SY486K MICS Lecture 1

Maritime Propulsion Systems

CDR Brien Croteau, USNA Cyber Science Department, January 2023

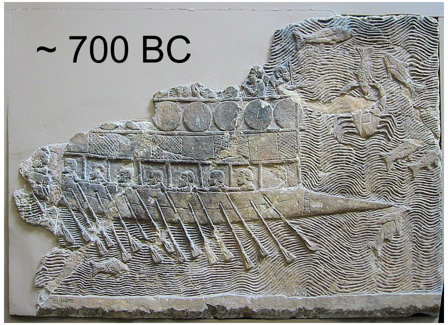
Outline

- Propulsion Types
- Power Generation
  - Steam
  - Diesel
  - Gas Turbine
  - LNG
  - Fuel Cell
- Typical Ship Configurations

Propulsion Types

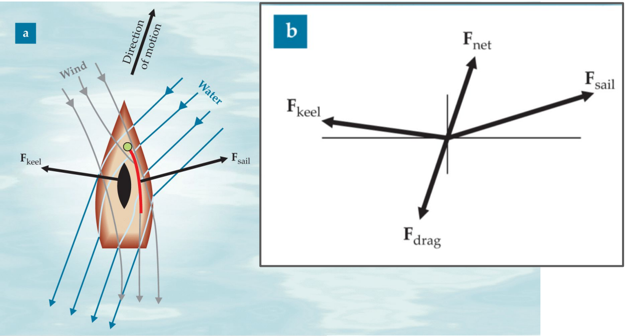
Oars/Paddles

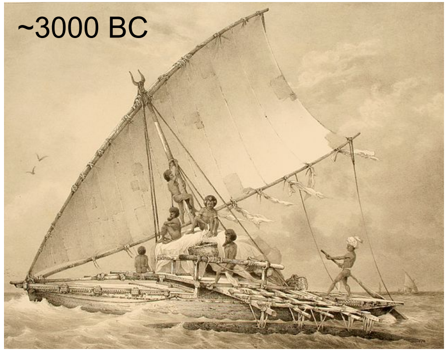
The difference between oars and paddles is that oars are used exclusively for rowing. In rowing the oar is connected to the vessel by means of a oarlock pivot point. The rower pulls on the short end of the oar, while the long end is in the water. By contrast, paddles, are held in both hands by the paddler, and are not attached to the vessel.

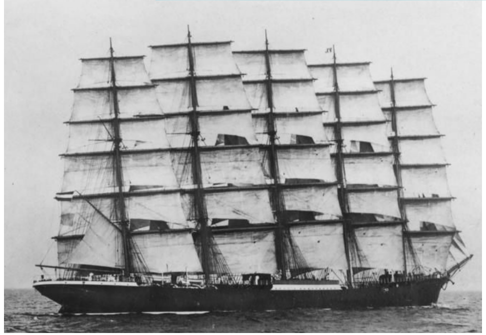


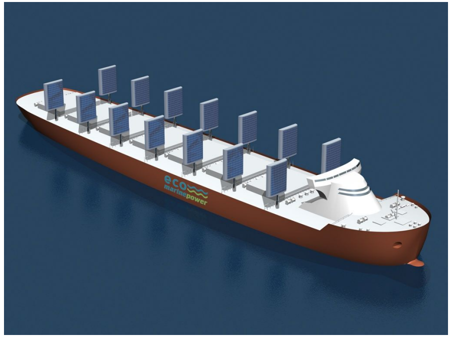
Sails

Use of an airfoil to create lift to propel the vessel forward.



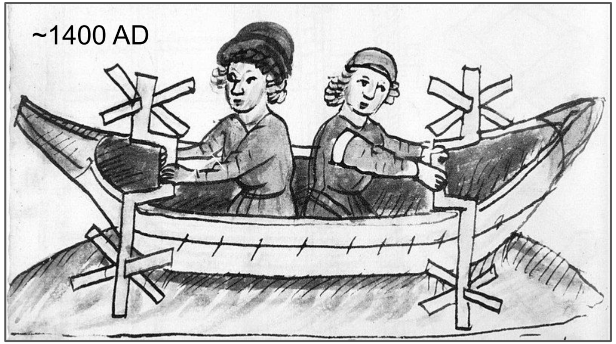


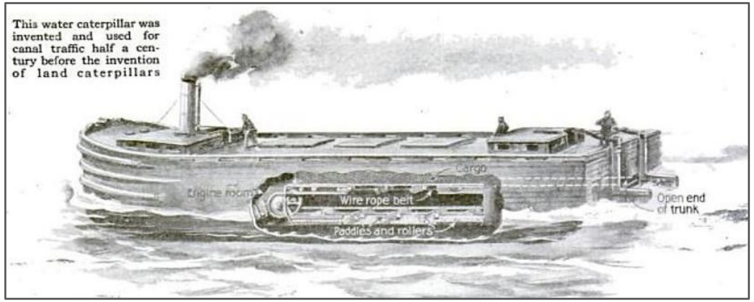




Paddlewheel / Caterpillar

The paddle wheel is a large steel framework wheel. The outer edge of the wheel is fitted with numerous, regularly spaced paddle blades (called floats or buckets). The bottom quarter or so of the wheel travels under water. Cat != [MHD](MHD)

