reduced Fuel Consumption

- Fuel injection characteristics can be optimised at a large number of load conditions whereas a conventional engine has to be optimised for the guaranteed load, typically at 90–100 % MCR.
- Constant pmax in the upper load range can be achieved by a combination of fuel injection timing and variation of the compression ratio (the latter by varying the timing of closing the exhaust valve). Due to this, the maximum pressure can be kept constant over a wider load range without overloading the engine, leading to SFOC reductions at part-load.
- Monitoring of the cylinder pressures ensures that the load distribution among the cylinders and the individual cylinder's firing pressure can be kept up to as new standard, maintaining the as new performance over the lifetime of the engine.

4.2.7 Operational Safety & Flexibility

The ME engine's crash stop and reverse running performance are improved because the timing of exhaust valves and fuel injection is optimal for all engine operation scenarios.

- ✓ Faster acceleration of the ME engine is possible because the scavenge air pressure can be increased faster than normal opening the exhaust valve earlier during acceleration.

- ✓ Dead slow running and slow steaming are improved significantly as the minimum rpm are 10–12 % of the MCR level, and dead slow running is more regular because the combustion is improved thanks to the electronic control of the fuel injection.
- ✓ The control system of the ME engine includes an on-line overload protection system, which ensures that the engine complies with the load-diagram and is not overloaded in the event that the propeller becomes too heavy running as a result of fouling of the hull and resistance from wind and waves.

4.2.8 Flexibilty Regarding Exhaust Gas Emission

The ME engine can be run in different modes, viz. The »Limited exhaust gas emission« mode and the »Low fuel oil consumption« mode.

- Smoke emission at low load is improved.
- The Alpha Lubricator, which is a computer controlled cylinder lubricator system with intermittent lubrication, enables a reduction in the lube oil dosage.
- Less weight: approximately 3 t/cyl. for a 600- mm-bore engine.

The ME engine range has proved to be very successful since its introduction. The first ME engine was put into service on the 37,500 dwt chemical tanker ***M/T Bow Cecil*** **(Odfjell, Norway)**. This engine, a 6L60MC/ME, has performed as desired for more than 16,000 hours. The ME range of engines is available from the 4S50ME-C through to the worlds most powerful ME engine, the 14K108ME-C.The advantages of the ME-C range of engines are quite comprehensive, as seen below:

4.2.9 Advantages :-

- ❖ Lower SFOC and better performance parameters thanks to variable electronically controlled timing of fuel injection and exhaust valves at any load
- ❖ Appropriate fuel injection pressure and rate shaping at any load
- ❖ Improved emission characteristics, with lower NOx and smokeless operation
- ❖ Easy change of operating mode during operation
- ❖ Simplicity of mechanical system with well proven traditional fuel injection technology familiar to any crew

- Control system with more precise timing, giving better engine balance with equalized thermal load in and between cylinders
- System comprising performance, adequate monitoring and diagnostics of engine for longer time between overhauls
- Lower rpm possible for manoeuvring
- Better acceleration, astern and crash stop performance
- Integrated Alpha Cylinder Lubricators
- Up-gradable to software development over the lifetime of the engine

CHAPTER 5

DUAL FUEL DIESEL-ELECTRIC PROPULSION

The dual fuel engine is basically a normal 4 stroke diesel which can utilize natural gas as fuel. The gas is injected into the air intake and a small amount of diesel is added in the combustion chamber to ignite the gas / air mixture. In addition to running on gas, dual-fuel engines can run on MDO. When running on MDO, the dual-fuel engine acts as a normal diesel engine.

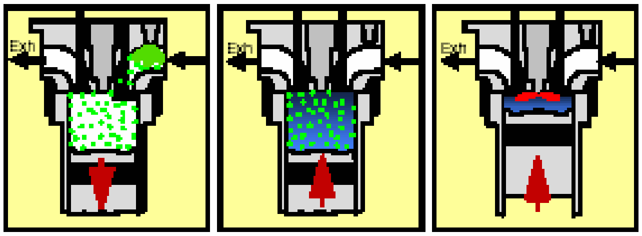


Fig. 4 - Dual-fuel engine working principle (gas mode)

In case the supply of gas is interrupted, the dual-fuel engine automatically transfers to diesel mode, without loss of engine power or speed. The transfer from diesel to gas mode is carried out fully-automatic on demand and is possible within one revolution of the engine.

