Module 4:

Ship-Board Energy Management

IMO Train the Trainer Course

Name of the Presenter

Affiliation of the presenter,
City, Country

Energy Efficient Ship Operation

Venue, City, Country
Day xx to Day yy, Month, Year

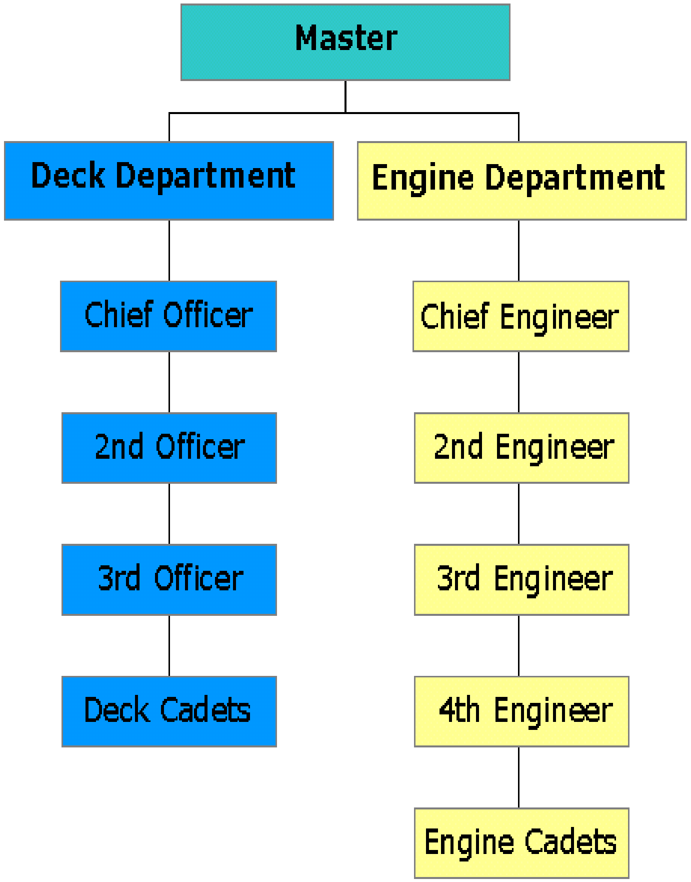
Content

- Ship-board organisation, roles and responsibilities.
- Overview of main ship-board EEMs.
- Trim optimisation, its impact and best practice.
- Ballast water management.
- Hull and propeller roughness and fouling.
- Engines and machinery utilization management.
- Fuel management: storage, treatment and purification.
- Technology upgrade.
- Steam system and boilers.

Ship-board Roles and Responsibilities

Ship-board organisation and responsibilities

- The Master is in full control and has ultimate responsibility.
- Deck department (Operation and Cargo)
  - Chief Officer
  - Second Officer, etc.
- Engine department (Technical)
  - Chief engineer
  - Second engineer, etc.
- Catering (steward's) department.
  - Chief Steward and his/her staff
  - Food and all aspects of provisions.
  - Cleaning and maintaining officers' quarter
  - Managing the stores, etc.



[Maritime Profession Promotion Foundation]

Main ship-board staff impact on energy saving

- **The Master:** His/her commitment to ship-board energy efficiency is vital; otherwise it will not succeed.
- **The Chief Officer** (2nd in command): Plays significant roles on the cargo and loading/unloading operations, ballast management operations, trim optimisation, etc.
- **The Chief Engineer:** Plays a major role on technical issues including the maintenance, condition and performance of engines and various machinery and the way they are utilised.
- **The Second Engineer:** By virtue of being the most engaged person in the engine department on day to day operation and maintenance of various systems, has the second most important role in engine department.

Importance of communications between departments

- **Main issue:** Lack of optimal communications between departments leads to waste of energy.

- For example, communication between deck and engine departments is essential for machinery use optimisation.

- To increase communications and collective planning, some policies may be put in place:
  - Set up daily meetings.
  - Plan ship-board work activities for reduction of electricity, compressed air, fresh water, etc. use together.
  - Plan cargo operations for saving energy.

Ship-board energy efficiency measures

- Optimized ship handling
  - Optimized trim
  - Optimized ballast
  - Optimum use of rudder and autopilot

- Optimized propulsion condition
  - Optimized hull
  - Clean propellers
  - Optimized main engines

- Optimized auxiliary machinery
- Fuel management
- Boilers and steam system
- Maintenance and energy efficiency
- Technical upgrades and retrofits

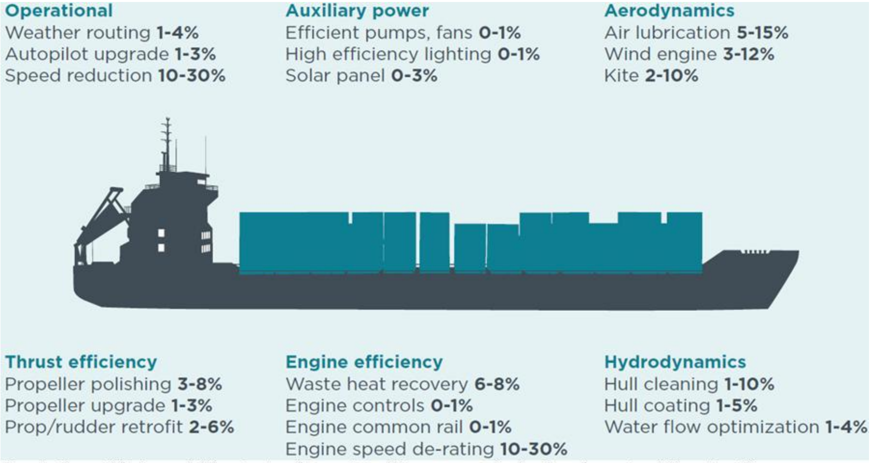


Figure 1: *Potential fuel use and CO_2 reductions from various efficiency approaches for ships (International Council on Clean Transportation (ICCT, July 2013). Long-term potential for increased shipping efficiency through the adoption of industry-leading practices.*

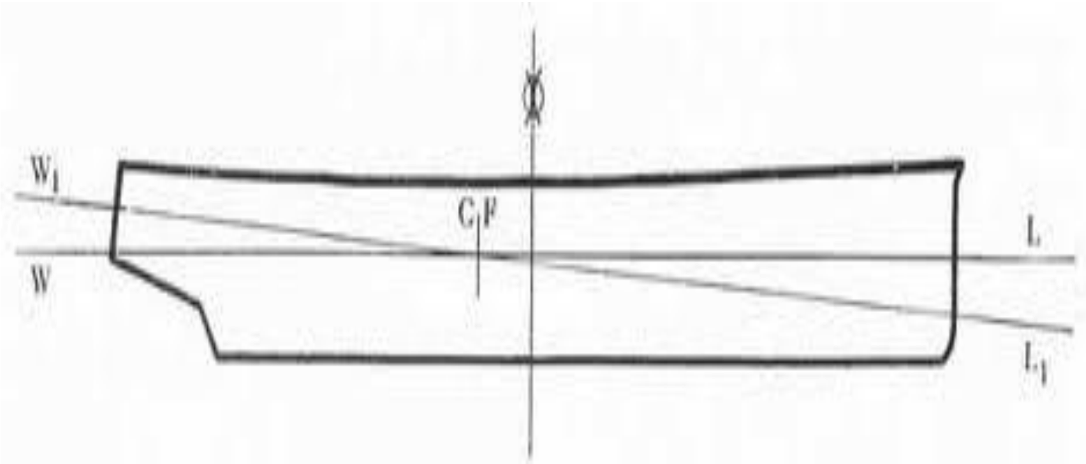
Trim Optimization

Definition of trim

- **Trim:** Trim is normally defined as the difference between the aft draft and the forward draft:

- **Trim = T_A-T_F (**Aft trim – Forward trim)

- Diagram shows trim to aft.



Trim Optimisation – Physics of trim

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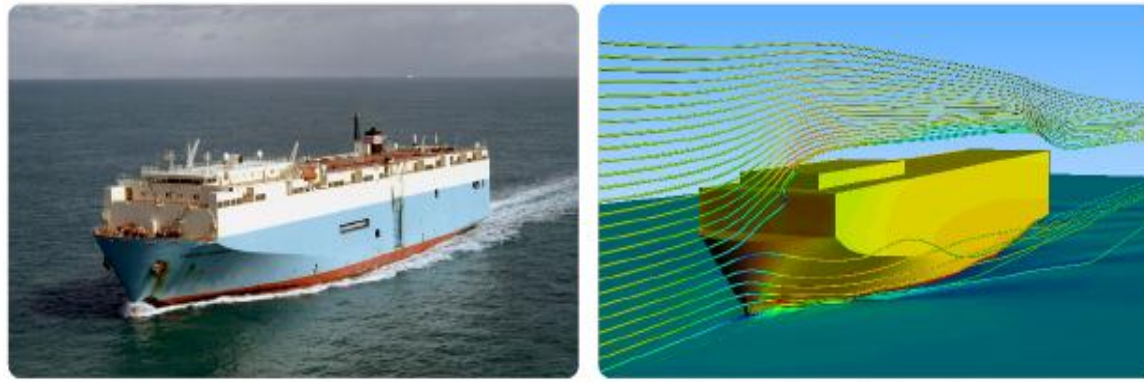
- The large dependencies of ship performance on the trim is because trim causes:
  - Changes to wave resistance
  - Changes to wetted surfaces (thus frictional resistance).
  - Changes to form resistance due to transom submergence

- Changes to various propulsion coefficients including:
  - Resistance coefficients
  - Thrust deduction
  - Wake fraction

- Changes to propulsive efficiencies including:
  - Relative rotative efficiency.
  - Propeller efficiency

Trim optimisation - Impact of Trim

- Trim impact depends on ship speed and draft.
- The impact of trim either is estimated by:
  - Model test or
  - Use of CFD
- Guidance table for trim is normally prepared for ship-board use.
- As indicated, the impact of trim could be significant.



When you choose trim optimisation from Lloyd's Register we create a computer model of your ship, enabling us to perform a rapid and cost-effective analysis.