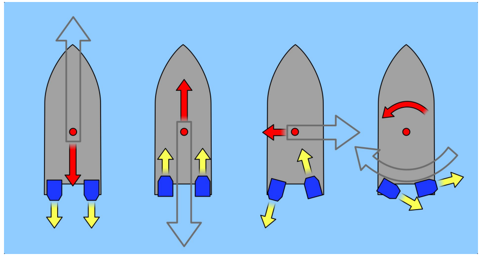


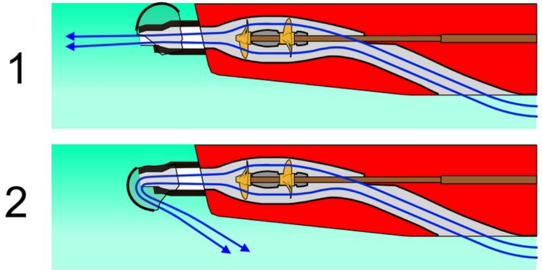


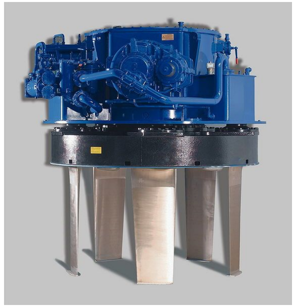
Pump-Jet / Cyclorotor

A pump-jet, hydrojet, or water jet is a marine system that produces a jet of water for propulsion. The mechanical arrangement may be a ducted propeller (axial-flow pump), a centrifugal pump, or a mixed flow pump.

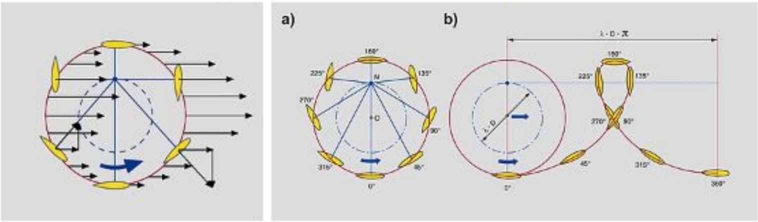
The Voith Schneider Propeller (VSP) is a specialized marine propulsion system based on a cyclorotor design. It is highly maneuverable, being able to change the direction of its thrust almost instantaneously. It is widely used on tugs and ferries.







Operation of a Voith Schneider propeller



Lift forces imparted to the VSP from the water body

Path of a blade in the water

Propellers

A propeller (colloquially often called a screw) is a device with a rotating hub and radiating blades that are set at a pitch to form a helical spiral which, when rotated, exerts linear thrust. Screw ship propellers were developed in the 1830's.

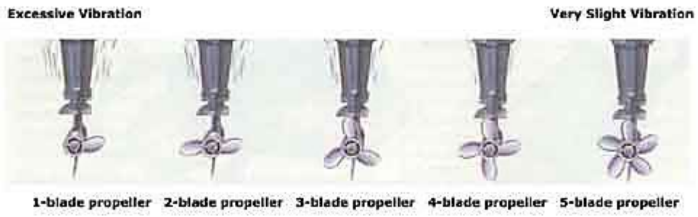
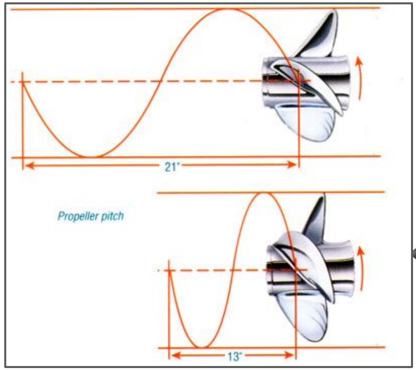
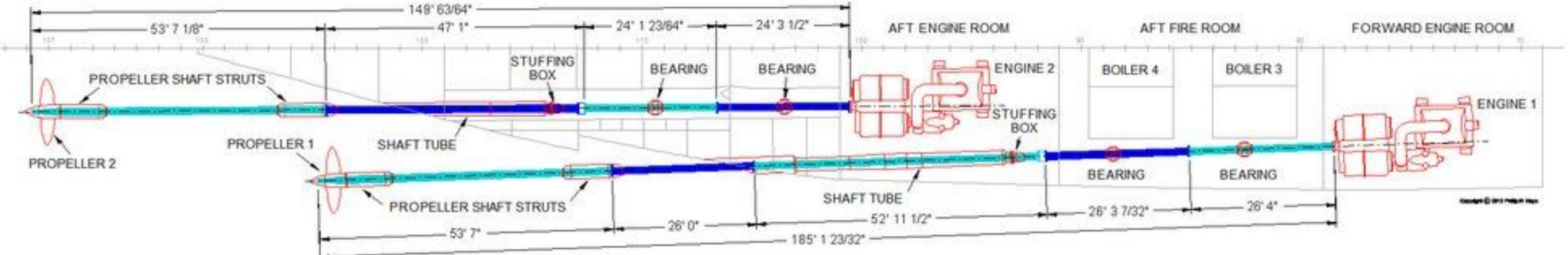


Figure 4-13
As blades are added, efficiency and vibration level decrease.