The system is extremely environment friendly. When using LNG as fuel there is very little NOx, no SOx and no particle emissions. The reduction of CO2 emissions totals approximately 100,000 mt per year compared to a standard steam-driven LNG carrier.

The Dual fuel engines are four-stroke engines which can be run alternatively in gas mode or liquid-fuelled diesel mode. In gas mode it runs as a lean-burn engine according to the Otto cycle. Ignition is initiated by injecting a small amount of diesel oil (pilot fuel), giving a high-energy ignition source for the main fuel gas charge in the cylinder. The 'micro-pilot' injection system uses less than 1 % of nominal fuel energy input. In liquid fuel mode the this engine works just like any diesel engine, utilising a traditional jerk pump fuel injection system. Transfers between the two operating modes take place without interruption in power supply. With a lean fuel mixture it is possible to achieve good engine characteristics regarding efficiency and emissions. However, at higher loads the useful operating window between knocking and misfiring is very narrow. Accordingly, electronic control of gas admission and pilot injection is employed in the DF engines to regulate the combustion process individually for each cylinder. Accurate control ensures that combustion stays within the operating window and has optimal performance for all cylinders under all conditions as the gas quality, ambient temperature etc. vary.

LNG cargo boil-off is a very good fuel for the DF engines. The only considerable variation in the gas composition, however, is the nitrogen content such that the energy content of the boil-off gas is lower than that of pure methane. The nitrogen content in the LNG vapour can be as much as 30 % in volume especially at the beginning of the laden voyage. This is not a problem for DF engines as they can run on such a gas mixture at their nominal output without de-rating.

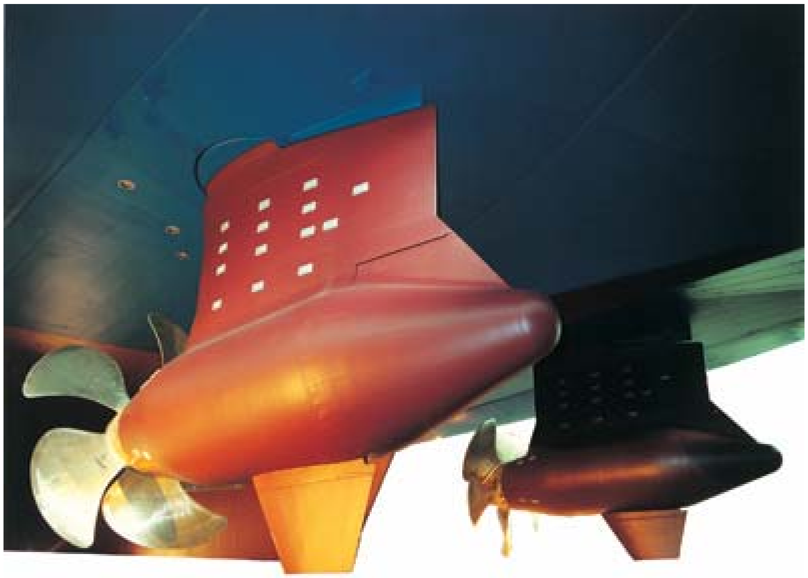
Electric propulsion system for LNG carriers

5.1 AZIPOD PROPULSION - Electric Marine Propulsion:-

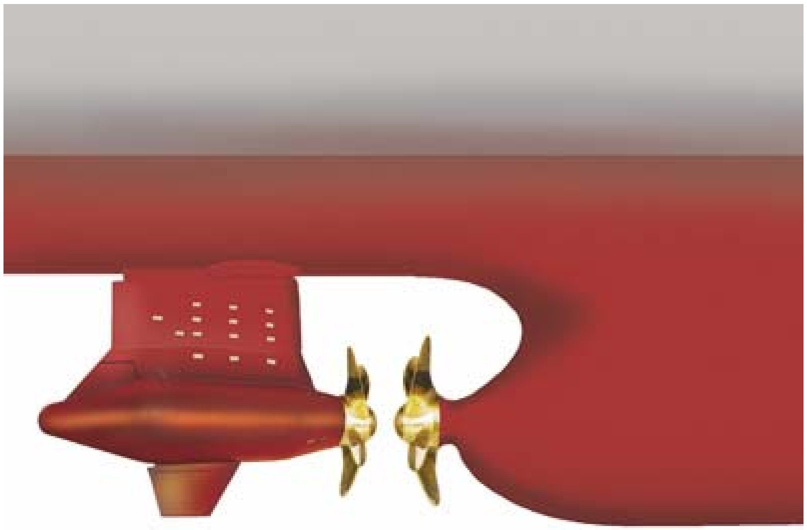
Azipod is a podded propulsion system, azimuthing through 360°C, cruising ahead of competition in the 5MW to 30MW class. It incorporates an electric motor mounted directly on an extremely short propeller shaft. The motor drives a fixed-pitch propeller. The motor is controlled by a frequency converter which produces full nominal torque, smooth and stepless, in either direction over the entire speed range, including standstill. The propeller rpm can be optimized according to the varying hydrodynamics of each project.