Speed		14 – 15.9 knots						16 – 17.9 knots					
Trim (metres)		-2 – -1.51	-1.5 – -1.01	-1 – -0.51	-0.5 – -0.01	0.01 – 0.5	0.51 – 1	-2 – -1.51	-1.5 – -1.01	-1 – -0.51	-0.5 – -0.01	0.01 – 0.5	0.51 – 1
Draught (metres)	7.9 – 8.5	Avoid 6.4%	Fair 2.5%	Good 1.6%	Optimal 0.0%	Fair 2.2%	Avoid 8.5%	Avoid 4.5%	Fair 2.1%	Good 6.4%	Optimal 0.0%	Fair 3.2%	Avoid 7.2%
	7.2 – 7.85	Fair 2.0%	Good 0.6%	Optimal 0.0%	Good 0.3%	Good 0.9%	Fair 2.8%	Good 1.2%	Good 0.6%	Good 0.0%	Optimal 0.0%	Good 0.4%	Avoid 3.3%
	6.5 – 7.15	Good 0.6%	Good 0.2%	Optimal 0.0%	Good 0.6%	Fair 2.0%	Avoid 3.0%	Good 0.1%	Optimal 0.0%	Good 0.1%	Good 0.5%	2.0% Fair	Fair 2.8%

An example section of the trim optimisation table you will receive for your ship. This contains a set of optimal trims according to draught and speed, and is specific to your vessel.

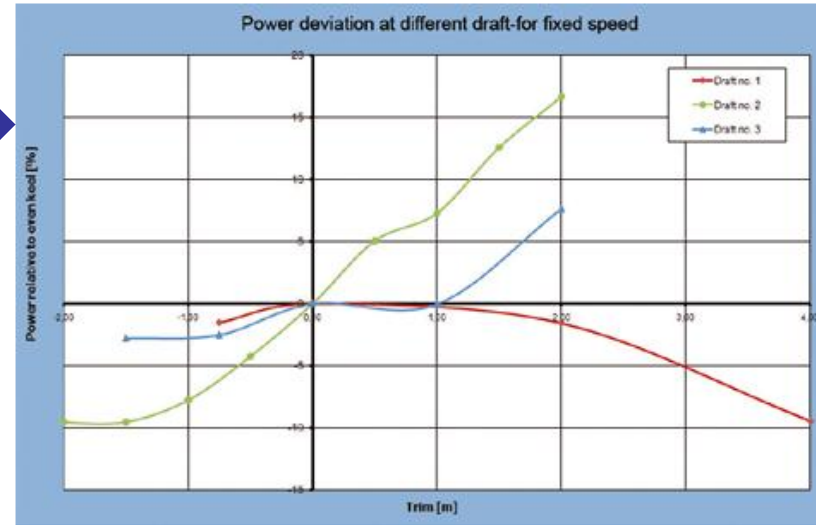
Source: Lloyd's Register

Trim Optimisation – Operation best practice

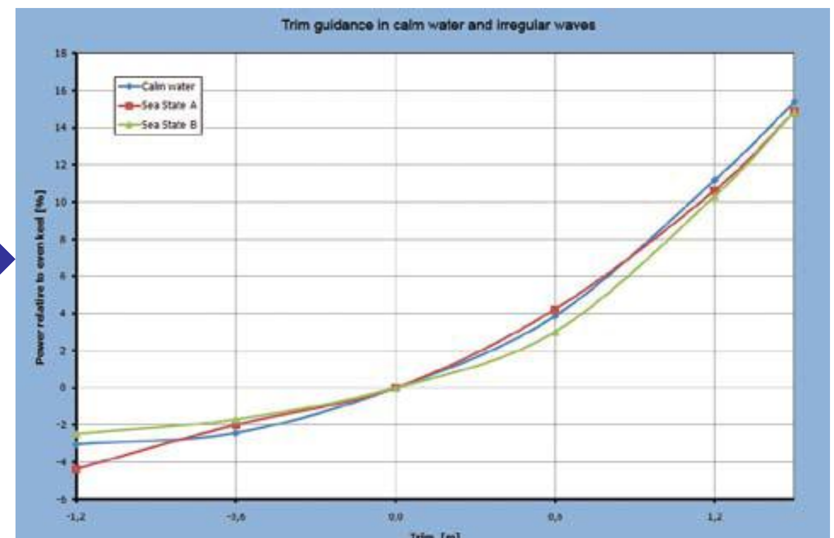
- Currently, the majority of ships use even keel operation (zero trim) as normal practice.
- This generally represents the optimal trim for ships with high block coefficients and non-pronounced bulbous bow (e.g. tankers).
- In ships with slimmer body and higher speed, the impact of trim on performance could be significant.
- In use of trim optimization, the following ship types would be given higher considerations:
  - Container ships
  - RoRo cargo and passenger ships
  - RoRo car carriers
- Effective use of the loading computers capabilities is important for safe trimming of the vessel.

Trim Optimisation – Impact of draft and sea condition on optimum trim

- Impact of draft on optimum trim?
- Optimum trim is a function of ship draft.



- Impact of sea conditions on optimum trim
- Sea conditions does not change the optimum trim significantly



*** Diagram are from Force Technology**

Trim Optimisation - Summary

- Trim influences ship fuel consumption significantly, with evidence showing up to 4% savings.
- Trim impact is via changes to ship hydrodynamics and resistances.
- For every ship, there is a range of optimal trim;
- The optimum trim is a function of ship speed and draft.
- For certain ship types in particular those with higher speeds, slimmer body, pronounced bulbous bow and flat stern, trim will have more impact.
- Optimal trim are established either through extensive model testing or CFD analytical methods.
- To achieve optimal trim, due consideration should be given to ship loading and its load planning.
- Ballast water and to some extent bunker fuel may be used to trim the vessel.

Ballast Water Optimization

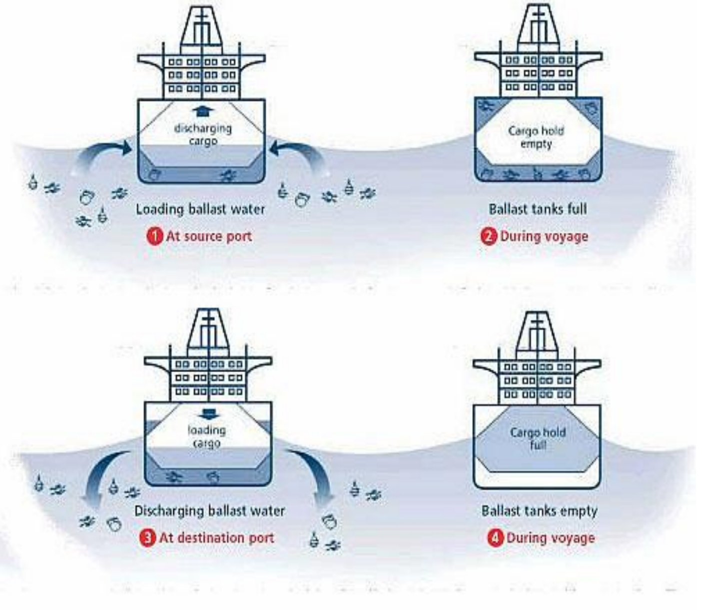
Ballast Water Optimisation

Why ballast water?

- Ballast water is essential to control trim, list, draught, stability and stresses of the ship.

Ballast water regulations?

- Ballast water activities on board ship is heavily regulated.
- The regulations mainly relate to prevention of specifics from their natural habitats to other ports.



Ballast water operations?

- Ballast water exchange
- Loading ballast water
- Discharging ballast water

How ballast water impacts energy efficiency?

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<u>In a number of ways:</u>

- **Amount of ballast water:** Changes ship displacement, thus wetted surfaces and ship resistance.
- Generally, the more ballast water or ballast sediments are carried, the bigger will be ship displacement and higher fuel consumption.
- **Change in ship trim:** Trim optimisation via effective use of ballast water could lead to gains in energy efficiency.
- **Ballast exchange process:** Energy is used for exchange of ballast. Therefore process optimisation could lead to reduction of energy use.

Ballast Water Optimisation: Ballast Water Management Plan (BWMP)

A BWMP specifies all aspects of ballast operations including:

- Acceptable methods for ballast exchange and relevant procedures.
- Details of the procedures for the disposal of sediments at sea and to shore and reception facilities.
- Designation of the officer on board in charge of the implementation of BWMP.
- Method of the sediment removal or reduction at sea, and when cleaning of the ballast tanks take place.

Ballast Water Optimisation

Methods of ballast exchange?

- **Sequential method** – Emptying and filling in sequence.
- **Flow-through method** – Continuous supply of water to tank with overflow from the top; water in should be at least 3 times the volume of the water in the tank.
- **Dilution method** – A process by which replacement ballast water is supplied through the top with simultaneous discharge from the bottom at the same flow rate and level in the tank during the operation.

Method of ballast exchange has implication for energy use

Ballast Water Optimisation: Reduction of tank sediments

<u>Sediments in ballast tanks?</u>

- IMO regulations stipulate that all ships shall remove and dispose of sediments from ballast tanks in accordance with the their Ballast Water Management Plan.

- To reduce the sediment levels, the following general aspects should be observed:

    - All practical steps should be undertaken not to uptake sediments.
    - Dispose of sediments in a safe way.

- Removal of sediments is good for energy efficiency.

Ballast Water Optimisation – Energy efficiency methods

- **Carrying less ballast water:**
    - To save fuel, it is generally desirable to carry less weight.
    - Less ballast should not contravene any of the regulations and compromise the ship safety.
    - Also, this should not cause non-optimal trim.

- **Efficient ballast management operations:** This means performing the operation in a way that is more energy efficient. For example:
    - **Gravity assisted** ballast exchange is preferred to simple pumping in/out processes.
    - **Sequential** ballast exchange is more energy efficient than the flow-through method as less water needs to be displaced.

- **Trim optimisation:** Ballast should be used for trim optimisation.

- **Sediment removal:** Sediment removal leads to more cargo capacity and energy efficiency.

Ballast Water Optimisation – Voyage management aspects

- The voyage should be planned taking into account when ballast water exchange can be carried out.

- Also, trim optimisation and adjustments while in passage should be pre-planned relative to the port normally even-keel operation.