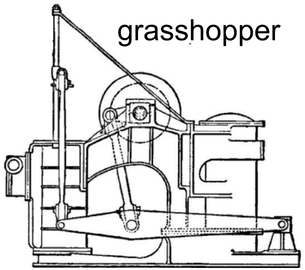


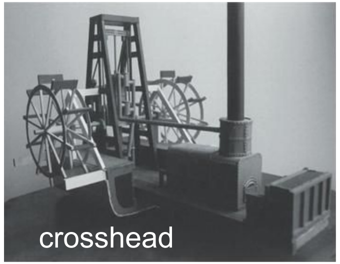
PROPELLER SHAFT ARRANGEMENT

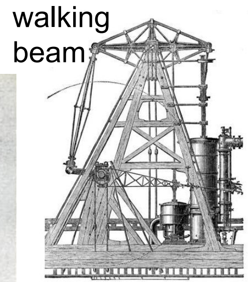
Power Generation

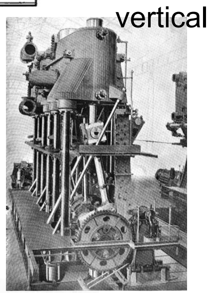
Early Steam Engines

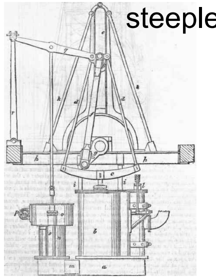
Early [marine steam engines]() came about around 1800 and started with reciprocating pistons and were classified by how the piston(s) moved.

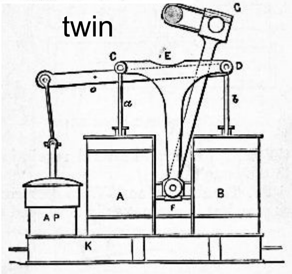


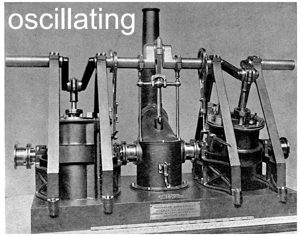


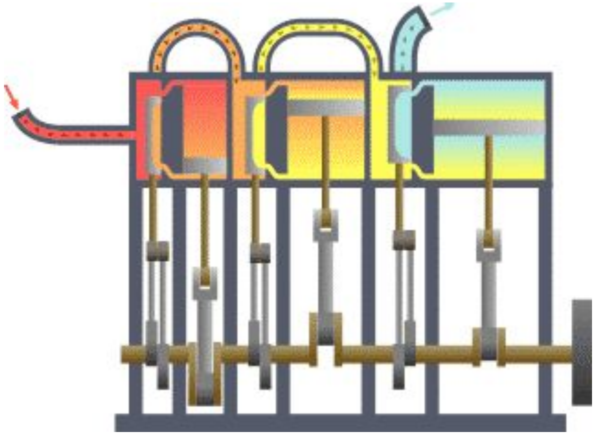




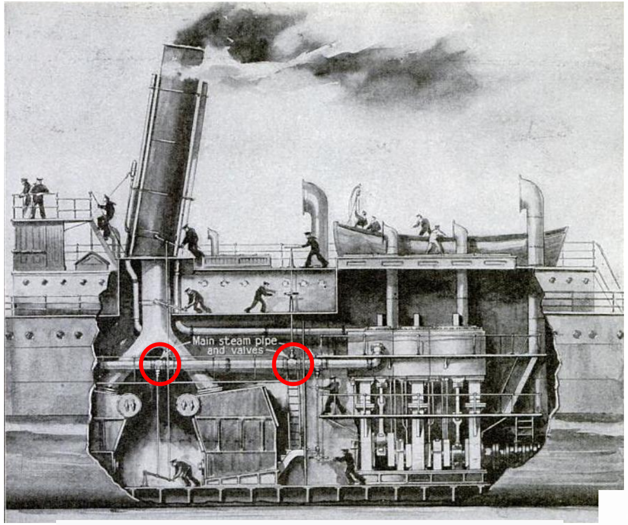




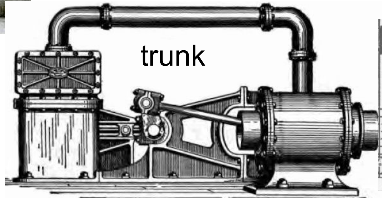


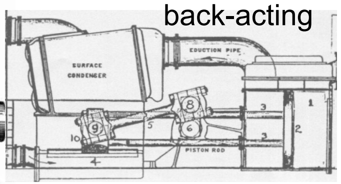


A compound engine is a steam engine that operates cylinders through more than one stage, at different pressure levels. Compound engines were a method of improving efficiency.



Period cutaway diagram of a triple-expansion steam engine installation, circa 1918. This particular diagram illustrates possible engine cutoff locations, after the *Lusitania* disaster and others made it clear that this was an important safety feature