5.2 CRP AZIPOD PROPULSION - High-Efficiency Contra-Rotating Propulsion System

Contra-rotating propulsion (CRP) means there are two propellers on the same line rotating in different directions - an Azipod is installed in place of a normal rudder, aligned downstream of the main propeller. The secondary propeller utilizes the remaining energy from the rotating water leaving the forward propeller.



Each Azipod® propulsion system is individually designed and optimized to achieve maximum performance.

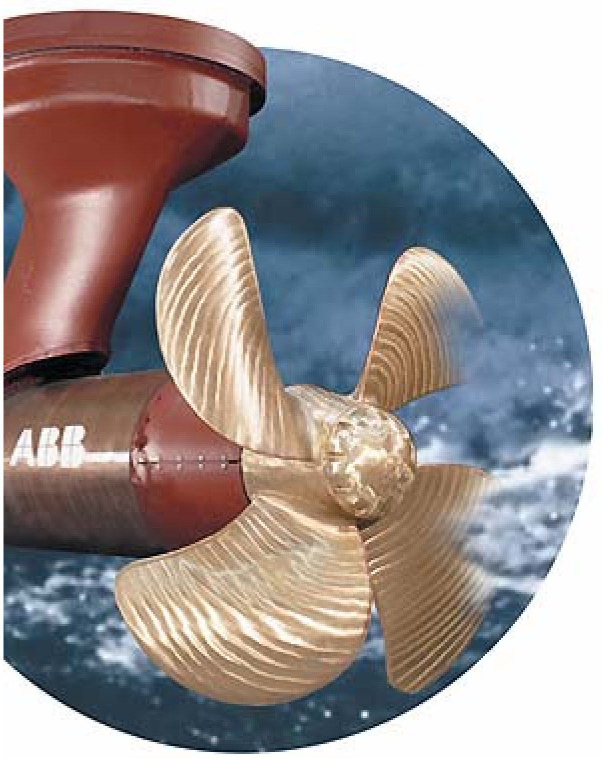


The system encompasses several unique advantages, resulting in the best hydrodynamic efficiency in the industry. Gains in efficiency are achieved by applying the CRP principle, dividing the load over two propellers and through utilization of the preferred single-skeg hull form.

Enhancing propulsion efficiency up to 15%, the CRP Azipod® propulsion system will have a big impact on vessel construction for ship types such as RoPax, ULCS and tankers.

5.3 COMPACT AZIPOD® PROPULSION - Marine Electric Thruster System:-

The Compact Azipod® is a electric thruster solution for smaller vessels, is standardized and modular, with high performance and low operating costs. The system is produced in five sizes from 0.5MW to 4.2MW and is available in propulsion and azimuthing thruster versions.



System construction is straightforward, consisting of a Propulsor Module and a Steering Module, providing unlimited azimuthing angels. The Propulsor Module incorporates an ultra-efficient permanent magnet synchronous motor with a fixed-pitch propeller mounted directly to the motor shaft. The compact motor is directly cooled by surrounding seawater, allowing for a simple mechanical construction and a slim pod with superb hydrodynamics.

5.4 First large size dual fuel electric carrier:-

Oslo, Norway ? December 12th, 2003 ? Chantiers de l´Atlantique, ALSTOM Group, has awarded ABB Marine a contract to supply the electric propulsion system for a new 153.000 m3 LNG carrier, owned by Gaz de France. The vessel will be built in France by Chantiers de l´Atlantique and delivered in 2005.