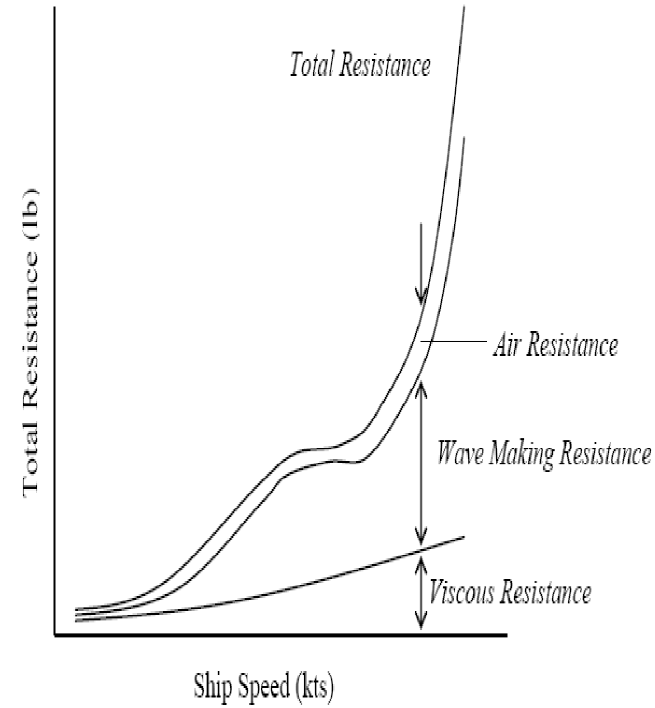
- Sediment uptake and removal should be controlled as part of voyage planning to ensure minimal level of sediments.

Hull and Propeller Condition and Cleaning

Speed-power relationship

- From flow theories:
  - Resistance $R = c \times V^2$
  - Power: $P = R \times V = c \times V^3$

- Actual values differ:
  - For large high speed ships (containerships) $P = c \times V^{4.5}$
  - For medium speed ships (RoRo, feeders, etc.) $P = c \times V^{4.0}$
  - For slow speed ships (tankers, etc.) $P = c \times V^{3.5}$

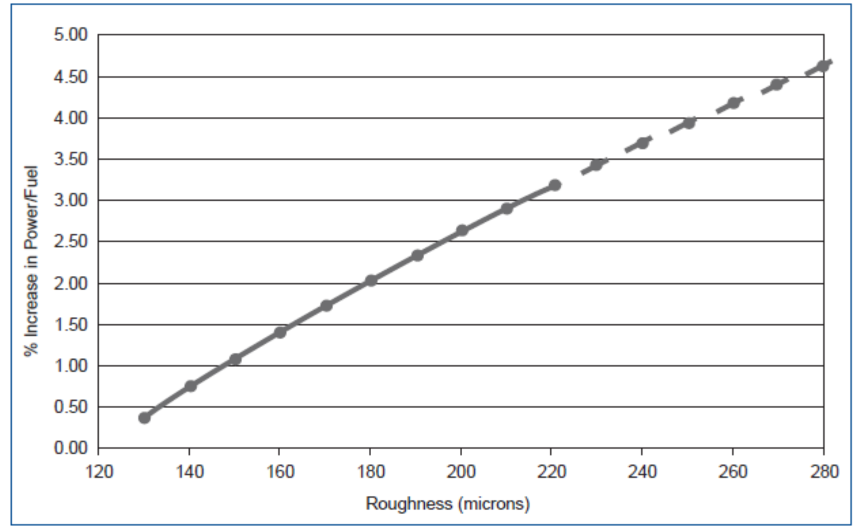


Hull Coating

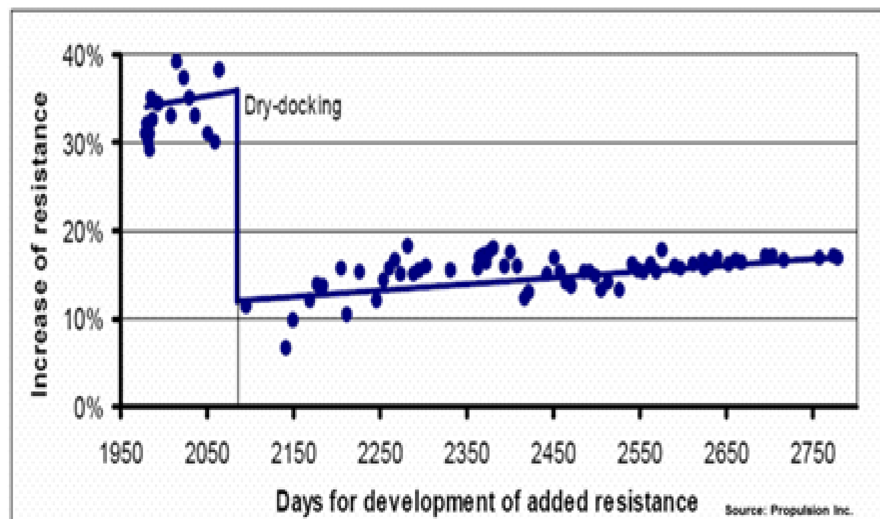
- For lower speed ships skin friction resistance dominates;
- For a VLCC at full load condition 90% of resistance is from hull friction;
- Strategy: Reducing hull friction resistance.
- There are advanced hull coating that may be used for this purpose.
- Application of advanced coatings will be more expensive but return on investment could be short.

Evidence of impact of hull condition

- There are ample evidence showing the significant impact of hull condition on fuel consumption



Source: International Paint 2004



Changes in ship resistance with time [Monk and Kane]

Main factors that influence hull fouling rates:

- Initial roughness of the hull
- Quality of hull coating
- Robustness of the coating with respect to mechanical damage
- The areas of the hull where there is sunlight
- Sea water temperature
- The salinity of the water (performance of coating will be a function of salinity of water)
- Amount of algae in the water
- Ship speed and its operation profile
- Hull maintenance

Main types of hull coatings

- **Controlled Depletion Polymer (CDP)** – A traditional antifouling:
  - Based on water soluble natural or synthetic pine rosin mixed with a biocide.
  - Typical life: 3 years.
  - The average hull roughness increase: 40 µm per year.

- **Self-Polishing Copolymer (SPC)**
  - An insoluble metallic or organic synthetic polymer that contains a biocide. No ship movement is required for self polishing.
  - Typical life: Five years for high quality systems
  - Average hull roughness increase: 20 µm per year.

- **Foul-release Coating**
  - A biocide-free coating with non-stick properties to control fouling.
  - Full release of all fouling due to ship speed is a challenge in some cases. Also, mechanical damage is especially critical
  - Average hull roughness increase: 5 µm per year, limited data.

Hull cleaning

- Regular in-service cleaning is beneficial if damage to coating is avoided.

- For partial cleaning, the priorities:
  - Forward third of hull.
  - Remainder of hull working from forward to aft with emphasis on areas which have more exposure to light.

- Regular cleaning of macro-fouling is highly recommended.

- For best results, the scheduling of cleaning should be based either on performance monitoring or on regular under-water inspections.

- Regular inspection, photographs and roughness measurements would be a prudent way to monitor the impact of cleaning and the condition of the coating.

Other aspects for hull cleaning

- **Regulatory Guidelines:** IMO MEPC.207(62) resolution on "Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species". This asks for a Bio-fouling Management Plan and a Bio-fouling Record Book to be on-board. This may limit the locational scope for cleaning of the hull.

- **Area of operation:** Anti-foul hull coatings are generally designed for salt water and area of operation will have impacts on choice of coating.

- **Hull cathodic protection system**: The installation of a hull cathodic protection system should could reduce the corrosion of the hull.

- **Lay-up:** If a ship has been in lay up in a high fouling area for a long time it may need to be taken to dry dock to be cleaned before it can be put into service.

Propeller aspects

- Similar to the hull surface, propellers suffer degradation in performance due to surface roughness.
- Polishing will mainly reduce the frictional losses of the propeller but will in many cases also reduce the rotational losses.
- Corrosion and cavitation erosion and impingement attack can cause roughness.
- Improper maintenance can also increase roughness.
- It has been estimated that polishing a roughened propeller surface may result in a decrease in fuel consumption of up to 3%.
- Divers can clean a 5 bladed and 10 m diameter propeller in about 3-4 hours for a cost of about US $3,000 in the Far East (Europe is more expensive).

Condition based hull and propeller cleaning

- Major questions:
  - What are the optimal timings for hull and propeller cleaning?
  - What is the best routine for cleaning whilst safeguarding the existing paint system.
  - What is the time and cost to apply a new coating and which one?

- Condition-based hull and propeller maintenance tries to give an answer for bullet 1. This can be done in two ways:
  - Measure/observe actual hull and propeller roughness/fouling and compare with baseline values that indicate when cleaning should be done. Use of divers.
  - Use performance analysis packages that track changes in fuel consumption, shaft power and main engine power to identify degrading surface conditions.

Engines and Machinery Load and Utilisation Management

Machinery load and operation profile

- The concept of “machinery load” optimisation and “parallel operation” reductions can be used for energy saving purposes.
- On-board ships, there are numerous instances that two machinery may be used in parallel; both at low loads.
- The load profile for a multi-machinery setup could provide valuable information on method of load sharing strategy and management between machinery.
- In such cases, there are always scope for reduction of machinery usage via reducing their parallel operations.

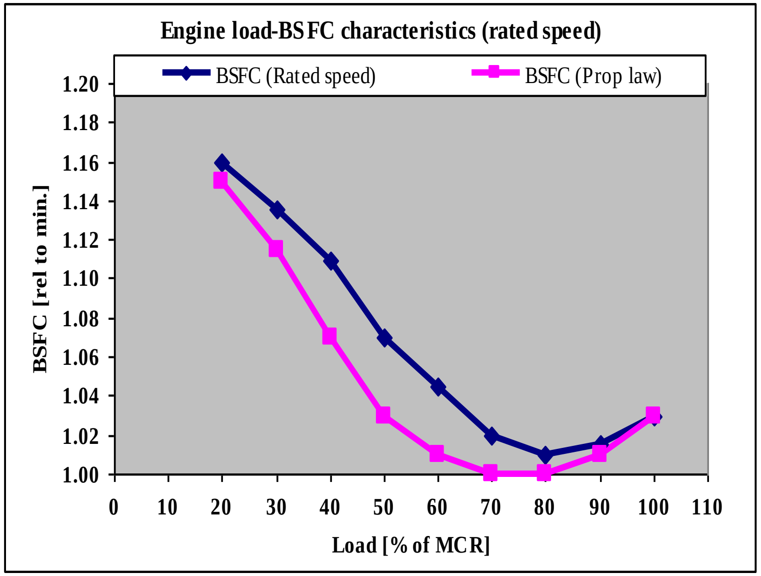
Engine load management
Engine fuel consumption characteristics

- **Load factor:** The engine load factor is defined the actual power output of the engine relative to its Maximum Continuous Rating (MCR).