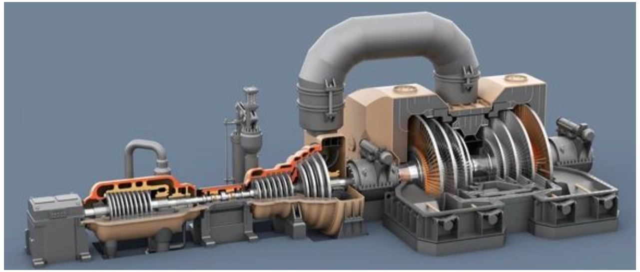


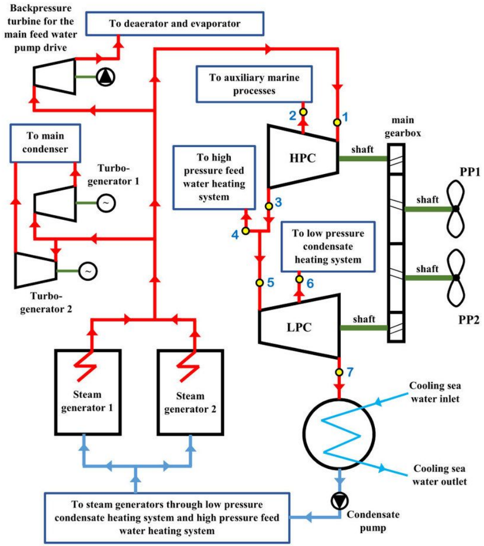


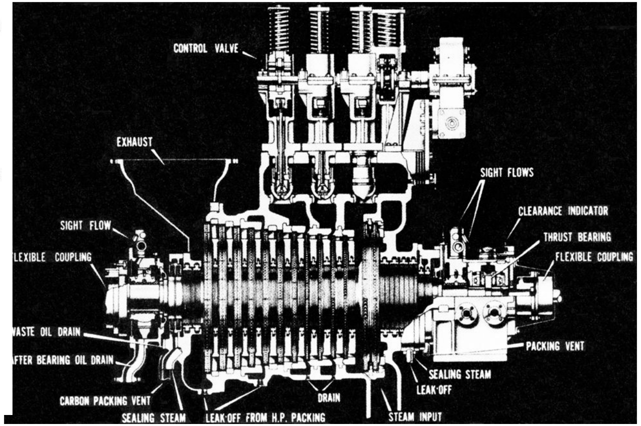
Steam Turbines

The steam turbine is a form of heat engine that derives much of its improvement in thermodynamic efficiency from the use of multiple stages in the expansion of the steam, which is closer to the ideal reversible expansion process.

In steamships, advantages of steam turbines over reciprocating engines are smaller size, lower maintenance, lighter weight, and lower vibration.

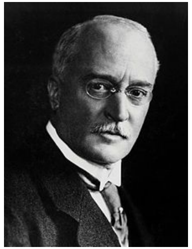


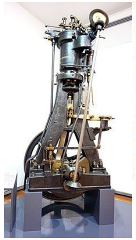




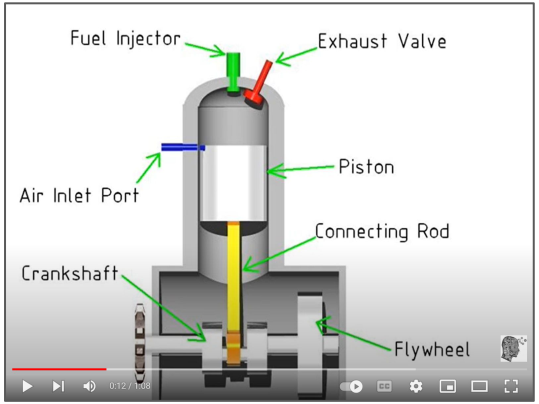
Diesel

Rudolf Diesel
1858-1913

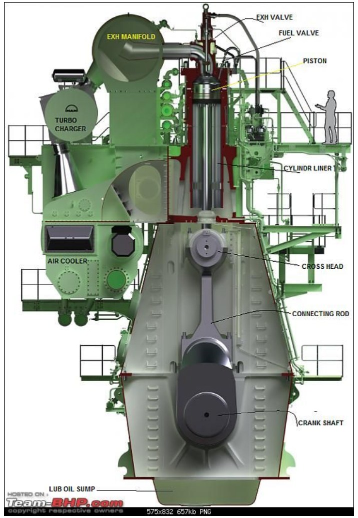




Most modern ships use a reciprocating diesel engine as their prime mover, due to their operating simplicity, robustness and fuel economy compared to most other prime mover mechanisms. The diesel engine has the highest thermal efficiency (engine efficiency) of any practical internal or external combustion engine due to its very high expansion ratio and inherent lean burn which enables heat dissipation by the excess air.



https://www.youtube.com/watch?v=HQk1u_kvQSA



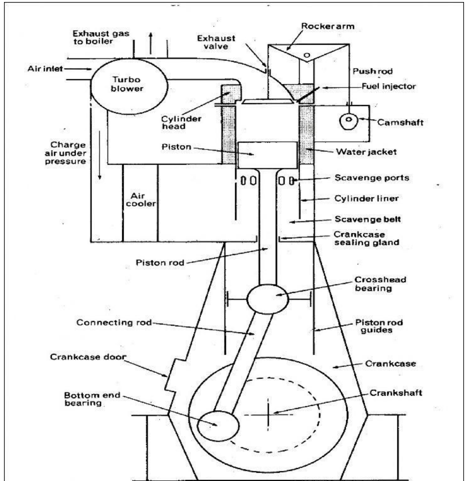
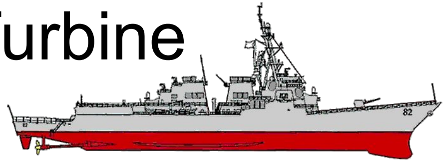
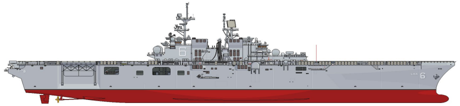
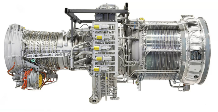


Figure 2.22 Typical slow-speed crosshead diesel engine.