This propulsion systems meet stringent safety, reliability, and cost efficiency requirements, as demanded by leading ship owners and gas charters.

Increased worldwide utilization and transportation of LNG has initiated several studies to explore alternatives to conventional steam turbine propulsion. For LNG carriers, electrical propulsion provides the highest overall efficiency and benefits for ship builders and for operators of the ship.

To the new Gaz de France LNG carrier, a complete propulsion drive system in a redundant electrical configuration is provided. The delivery will include medium speed propulsion motors of a total of 28 MW, medium-voltage frequency converters (ABB ACS 6000), and a propulsion control system.

The frequency converters use the Direct Torque Control (DTC) technology, a genuine motor control method developed. The converter technology gives improved performance and controllability of the propulsion system compared to alternative methods, and a simpler electrical power system without harmonic filters.

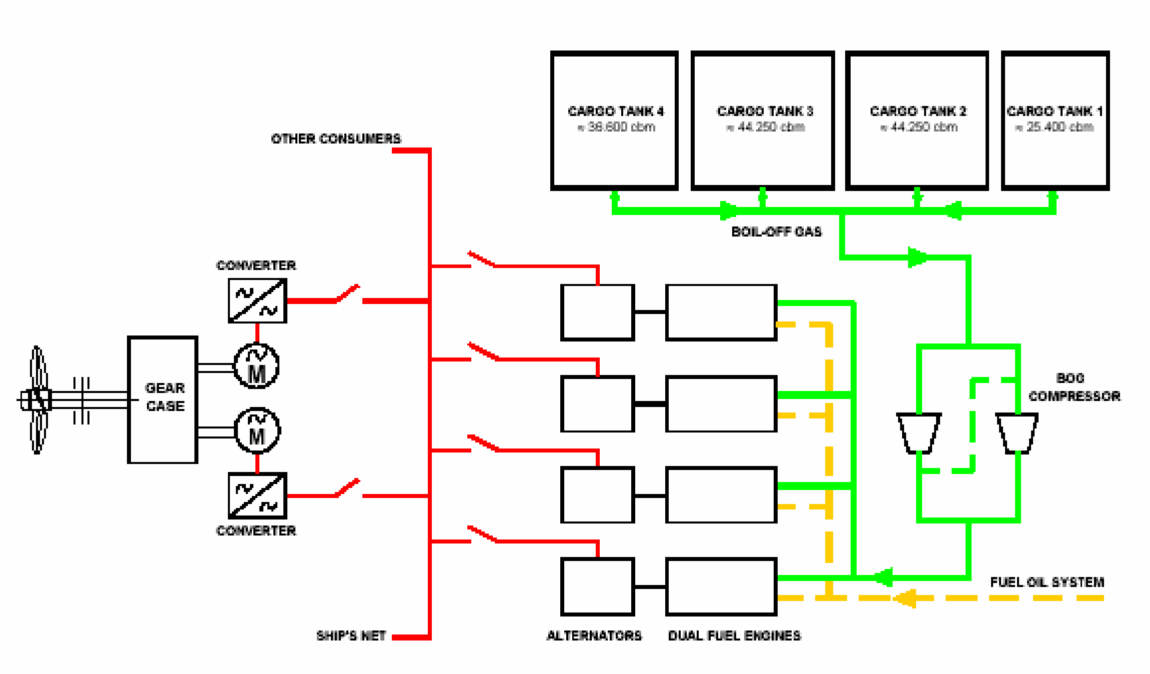


Figure 2: Diagram of Diesel-Electric Propulsion

The diagram of the system is shown in fig. 2. Four diesels provide electrical power for the main propulsion motors and the other electrical consumers. This gives a high flexibility between different operating modes. The total power installed is less than for any other propulsion alternative because of this flexibility. As the diesels are producing electricity, an in-line arrangement of shaft/gearbox/engine is not necessary. So the diesels can be arranged on a higher deck, thus reducing engine room space demand. The layout offers multiple redundancy, apart from the shafting and the gearbox. Even in the event that two diesels should fail, or one electric motor is out of use, the ship would be able to sail at about 75% of its design speed. An LNGC of about 145,000 m³ with diesel-electric propulsion will be able to take about 5000 m³ more cargo than a steam-driven ship with same overall dimensions.