- Load factor is normally specified in percent.

- It is well know that the efficiency of a diesel engine is a function of its load level or its load factor.

- Load management aims to operate engines at a more optimal load.



Main engine load management?

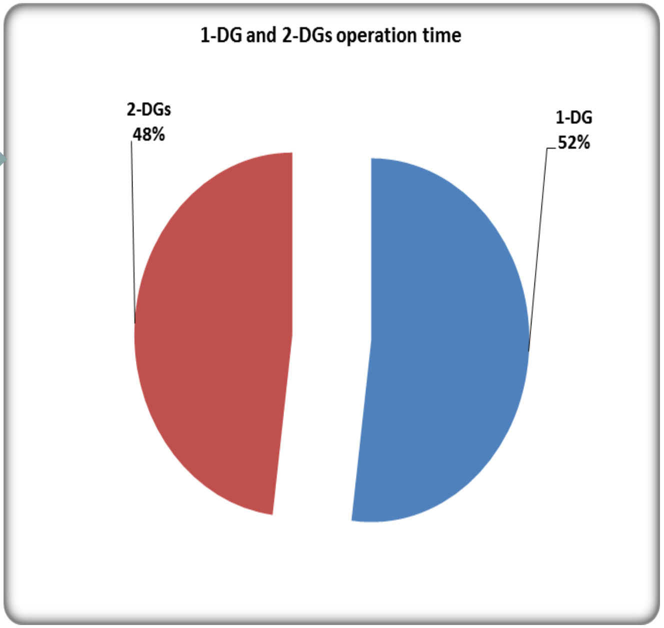
- For main engine, there is not much that could be done as far as load management is concerned. Reason:
  - Normally ships have one main engine and load management applies to cases with more than one engine.

Auxiliary engines load management

- Load management for auxiliary engines is an effective way of reducing the engines' fuel consumption and maintenance.
- On-board ships, normally two Diesel Generators are operated for long periods.
- This leads to engine operation at low load factor.
- The periods for which these conditions are sustained can include:
    - All discharge ports,
    - Standby periods,
    - Tank cleaning periods,
    - Movement in restricted waters and ballast exchange periods.
- Operation of diesel engines at low loads causes poor engine maintenance

Auxiliary engines load management

- How to establish if engine load is properly managed?
- Answer:
  - The load factor or utilisation factor of engines needs to be established.
  - Benchmarking of this information could indicate if engines are used optimally.



- Methods to reduce two-engines simultaneous operations are:
  - System planning for reduction of electrical load, thus switch off one engine.
  - Use of “Power Management System (PMS)” to reduce the use of two engines at low loads each.

Pumps / compressors / fans

- **Fouling reduction:**
  - Fouling in fluid machinery is a common cause of performance deterioration.
  - Fouling can be controlled via best-practice maintenance activities.
  - For examples, fans are very sensitive to inlet fouling.

- **Mulit-machinery management:** In general in a multi-machinery configuration (e.g. chiller plant compressors), the minimum number of machinery running for a particular duty represents the best machinery management strategy
  - This also ensures minimum energy use and maintenance.

- **Reducing idling mode of operation:**
  - Each machinery should be operated at its optimum efficiency.
  - The none-productive hours of operation must be minimised by on-off controls.
  - In particular, late turn-off and early turn-on of machinery should be avoided.

Pumps / compressors / fans flow control

- Method of flow control is an important aspect of machinery energy saving.

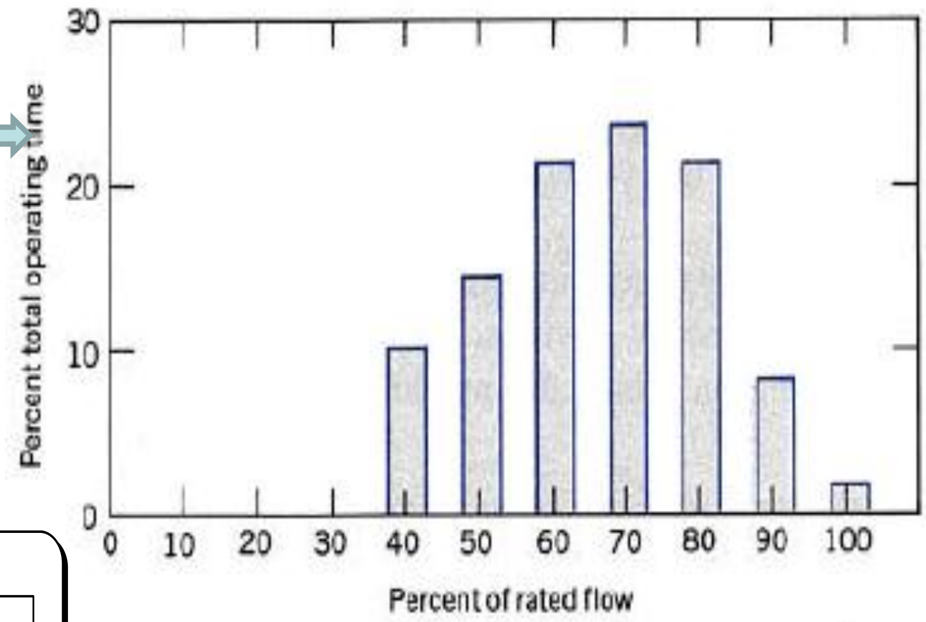
- **Throttle flow control:** A pump with variable flow requirements that is controlled by throttling could save energy by:
  - Replace the constant speed drive to variable speed drive.
  - Replace throttle control with on-off control, if feasible.

- **Excessive flow:** For example, pump flow rates in excess of system requirements, lead to increased energy losses. To avoid:
  - Ensure that pump flow is controlled according to process needs.
  - Review and adjust control settings.

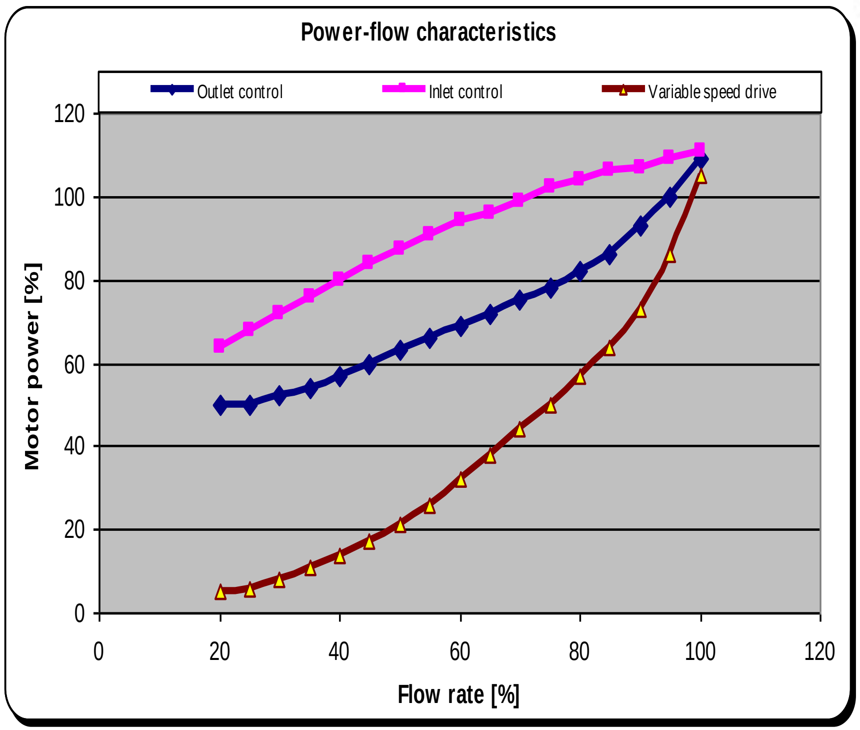
- **Demand control and demand reduction:** For example by:
  - Conservation policies on use of air, water, etc.
  - Preventing all leakages.

Auxiliary machinery – Variable speed drives

- Many machinery may have variable flow regimes.
- In such cases, use of variable speed drives could lead to energy saving.

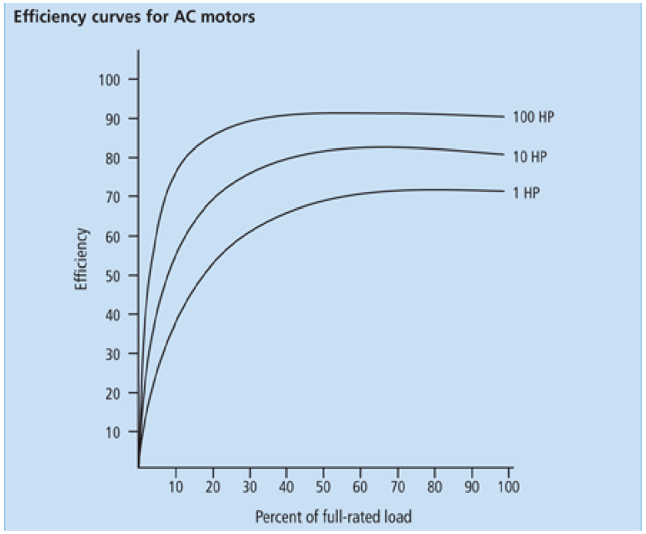


Load profile for a typical pump.



Electric motors

- Electric motor efficiency is highest at high loads, dropping below 40% load factor.
- Electric motors efficiencies are usually around 60 to 95% depending on their size.
- Main energy efficiency aspects associated with electric motors are as follows:
  - **Sizing:** Oversize may not be efficient.
  - **Operation profile:** Steady profile versus variable.
  - **Good maintenance**
- **Power factor:** Actual power in kW divided by electrical kVAR. A low power factor means added electric network losses.



System Planning for Energy Use Reduction

System planning – Areas to cover

- Ship operation involves a variety of activities and tasks including:
    - Loading / Unloading
    - Ballasting / de-ballasting
    - Inner gas generation and top ups (oil/product tankers)
    - Bunkering
    - Manoeuvring
    - Stand-by
    - Normal passage operation
    - Waiting and anchorage, Etc.