Gas Turbine

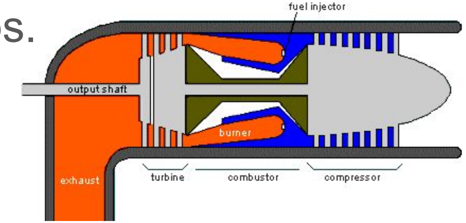


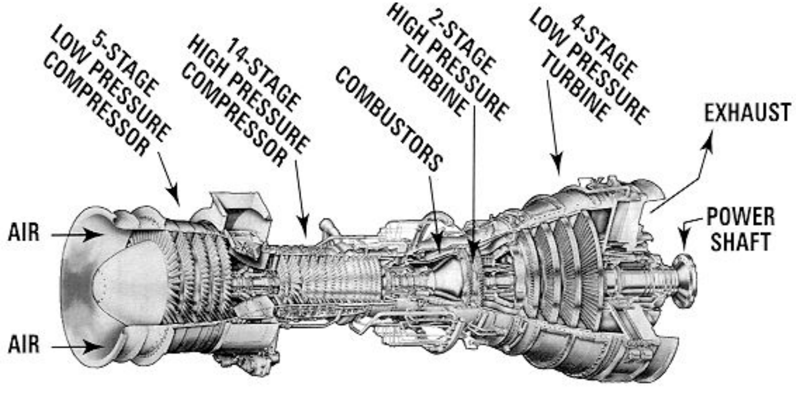


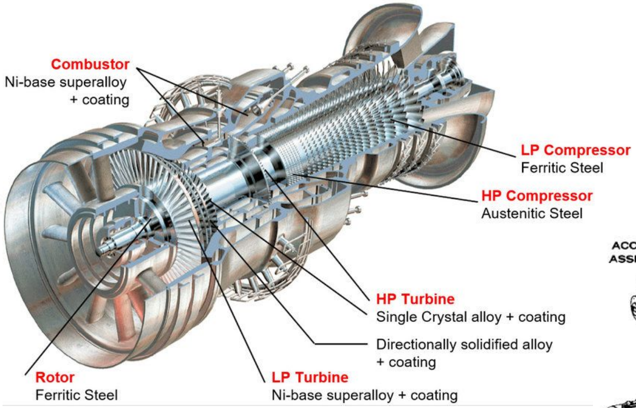


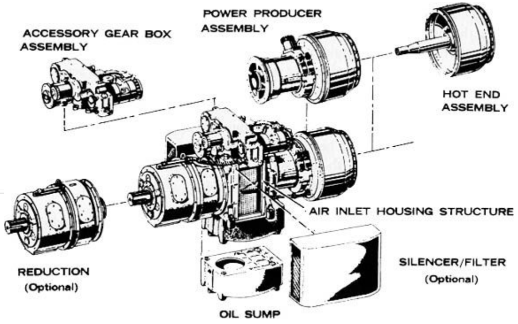
GE LM2500

The gas turbine is most familiar to people in it's application to the aerospace industry. Low weight to power ratio, compactness, and a reliable simple design are the major advantages. Because of their poor thermal efficiency at low power (cruising) output, it is common for ships using them to have diesel engines for cruising, with gas turbines reserved for when higher speeds are needed. More common in warships.







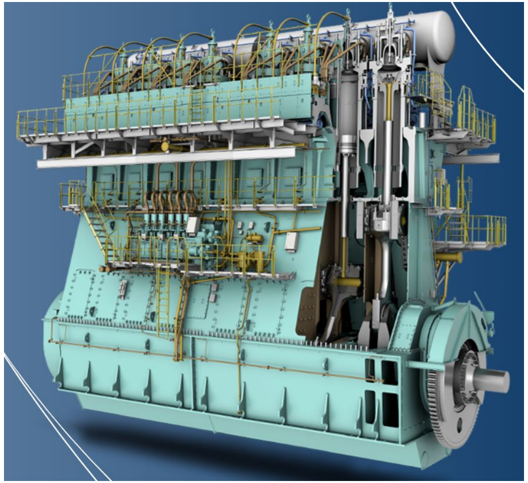


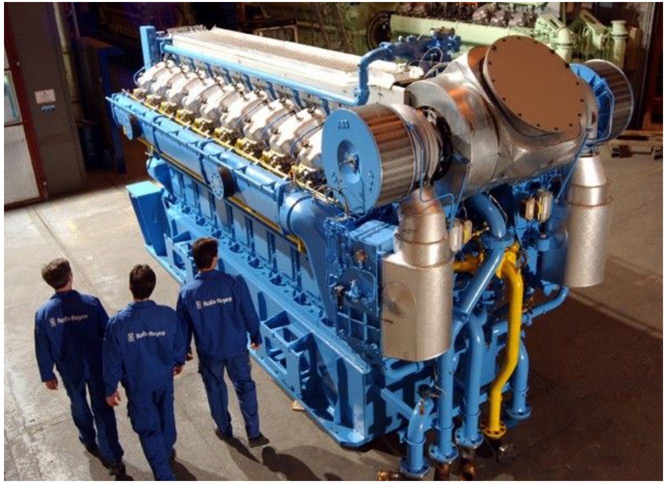
LNG / Tri-Fuel

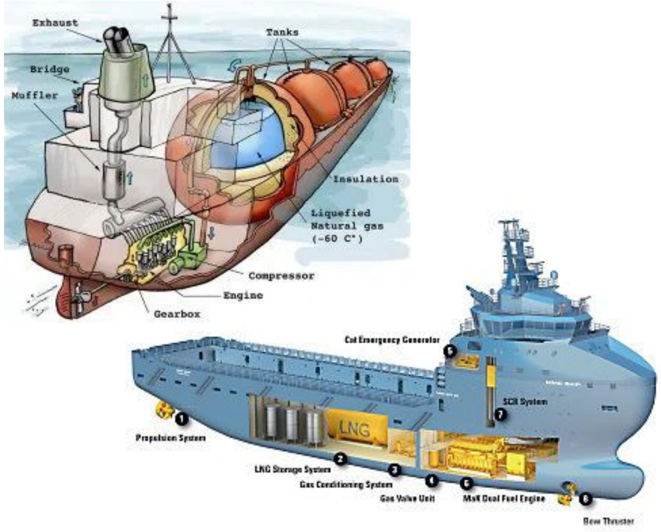
MARPOL Annex VI came into force on 19 May 2005. It introduces requirements to regulate the air pollution being emitted by ships