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The number and size of these sets of course largely depends on the ship size and speed, but also on the envisaged operating philosophy. An LNG carrier with a cargo capacity of some 150'000 m3 will typically require one six- and three twelve cylinder engines. An LNG carrier with a cargo capacity of 200'000 m3 will typically require two six- and four nine-cylinder engines, and a ship of 250'000 m3 cargo capacity will do with two six- and four twelve-cylinder dual-fuel engines. The generated electric power is fed to an electric drive fairly similar to those used on contemporary cruise ships. Two 'high-speed' electric propulsion motors drive a fixed-pitch propeller through a reduction gear. Twin 'low-speed' electric motors mounted on the same shaft can be selected to drive the propeller without assistance of a gearbox alternatively. For the larger ships, twin screw arrangements can be selected without significantly increasing the complexity of the machinery installation.

5.5 Advantages:-

The main advantages of electric propulsion are:

- Reduced lifecycle cost by improving the operational economy with reduced fuel consumption and maintenance cost
- Increased payload through efficient modularization and flexible location of machinery components
- Safety and reliability with improved manoeuvrability, high redundancy and standardized proven technology
- Environmental benefits from lower fuel consumption and emissions resulting from constant speed engine operation with optimized loading and high efficiency
- Better comfort for crew and passengers due to reduced vibration and noise
- High performance due to maximum torque at zero speed
- Flexible and easy installation compared to diesel mechanical systems

Hence the main arguments in its favour are high fuel efficiency, safety, and flexible and efficient use of the installed machinery. The selection of either single or twin screws has to be based on the operating profile and redundancy requirements specific for each project.

The main **disadvantages** of this system compared to the alternatives are the slightly higher initial costs and the small efficiency loss in the power generation process

5.6 Four generating sets:-

The number of engines and the power output of each unit are determined by the shaft power needed and also by the degree of redundancy requested. Generally speaking on a typical 138,000 m3 ship with the need for some 34 MW total engine output, the power plant would consist of four generating sets. The maximum continuous output of these engines are 950 kW/cylinder at 500 or 514 rev/min (50 or 60 Hz respectively) and their thermal efficiency is as high as 48 %. Four engines provide some redundancy if one of the engines is out of service, and also flexibility for the different operating modes such as manoeuvring, waiting off ports, loading and unloading. Additionally, they allow flexible preventive maintenance at sea and during port calls, which is not the case with the steam plant or other single-engine alternatives.

5.7 High total efficiency:-

Recent studies suggest that the most beneficial solution, both economically and environmentally, for topping up the energy available from boil-off gas is to use forced boil-off instead of diesel fuel oil. This solution, in combination with DF-electric propulsion, is economically very attractive in both installation and operating costs. **Recent evaluations in the industry have calculated annual savings in total operating costs of between 2.2 and 2.8 million USD compared with a traditional steam turbine** LNG carrier. As the dual-fuel engine is operated on low-pressure gas, below five bar at the engine inlet, the fuel gas compressor package is essentially similar (only two-stage instead of single-stage) to that already used in the current steam-powered fleet. **The main difference is that the total efficiency of the DF-electric plant is well above 40 % compared to less than 30 % for the steam plant. The difference is even greater in part-load operation.**

5.8 Outline of the DF-electric LNG carrier:-

The DF-electric LNG carrier concept is designed for a single-screw vessel with four cargo tanks and a capacity of about 138,000 m3. The hull has a transom stern, a single-skeg aft body and a bulbous bow. The propulsion machinery and accommodation spaces are arranged in the stern part. The cargo machinery room is arranged separate from the accommodation space on the upper deck.

Two cargo tank system variants can be applied:

Membrane and spherical types. Both variants have a length bp of 275 m, breadth of 43 m and 48 m respectively, and design draught of 11 m. The main machinery consists of four nine-cylinder in-line W50DF dual-fuel engines, each driving an alternator. Each main engine develops 8550 kW at 514 rev/min, giving a total output of 34.2 MW. The main generators feed the ship's electrical network and, through a variable-speed drive system, the propulsion motors. A 500 kW emergency diesel generator set is also installed. The single, five-bladed fixed pitch propeller is driven by two 13.5 MW AC propulsion motors through couplings and a twin-input/single-output reduction gear. There are also two 1000 kW bow thrusters. To enhance the redundancy of the propulsion plant, the main engine rooms and casings are divided with a fire-resistant bulkhead. The main engine rooms are under diminished air pressure. A back-up arrangement of a thermal oxidiser is provided to dispose of boil-off gas during long periods of low-load operation. The service speed of the ship is about 19.5 knots at the design draught of 11.0 m and with 15 % sea margin, which corresponds to 27 MW shaft power. The power for accommodation and machinery ancillary consumers is about 1 MW.