- How many machinery do we need for each of the above modes?

- System planning helps use of less machinery for doing the same job.

System planning – For electrical load reduction

- Avoidance of unnecessary energy use via switching off the machinery when not needed.

- As a general rule, all non-essential and not-required machinery that do not affect the ship and personnel safety should be stopped.

- Such items should be identified first and then procedures for the execution of tasks to be developed and implemented.

- Avoidance of parallel operation of electrical generators; when one is sufficient for the purpose.

- Optimized HVAC operation on board. The HVAC system operation should be aligned to outside and inside weather conditions.

- A proper coordination should be maintained on board between deck and engine departments especially for use of machinery/equipment.

System planning – For auxiliary machinery use reduction

- There are a significant number of redundant machinery on board ships.
- In practice, they are normally used more than necessary.
- This could include many fans and pumps.
- Proper planning of use of the number of machinery versus operation mode is an effective way of achieving this objective.
- For example, when ship is in port, the plan should include switching off one or two engine room ventilation fans as main engine is not operating any more.
- To ensure safe operation, all these need to be proactively planned and executed.
- Coordination of deck and engine departs are essential.

System planning – For auxiliary boiler use reduction

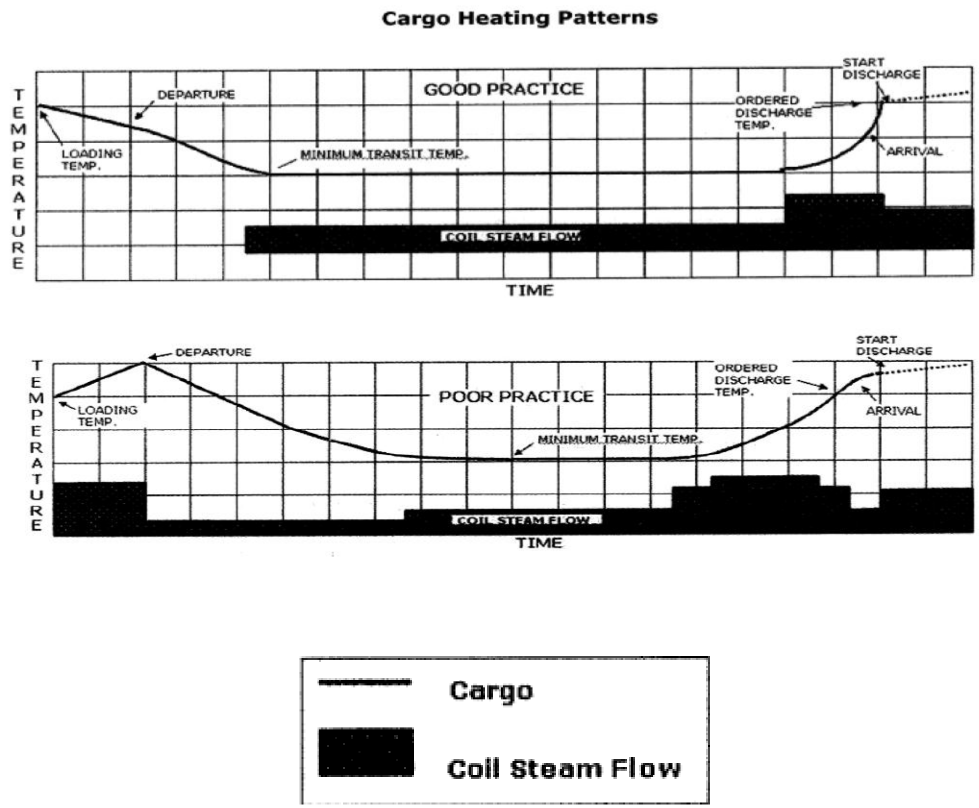
- In the majority of ships, under normal sea going conditions, the exhaust gas economiser is sufficient to produce enough steam for ship services.

- To avoid additional use of auxiliary boilers:
  - The requirement for steam need to be examined and planned in such a way that firing of the auxiliary boilers are minimised.
  - Also, the steam system maintenance should be done properly.

- Cargo heating plan
  - For ships with cargo heating requirements, it is prudent to have and follow a proper cargo heating plan.
  - A heating plan should be made soon after loading cargo and reviewed/updated on a daily basis.
  - It is also part of best practice for vessels to complete the heating abstract (daily basis) after completion of each voyage.

Cargo Heating Plan

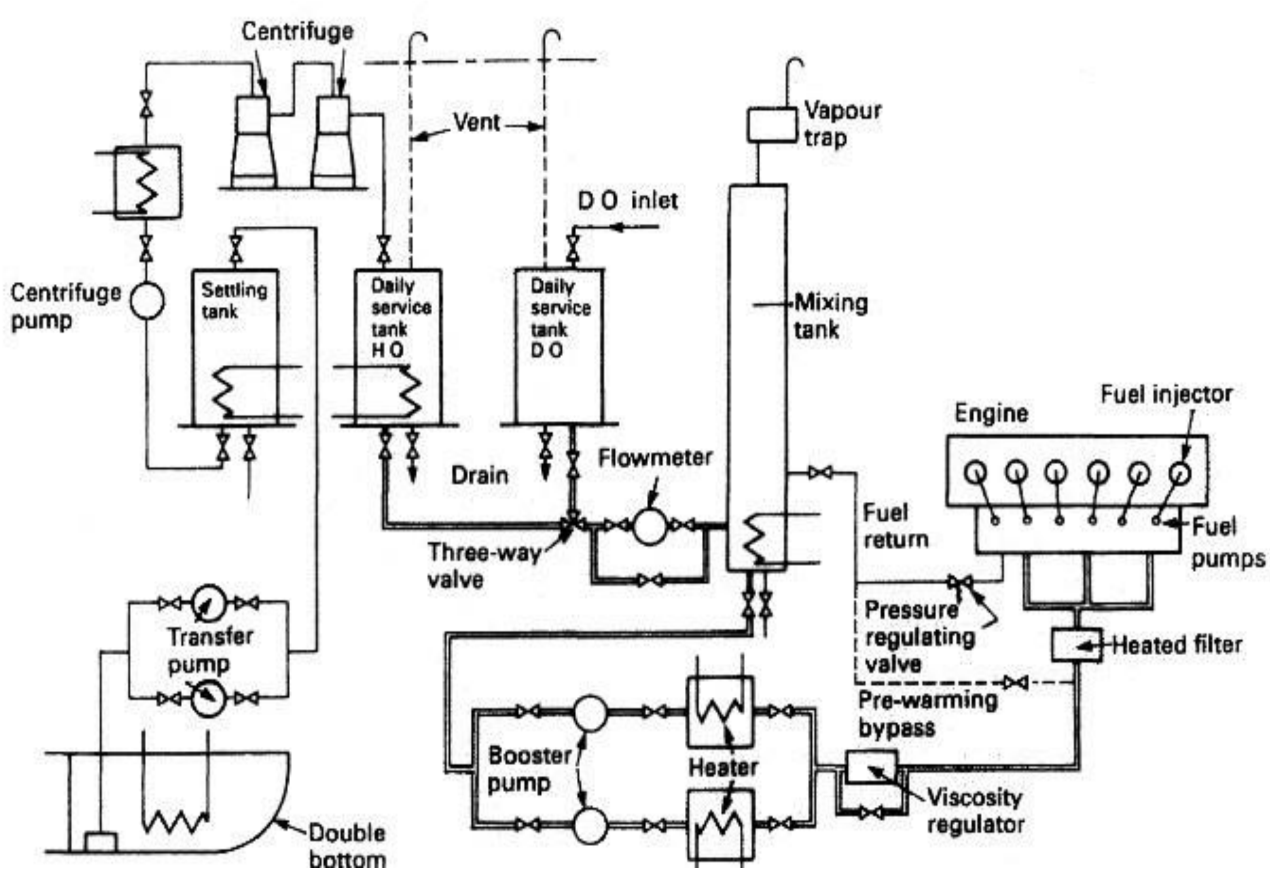
- The following figure shows two typical cargo heating pattern graphs.



Fuel Management

Typical fuel oil system

- Storage tanks
- Transfer pumps
- Settling tank
- Purifiers (centrifuge)
- Service tanks
- Flow meter
- Heaters
- Viscosity regulator



Typical fuel oil system for a cargo ship [Source: http://www.machineryspaces.com/fuel-oil-treatment.html]

Fuel management aspects

- Fuel quality has significant impact on engines' and boilers reliability and performance.

- The limits for fuel quality parameter as set out in International marine fuel standard, ISO 8217.

- The standard specifications are based on the understanding that the fuel will be treated on-board.

- Fuel management relates to:
  - Bunkering
  - Storage
  - Transfer and treatment
  - Combustion
  - Etc.

Fuel bunkering main activities

- **Handling:** Safe handling and pollution prevention
- **Quantity:** Correct measurements before, during and after bunker operations,
- **Storage of delivered fuel:** Use of correct storage tanks (to avoid mixing of incompatible fuels)
- **Samples:** Collection of representative samples for regulatory purposes
- **Quality:** Analysis of fully representative samples as first line of defence against poor quality fuels.

Fuel quality and quantity assurance

Importance of knowing your fuel helps with:

- Appropriate ship-board storage, handling, treatment and combustion.
- The use of fuel in a most safe and efficient way.
- Compliance to environmental regulations.
- Maximise combustion performance.
- Reduce commercial, technical and operational risks associated with using varying quality fuels.

Fuel storage and transfer

Avoid co-mingling:

- Do not mix different batches of fuels to the extent possible.
- Incompatibility is the most common problem with the bunker fuel mixing that leads to clogged filters, engine damage, etc.

Clogged fuel pipes due to poor quality of fuel

Bunker quantity measurement

- **Manual gauging of all the fuel tanks before and after bunkers**
- **Ship-board fuel inventory analysis:**
  - This is normally done through tank sounding and is currently the most widely used practice.
- **Use of the mass flow meters:**
  - Based on the performance of the available technologies.
  - A number of options are available (volumetric, Coriolis, ultrasound).
  - All require varied degrees of correction for fuel density and temperature.

Fuel treatment - Settling tank

- The role of settling tank is to separate heavy residues and water from the fuel through the natural settling process.