INTERNATIONAL MARITIME ORGANIZATION

Liquefied natural gas (LNG) engines offer the marine transportation industry with an environmentally friendly alternative to provide power to vessels. The natural gas is stored in liquid state and the boil-off gas is routed to and burned in dual- (or tri-) fuel engines. The International Convention for the Prevention of Pollution from Ships, 1973 modified in 1978, or "MARPOL 73/78" is one of the most important international marine environmental conventions.



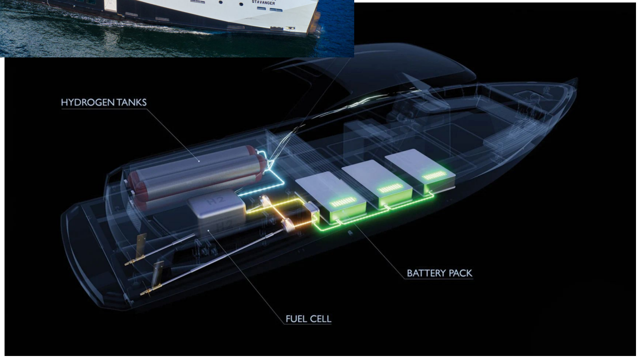


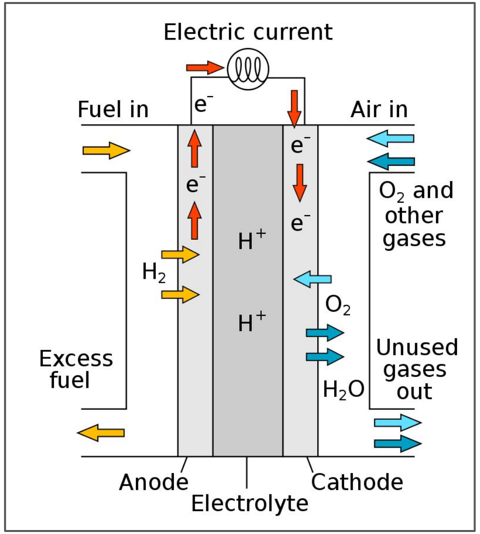


Fuel Cell / Electrical

A fuel cell is an electrochemical cell that converts the chemical energy of a fuel (often hydrogen) and an oxidizing agent into electricity through a pair of redox reactions. Fuel cells can produce electricity continuously for as long as fuel and oxygen are supplied.