5.8.1 Operating Economy:-

As dual-fuel engines have the ability to run on both gas and MDO, the choice of fuel is up to operator. Several independent studies have however confirmed that forcing additional boil-off gas to complement the natural boil-off gas is the way to profit most from the potential of the dual-fuel-electric solution. Firstly, forced boil-off gas is cheaper than alternative fuels. Secondly, it is lighter than alternative fuels. Fuel ‘bunkers’ weight is thus reduced, and at a given displacement, the ship will be able to carry more cargo weight. Carrying more cargo volume is enabled by the fact that the dual-fuel-electric solution saves engine room space (Fig. 7). Even when using a small part of the cargo as fuel, a dual-fuel-electric LNG carrier will deliver more cargo to the unloading port in this way.

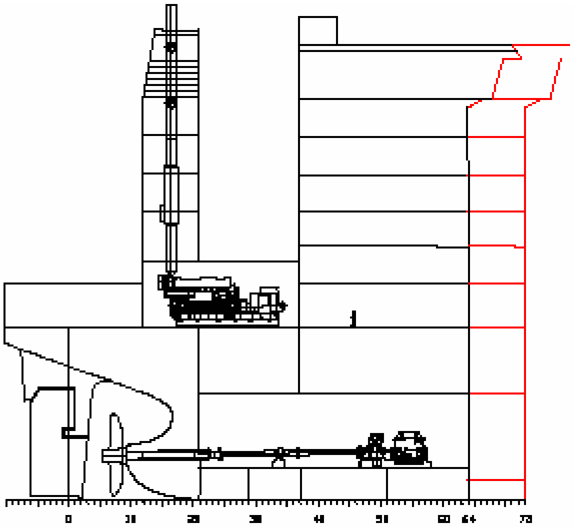


Fig. 7 - Dual-fuel-electric machinery

The efficiency of the propulsion machinery of a dualfuel- electric LNG carrier is approximately 41% and the efficiency of the electric power generation machinery is around 44%, compared to 29% and 25% respectively for a steam turbine installation. A two-stroke diesel engine installation will have a propulsion machinery efficiency of about 48% and the efficiency of the electric power generation machinery will be about 41%, but will consume a substantially higher amount of electric power due to the presence of the liquefaction plant. Adding the cheaper fuel of the dual-fuel-electric LNG carrier to the equation, this solution clearly excels in terms of operating costs (Fig. 8).

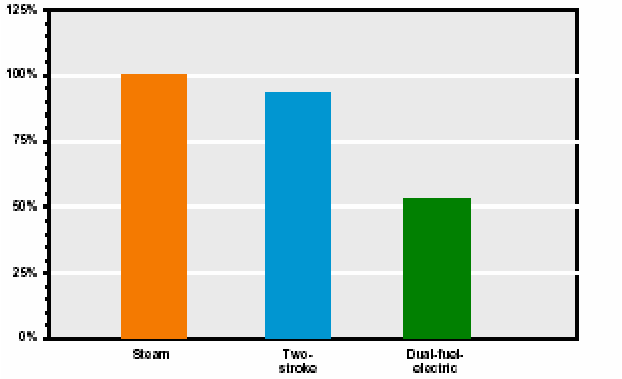


Fig 8. - Operating costs

5.8.2 Environmental-Friendliness:-

When exclusively using natural and forced boil-off gas as fuel, the dual-fuel electric solution shows unrivalled emission values (Fig. 9). All other machinery alternatives suffer from the use of HFO, either used uniquely or in combination with natural boil-off gas.