- To provide best performance:
  - Settling tank temperature should normally be maintained between 60-70C for HFO.
  - Transfer of fuel to the settling tank for top up to be in small quantities at frequent intervals not to cause major change in temperature or settling disturbances.
  - Drain off water and sludge at the settling tank bottom drains at regular intervals.
  - It is always preferable to use the lower blow-down outlet to minimise the space available for sludge accumulation and give early warning of contamination issues.

Fuel treatment - Purification

- Centrifugal separators are used to separate sludge, water, cat fines, etc.
- The efficiency of a centrifugal separator is affected by:
  - Composition of the fuel
  - Quantity of fuel
  - Temperature of fuel
  - Cleanliness of the separator and its general working conditions.

- For good purifier performance:
  - Operate purifiers in an optimum manner.
  - Make sure purification system and its disks are correctly working.

Fuel treatment – Viscosity control

- For use of fuels in engines, an optimal injection viscosity is required.
- This is achieved via fuel temperature control.
- Incorrect injection viscosity results in poor atomisation which affects the engine efficiency and emissions.

Fuel steam heating for viscosity control

Fuel additives

- Additives could provide benefits for marine fuels mainly in areas:
  - Improvement of fuel combustion
  - Reduction of particulate matter and visible smoke.
  - Overcoming soot build-up in the exhaust system
  - Economiser improvements via keeping them clean, foul free with a reduction in risk of fire.
  - Reduction and inhibition of deposit build-up on piston rings, injector nozzles and valves.
  - Reduction and prevention of cylinder liner lacquering build-up.
  - Protection against fuel pump and injector needle seizures

Summary of fuel management energy efficiency measures

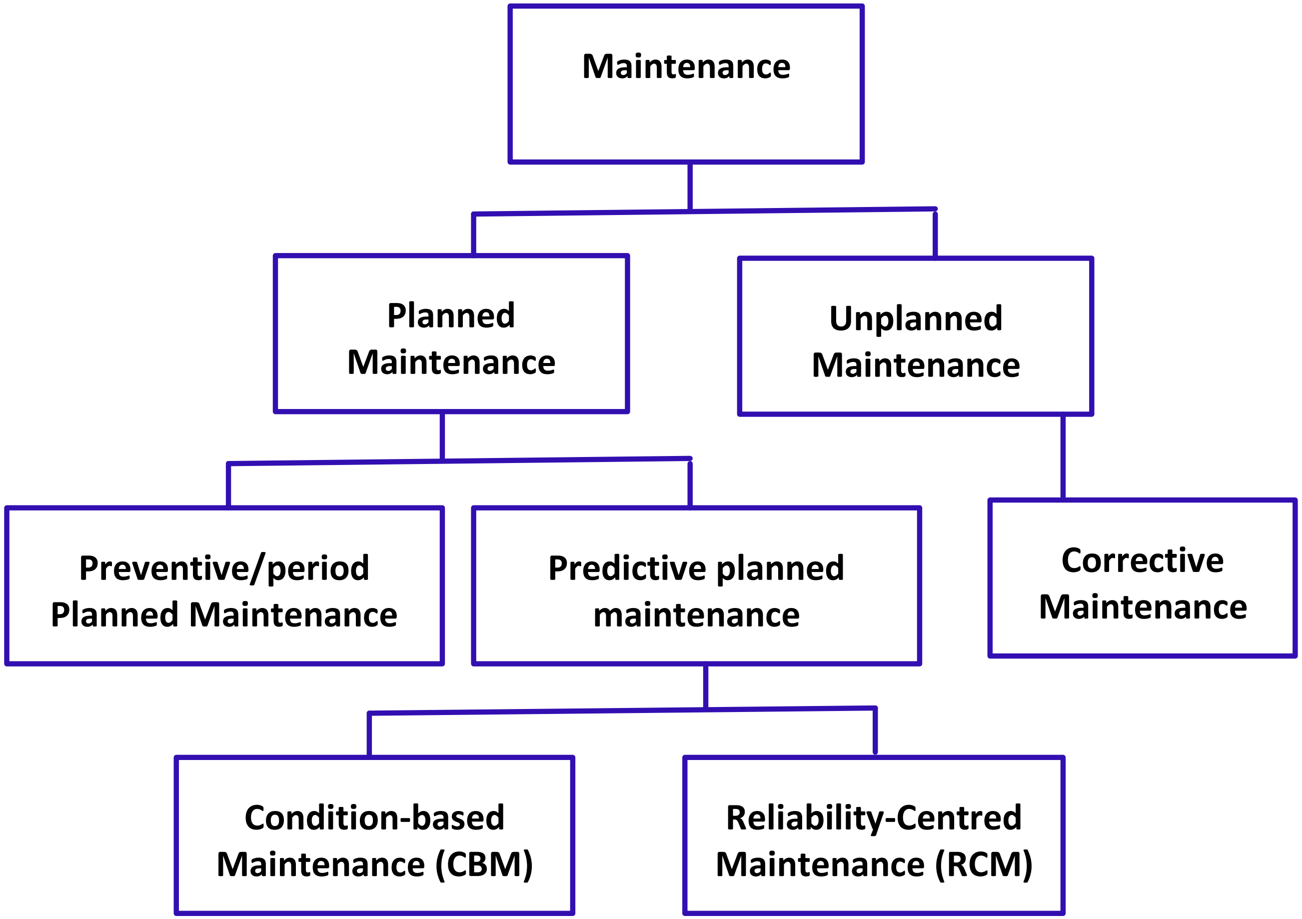
- Economical amount of bunker to be carried around.
- Proper temperature control of fuel at various stages of treatment.
- Ensure tank fittings (manhole covers, vent pipes, etc.) do not allow water, cargo or other material to get into the fuel.
- Ensure heating coils are tight.
- Ensure that tank wall condition is in good order
- Maintain settling tanks at a correct temperature
- Periodically verify that the viscosity controller is working correctly.
- Monitor fuel oil sludge levels and ensure that sludge levels are not high due to poor maintenance of the purifiers.
- Fuel measurement and metering is the first step for subsequent performance analysis of various engines and boilers.

Ship Maintenance and Energy Efficiency

Requirements for maintenance management

- International Safety Management Code (ISM) specifies the regulations for ship maintenance for safety
- The ISM Code stipulates that each ship operator is responsible for the safe and pollution free operation of the ship.
- The part of the ISM Code on "maintenance of the ship and its equipment" describes in general how ships should be maintained, inspected, non-conformities be reported and corrective actions are taken.
- From ISM Code perspective, efforts should be directed at safety and environmental protection.
- Fortunately, energy efficiency is compatible with good maintenance and improves accordingly.

Types of maintenance



Types of maintenance

- **Unplanned Maintenance: (**breakdown maintenance).
- **Corrective maintenance:** The corrective maintenance may be defined as maintenance which is carried out after failure detection.

- **Planned Maintenance:** Maintenance according to a defined schedule
- **Preventive Maintenance:** (a subset of planned maintenance). Preventive maintenance usually depends on the manufacturer‘s recommendations and past experience for scheduling repair or replacement time.
- **Predictive Maintenance:** This is a subset of planned maintenance**.** This is generally based on what is referred to as:
  - **Condition-based maintenance** (CBM); or
  - **Reliability-based maintenance** (RCM).

Maintenance and energy efficiency

- Good maintenance is fundamental for energy efficient operation of machineries and systems.

- Maintenance of the hull, propeller and main engine are very effective for energy efficiency as discussed before.

  - These items will not be discussed further.

Maintenance for energy efficiency
Mechanical transmission systems

- Shaft and couplings alignment
- V-belt slippage reduction
- Chain and gear alignment
- Proper bearing lubrication

Maintenance for energy efficiency
Steam system maintenance

- Steam trap maintenance and inspection programs.
- Reduced fouling of boilers
- Adjustment of combustion air in relation to fuel flow (excess air control)
- Leak detection programs for hot water and steam.
- Insulation inspection programmes to reduce heat losses from the system
- End-use steam optimisation via improved cleaning of the heat transfer surfaces, etc.

Maintenance for energy efficiency
Compressed air system

- Compressed air systems can be treated similar to steam system:
  - Air leaks prevention,
  - Excessive end-use air consumption reduction
  - Optimal condition of air compressors

- <u>Compressors:</u> Poor maintenance of compressors or incorrect pressure settings would lead to extra running hours and thus more energy use.
- <u>Air leaks:</u> Any air leakage in the system would require the compressors to run more than necessary.
- <u>End use devices maintenance:</u> The compressed air is used for end-use devices that may have a poor state of maintenance. This will lead to extra need for compressed air generation.

Technical Upgrade and Retrofit

Overview

- There are a good number of “Energy Efficient Technologies (EETs) that if used can lead to ship-board energy saving.
- The EETs are normally candidates for new ship constructions as their use on existing ships may not be cost effective.
- However, there are a number of technologies that could be used on existing ships.
- This is referred to as “technology upgrade”
- A number of such technologies are reviewed in this section.

Devices forward of propeller - Ducts

- A number of designs exists
- <u>Wake field equalisation:</u> The installed duct provides a more uniform wake field for the propeller.
- <u>Reduction of propeller hub vortex:</u> An improved flow behind the duct significantly reduces the propeller hub vortex.
- More suitable for the larger ships and hull forms.