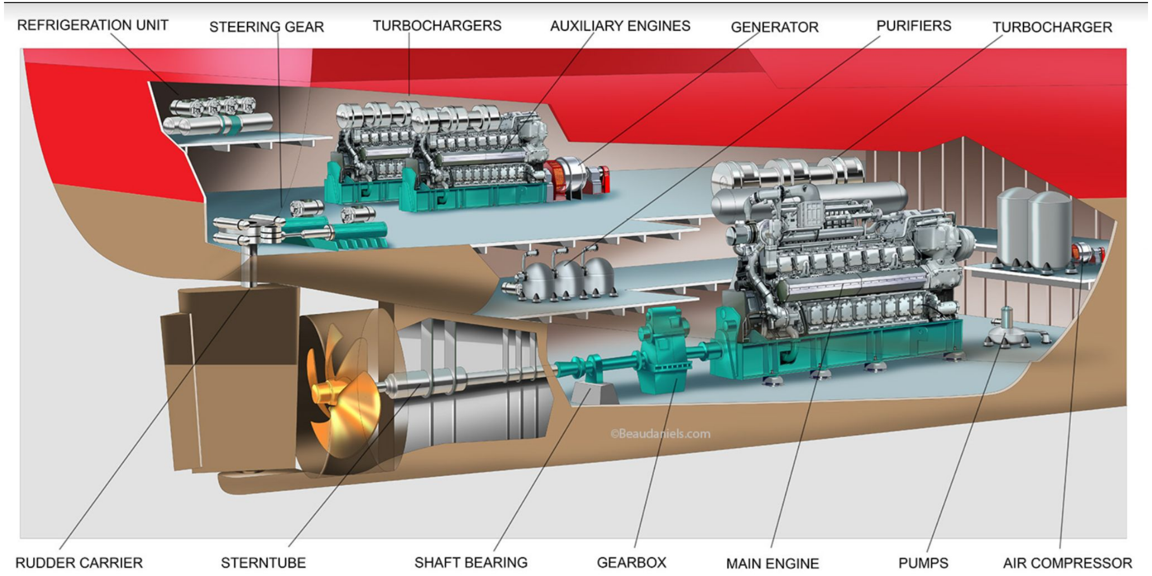
[MF Hydra](#)
Norway 2022



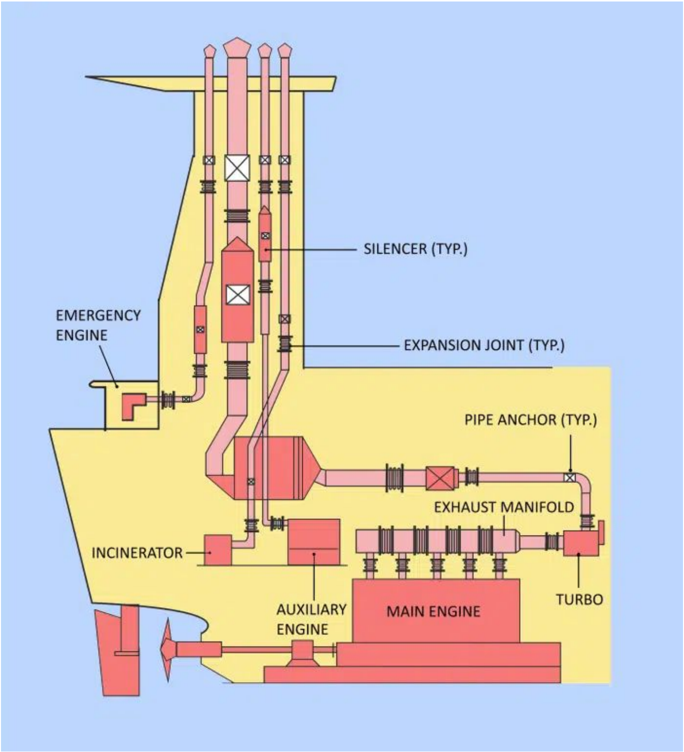


Ship Configurations

Cutaway of a Typical Ship Engine Room

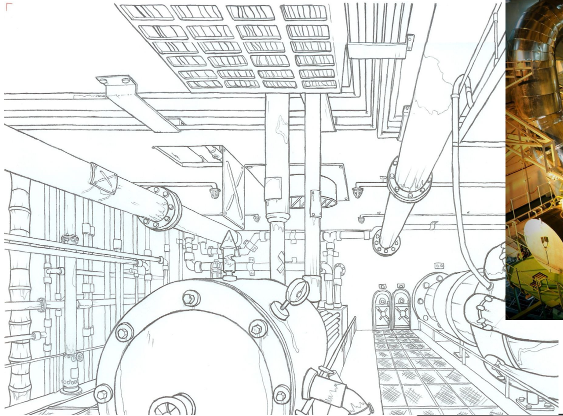


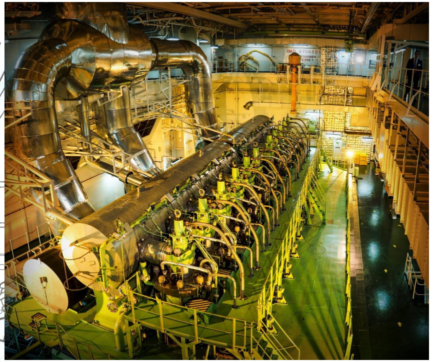
https://www.behance.net/gallery/31936141/EXXONMOBIL-FPSO-Vessel