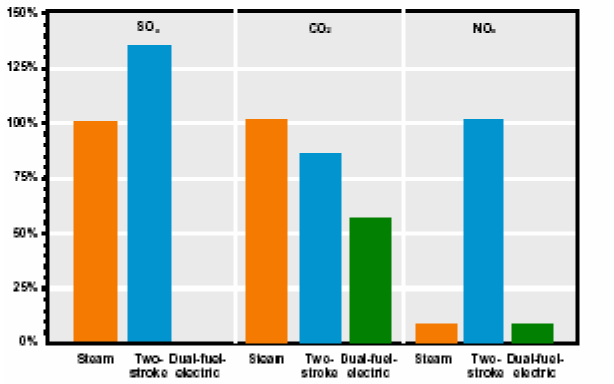


Fig. 9 - Exhaust gas emissions

5.8.3 Safety:-

A 'Safety Concept' for dual-fuel-electric machinery onboard LNG carriers has been developed to make sure that the safety of the installation complies with class and at least matches the safety of steam turbine installations. The recent introduction of double-wall gas piping on the engine pipeline will further increase the safety of the solution. With several potential customers and class, safety studies including hazard identification, FMEA and hazardous operations studies, have been conducted to further validate the safety of the solution.

5.8.4 Reliability:-

The diesel engine has proven its reliability in various demanding marine applications, such as cruise ships. The use of gas as compared to HFO further enhances this inherited reliability.

5.8.5 Redundancy:-

Electric propulsion systems are in their essence highly redundant, as more or less all primary functions of the system are distributed over more than one component. The dual-fuel-electric installation features multiple generating sets, potentially distributed over multiple engine rooms, has twin transformers and converters, and features twin electric propulsion motors with double windings.

5.8.6 ‘Maintainability’:-

Case studies for various customers have shown that the required maintenance on dual-fuel-electric installations can easily be carried out without affecting the ship’s operational performance. Maintenance of dual-fuelelectric installations is more costly than of steam turbine installation, but does no harm to the ship’s operating economy.

5.8.7 ‘Crewability’:-

Dual-fuel-electric installations can be operated and maintained by diesel engine crews. There is no need for crew members with exceptional skills or experience.

5.8.8 Others:-

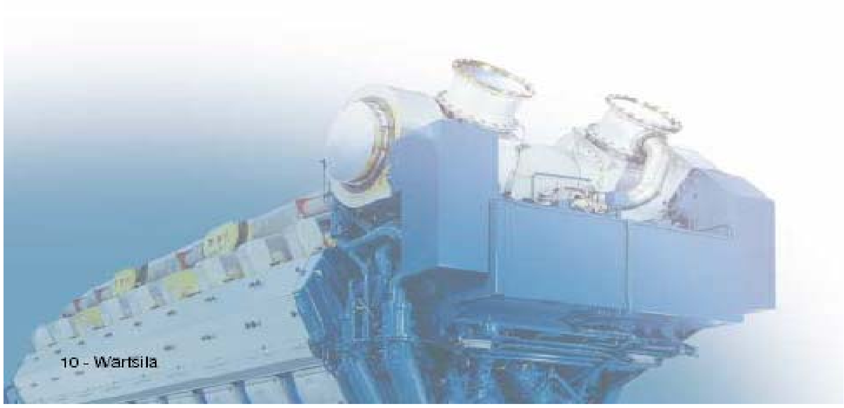
The dual-fuel-electric installation provides excellent propulsion characteristics for navigation in ice, due to the availability of full propeller torque at zero speed and excellent manoeuvring characteristics. Dual-fuel-electric installations can easily cope with the power requirements of dynamic positioning systems. This might become a valuable feature, as an increasing amount of offshore LNG terminals is envisaged.