Mewis duct

Wake equalizing duct

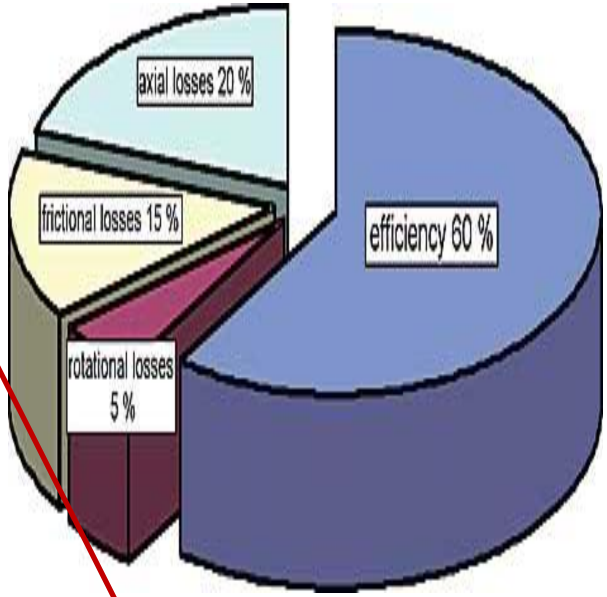
Devices forward of propeller – Pre-swirl stator

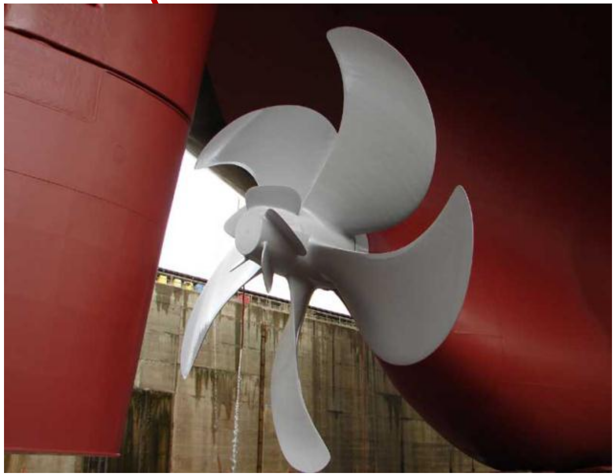
- Enhanced propeller efficiency via fitting of the bladed stators on the hull immediately forward of the propeller.
- The stator fins adjusts the flow into propeller as the same happens in in normal pumps with guide vanes.
- A gain of 4% in propulsion power is claimed.
- As with the ducts, the device is especially suitable for the larger ships and hull forms.
- Its first installation on a 320,000 DWT VLCC has resulted in a 4% reduction in fuel consumption with more installations afterwards

DSME system [SPPA]

Propeller Boss Cap Fins (PBCF)

- Propeller has some flow losses that is recovered by PBCF.
- PBCF eliminates or reduces the hub vortices generated.
- As a result, PBCF can play an important role in reducing propeller generated noise and vibration.
- It is suitable for slow speed vessel.
- PBCF boost propulsive efficiency by about 5% and ship fuel efficiency by about 2%.
- PBCF can be retrofitted easily to an existing ship.

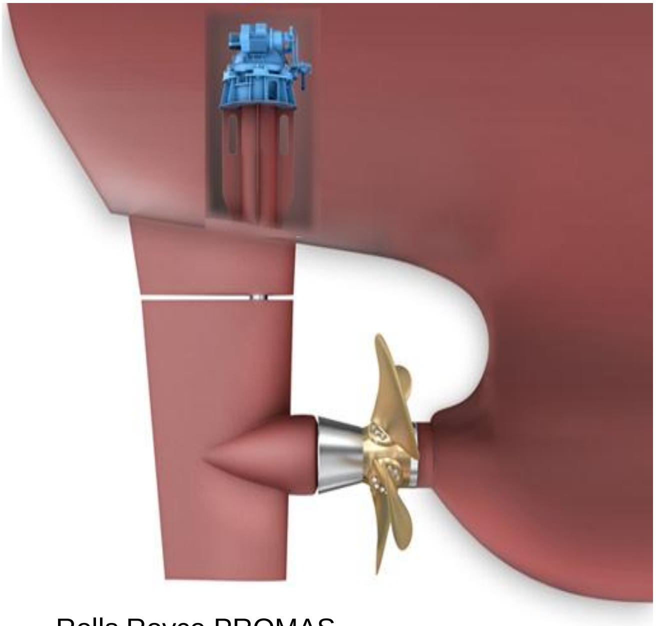




Fathom

Integrated propeller and rudder units

- An integrated system of propeller and rudder from fluid flow points of views.
- The effect of these units has been reasonably well documented in tests on models and in full-scale trials.
- A reduction of about 5% in required power of the vessel for design speed can by typical savings.
- The units are applicable to general cargo vessels, RoPax vessels and container vessels operating at relatively high speed.



Rolls Royce PROMAS

Ducted propellers

- Compared to the conventional propeller, the ducted propeller arrangement allows a larger mass of water to be supplied to the propeller.

- It provides higher efficiencies due to improved flow pattern.

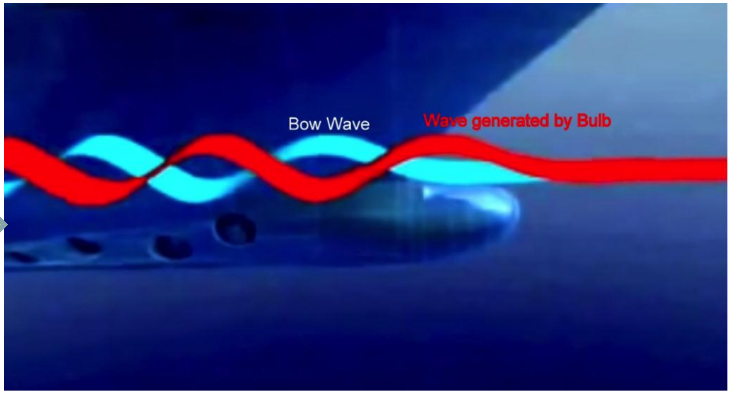
- Similar to Mewis Duct, it may have more positive impact on certain ship types and designs.

- On the negative side, the duct:
  - Additional flow resistances.
  - Prone to fouling

- Ducted propellers are suited for ships operating at high propeller loadings, such as tankers, bulk carriers, tugs, etc.

Fore-body optimization and bulbous bow

- Fore-body optimization includes consideration of for example bulb design.
- A properly designed bulbous bow reduces wave resistance by producing its own wave system that is out of phase with the bow wave from the hull, creating a cancelling effect



Soumya Chakrabortv

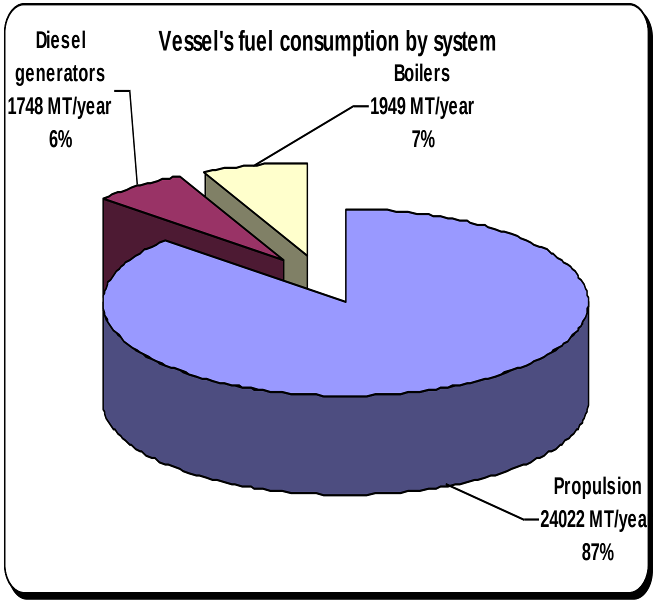
A Maersk ship doing a "nose job"!