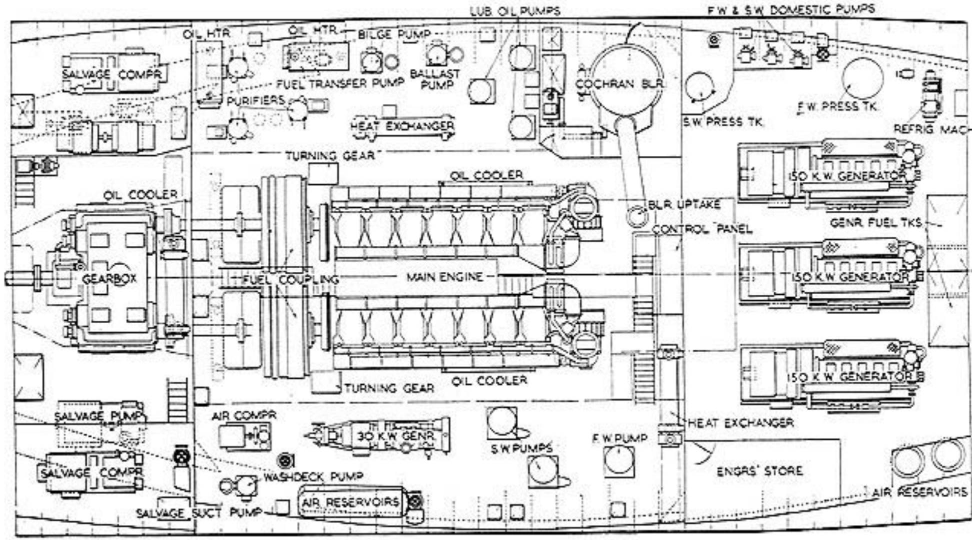


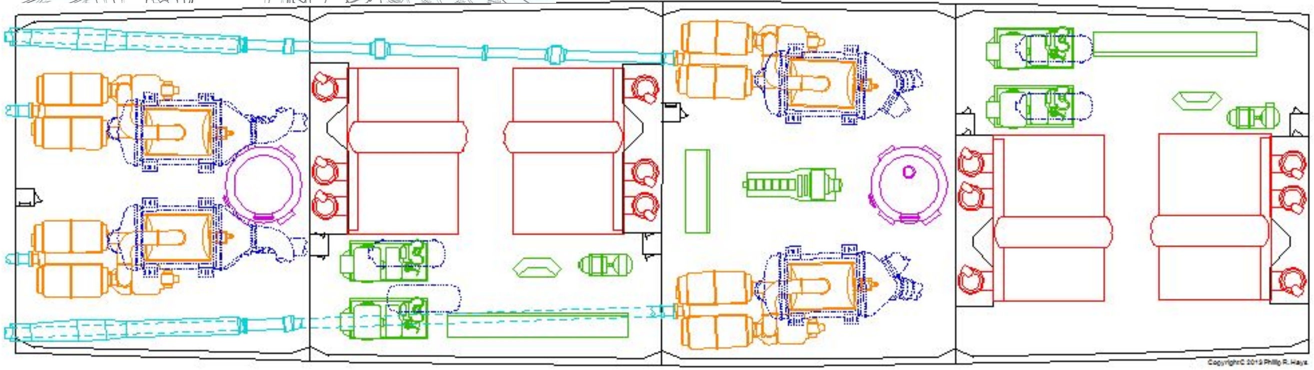
https://www.marineinsight.com/main-engine/exhaust-gas-system-of-main-engine-on-ship/

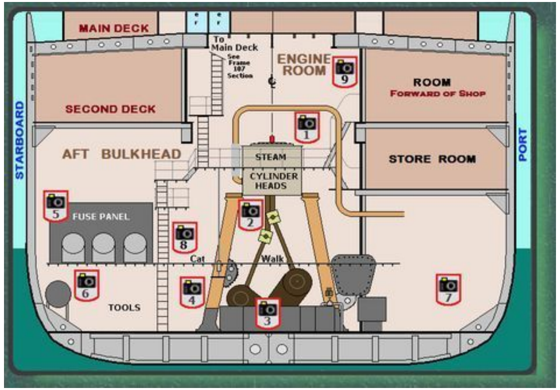
Typical Engine Room Layout











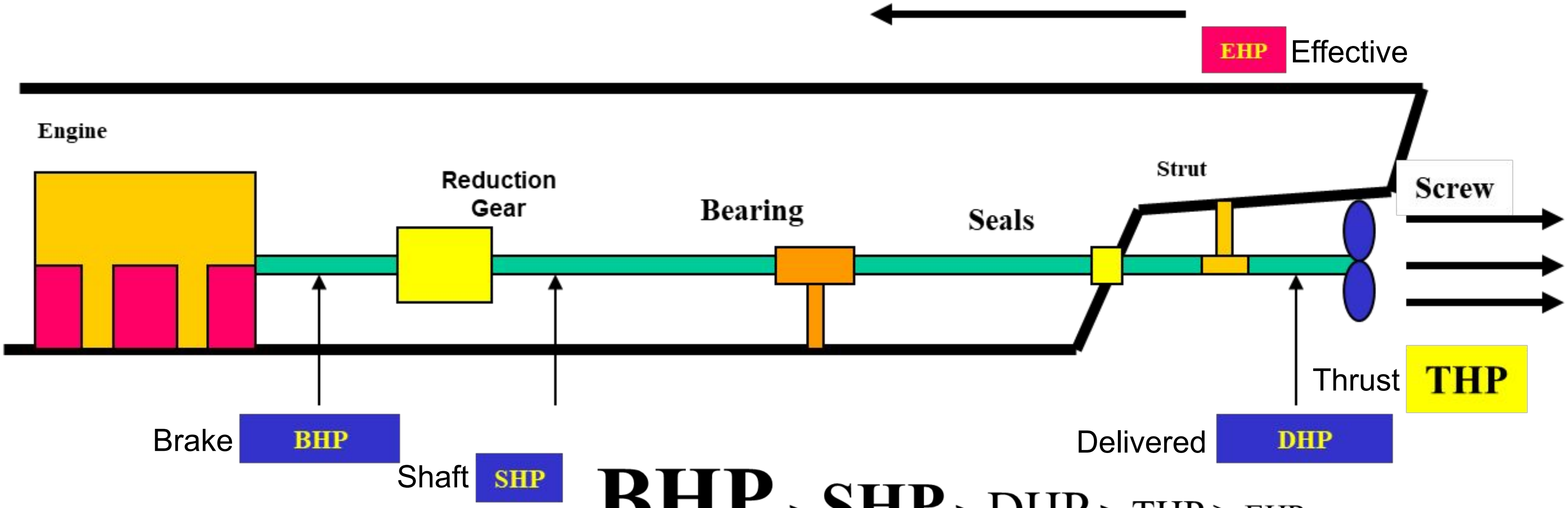
AFT ENGINE ROOM　AFT FIRE ROOM　FORWARD ENGINE ROOM　FORWARD FIRE ROOM

USS Oklahoma City CL91

Drivechain

There are losses that occur as the power is transferred to the propeller to generate thrust.

Gear Efficiency	$\eta_{gear} = \dfrac{SHP}{BHP} \approx 0.95 - 0.99$
Shaft Efficiency	$\eta_{shaft} = \dfrac{DHP}{SHP} \approx 0.97 - 0.99$
Propeller Efficiency	$\eta_{propeller} = \dfrac{THP}{DHP} \approx 0.65 - 0.75$
Hull Efficiency	$\eta_{hull} = \dfrac{EHP}{THP}$



$$\mathbf{BHP} > \mathbf{SHP} > \mathrm{DHP} > \mathrm{THP} > \mathrm{EHP}$$

Reduction Gears