5.9 Future operating profiles:-

When specifying propulsion machinery options for LNG carriers it is essential to consider the differences in operating profiles, fleet configurations and shipping routes. he basic case today is an approx. 138,000 m3 vessel with an operating speed of around 19.5 knots and the corresponding power required at the propeller of about 27 MW. However, future operating profiles of LNG carriers will require more flexibility from the power plant. Already there have been inquiries about ships that would normally operate at about 15 knots, but have to be capable of doing 19 knots on spot cargo trades. It is then very important that the power plant is efficient also in part-load operation. The maximum required electrical power for cargo pumping and other consumers is roughly 6 MW whereas the minimum can be less than 1 MW. As stated previously, the energy in the boil-off gas will vary considerably during the round voyage of an LNG carrier. When converting the energy content available in the boil-off gas of the above-mentioned size of LNG carrier into mechanical power at the propeller shaft using modern dual-fuel engines, figures ranging from the 12 MW in the worst case up to 25 MW at the best can be calculated for the laden voyage. In ballast, the corresponding figures are typically about half, but can be even lower. Thus, even in the best case the natural boil-off would not be enough to cope with the energy consumption, and either forced boil-off gas or supplementary liquid fuel is needed to make up the shortfall. The selection of supplementary fuel depends on the result of a feasibility study taking into account not only the operating profile of the ship but also oil price trends and the availability of bunkers of the correct grade in the vicinity of the LNG terminals. One option might be not to use the boil-off gas as fuel for propulsion power at all. Instead, this gas could be reliquefied and returned back to the cargo tanks to be carried to the final destination. Propulsion could then be based on diesel engines burning heavy fuel oil, as in almost any other modern large cargo vessel today. Suitable reliquefaction plant has been tested in marine conditions but the technology is not yet considered mature. The plant would be quite expensive and imposes a high electrical demand. Therefore, in addition to the technical risk, a reliquefaction plant is very sensitive to the ratio of LNG to heavy fuel oil prices.

5.10 Market Introduction:-

The first dual-fuel-electric ships running on LNG, *Viking Energy* and *Stril Pioner*, are in operation since 2002 and the first dual-fuel-electric LNG carrier, *Gaz de France Energy*, is currently nearing completion and is scheduled to enter Commercial operation in November this year.



CHAPTER 6

GAS TURBINE ALTERNATIVES

Gas turbine is, in essence, designed to burn gas. As electric drive is being increasingly used and accepted, gas turbines are becoming more and more potential as prime movers. When coupled to an exhaust heat utilising steam turbine, fuel efficiency of such a so called COGES plant increases to a very competitive level. Most gas turbines yield around 20..24 MW in COGES use, thus requiring a booster diesel generator set to reach the power level required in a contemporary large LNG carrier. Figure 3 presents a schematic view of such a machinery.

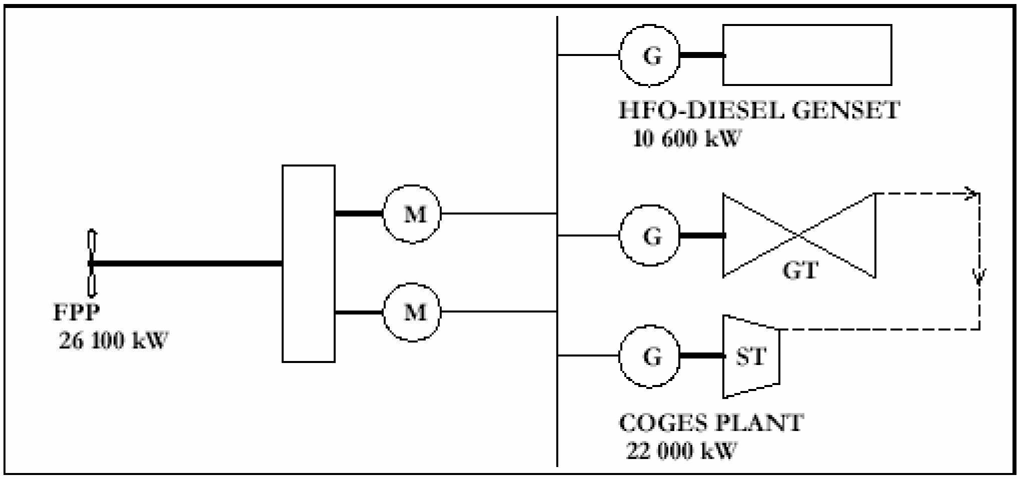


Figure 3 Gas turbine option with two electrical motors for redundancy. Gas turbine burns the boil-off

6.1 Aero-derivative Marine Gas Turbines:-

Aero-derivative gas turbines have entered the commercial marine propulsion market in the 1990s. Before the 1990s, most marine gas turbine applications were naval vessels, but there are some notorious exceptions. The most famous is GTS Finnjet, commissioned in 1977, built by Wärtsilä's Helsinki shipyard as hull number 407. Two Pratt & Whitney FT4C-1D aero-derivative gas turbines give her displacement hull with Swedish/Finnish Ice Class 1A Super a speed of 33.5 knots. After 25 years in the business, she still going strong and is very popular with her passengers.

What makes a gas turbine suitable or even ideal for marine propulsion applications?