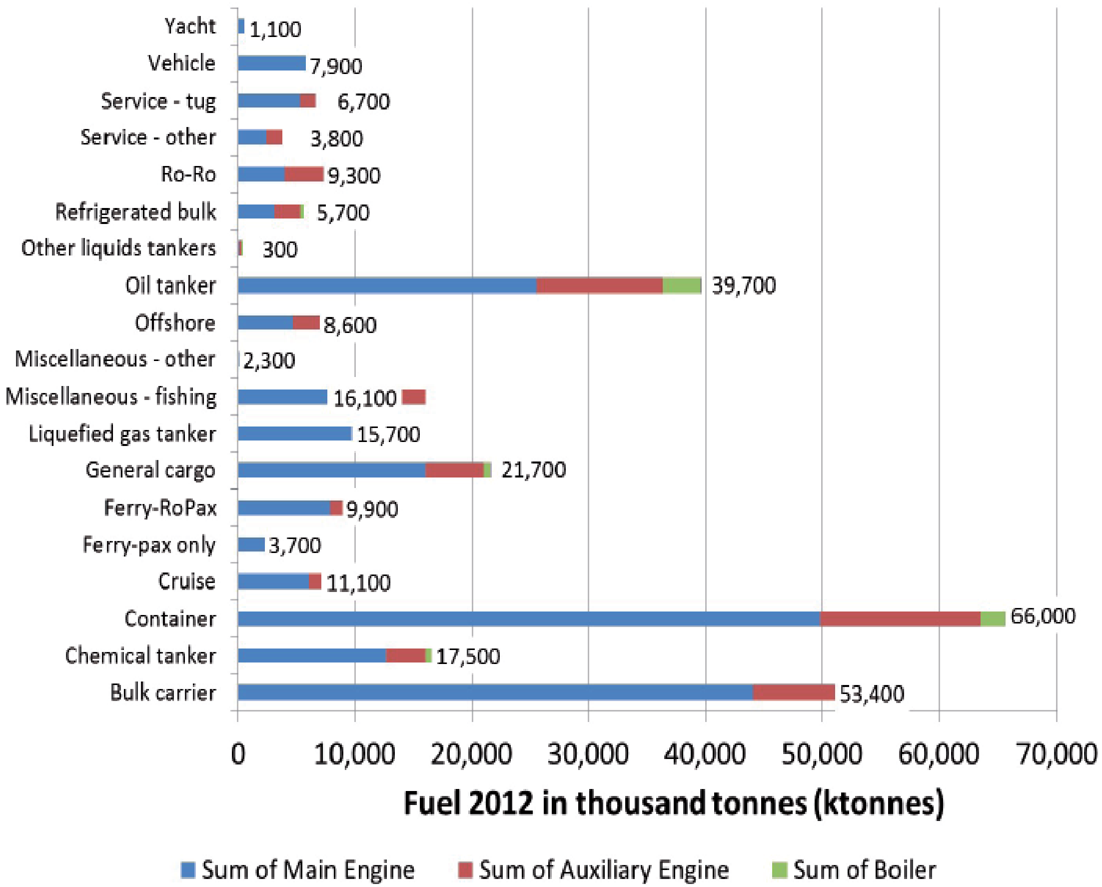
Maersk, Jonathan Wichmann

Boilers and Steam System

Energy use in boilers

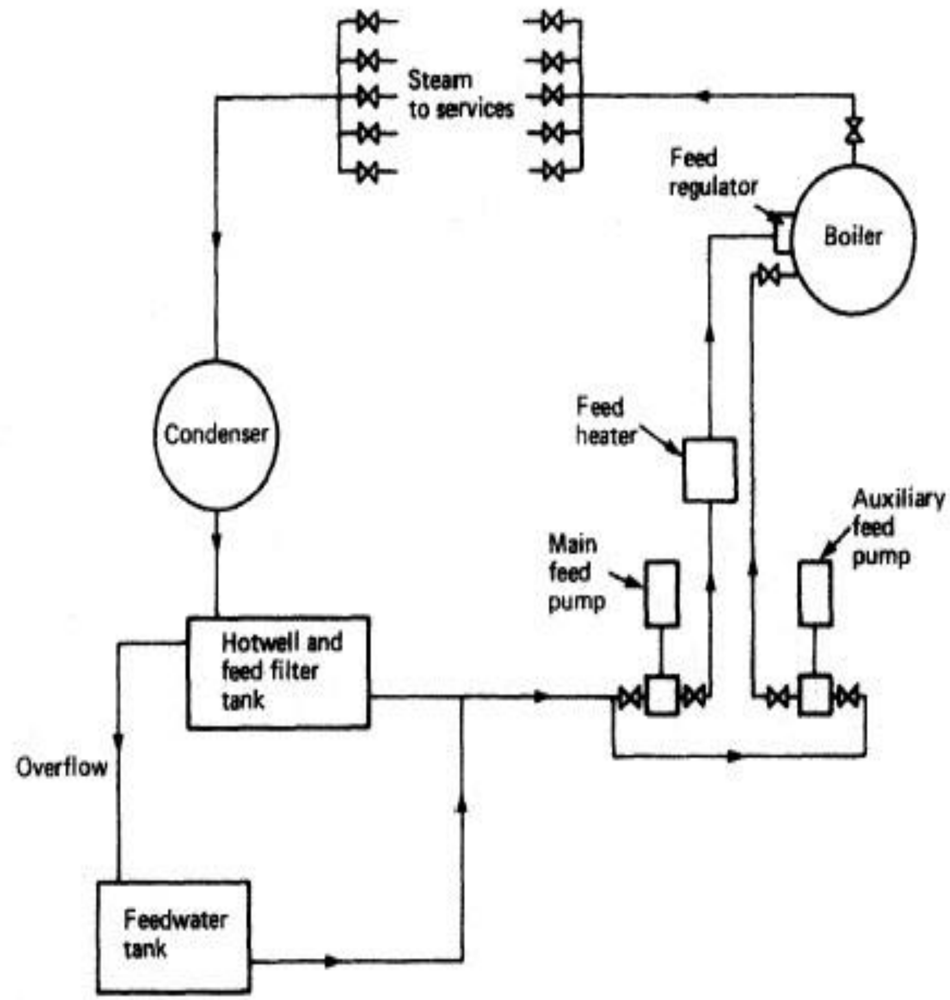
- For some ship types, fuel consumption by boilers can be significant.





Overview of steam system

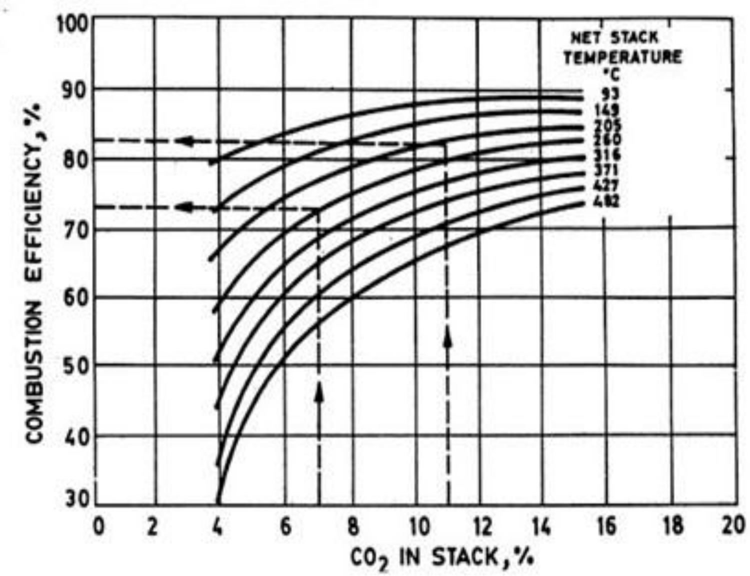
- The main boilers (steam ships)
- The auxiliary boilers.
- The exhaust gas economiser
- The steam distribution system.
- Steam end-use: This refers to the the steam consuming machinery and equipment



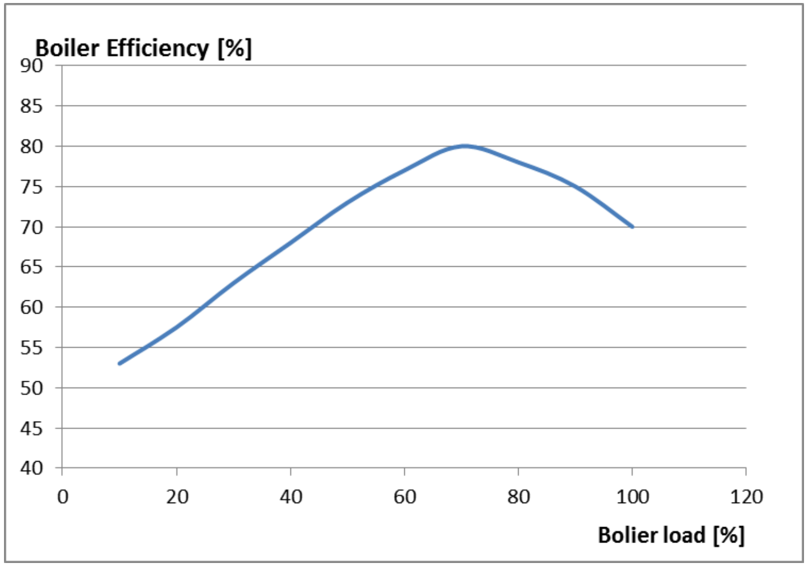
Boiler energy efficiency measures

For good operation and maintenance, avoid:

- Fouling of all heat transfer surfaces
- Fouling of boiler tubes and heat transfer surfaces on the gas side
- Fouling or scaling of boiler tubes on the water side.
- Low hot well temperature
- High blow-down levels
- Excess air in the boiler
- Low load factor operation



BOILER COMBUSTION EFFICIENCY INCREASE



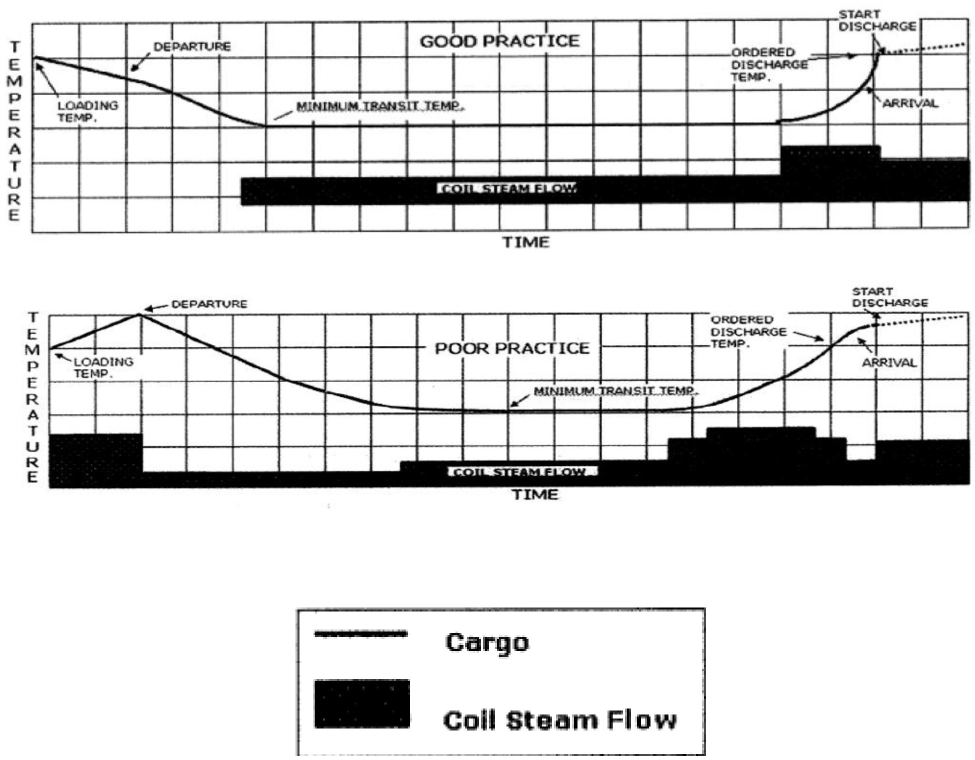
Steam system energy efficiency measures

- **Steam distribution system energy efficiency measures**
  - Reduce steam leakage
  - Reduce heat loss due to inadequate insulation
  - Reduce steam trap losses
- **Steam end-use energy efficiency measures**
  - Steam end-use could vary according to ship types. The main users of steam include:
    - Steam-driven cargo pumps in tankers.
    - Steam driven ballast pumps
    - Cargo heating
    - Fuel storage, treatment and condition system
    - Fresh water generation especially in cruise ships
    - HVAC system in particular in cruise ships

Steam end use optimisation

- Cargo heating planning and optimisation
- Steam for cargo discharge or ballast water operation
- Inert Gas Generation (IGG)

Cargo Heating Patterns



Steam system: Ship-board best practice

- Steam pipes insulation should be kept in good condition.
- Boiler insulation should be kept in good condition.
- Steam leaks are to be identified and stopped.
- Boiler pressure setting for burner start/stop is to be as wide as practicable.
- Cargo tank heating according to the specification of cargo.
- Fuel temperature in storage, settling ad supply tanks shall be monitored and kept at acceptable lower limits.
- Steam trap maintenance should be carried out regularly.
- Starting of auxiliary boilers too far in advance of intended use is to be avoided.
- Steam dumping when possible is to be avoided.
- Pipe/ valve lagging/insulation is to be maintained
- Bunker tank heating is to be optimized.

Thank you for your attention

ANY QUESTIONS?

For more information please see:
www.imo.org