Liquid cargo handling

Oil and chemical cargoes

General

Pumping systems

- Mini pump room
- Kofferdam pump room
- Submerged pumps system
- Pump room system

Equipment

- Cargo pumps
- Inert gas equipment

Cargo heating and tank washing

Liquidified gas cargoes

General

LPG cargoes

- Tanks
- Cargo pumps
- Reliquefaction plant

LNG cargoes

- Cargo tanks
- Pumps
- Boil off gas as fuel

Products Tankers Machinery Plants

Large black products tankers are similar to crude carriers:
low speed engine (5 .. 6 cyl, 8 .. 12 MW) fixed pitch propeller
- bow thruster
- 3 auxiliary diesel generators, no shaft generator
- two 15 t/h boilers for heating and possibly steam driven cargo pumps
- inert gas generator

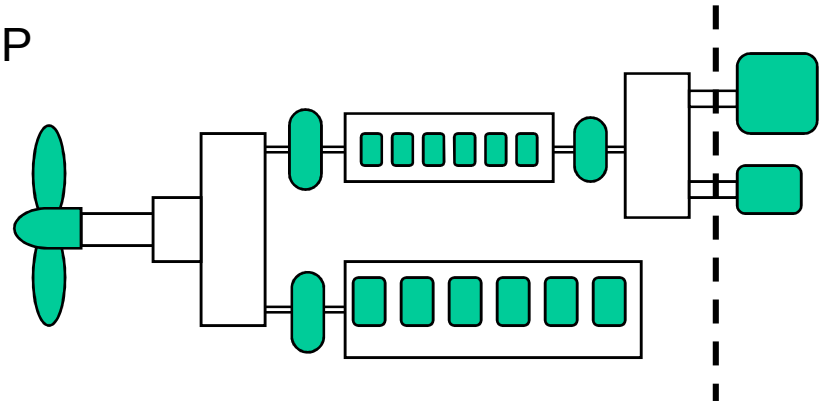
Medium size light products tanker basic choise:
single medium speed engine (6 .. 9 cyl, 3 .. 8 MW)
- one controllable pitch propeller
- bow thruster
- 3 auxiliary diesel generators, often secondary shaft generator
- steam boiler only for ship heating purposes
- inert gas generator

Products Tankers - Machinery alternatives

1

Two medium speed engines, single CPP

Smaller engine drives cargo pumps (direct shaft to pump in pump room, hydraulic power pack or primary shaft generator).

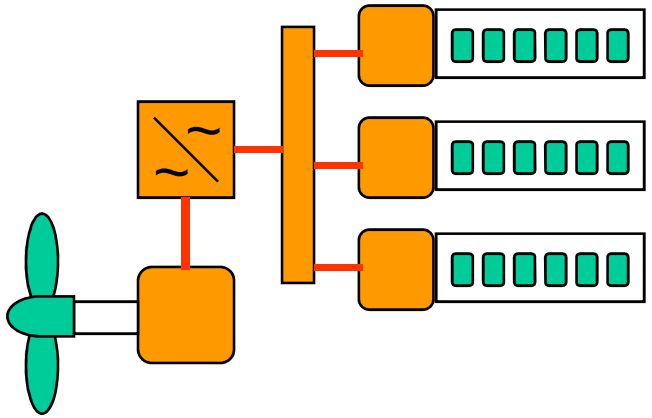


2

2-3 medium speed engines, electric drive and FP propeller

Electrically driven pump in each cargo tank. POD propulsion feasible if fuel costs are not decisive.

The same frequency converters utilised for propulsion and cargo pump drive



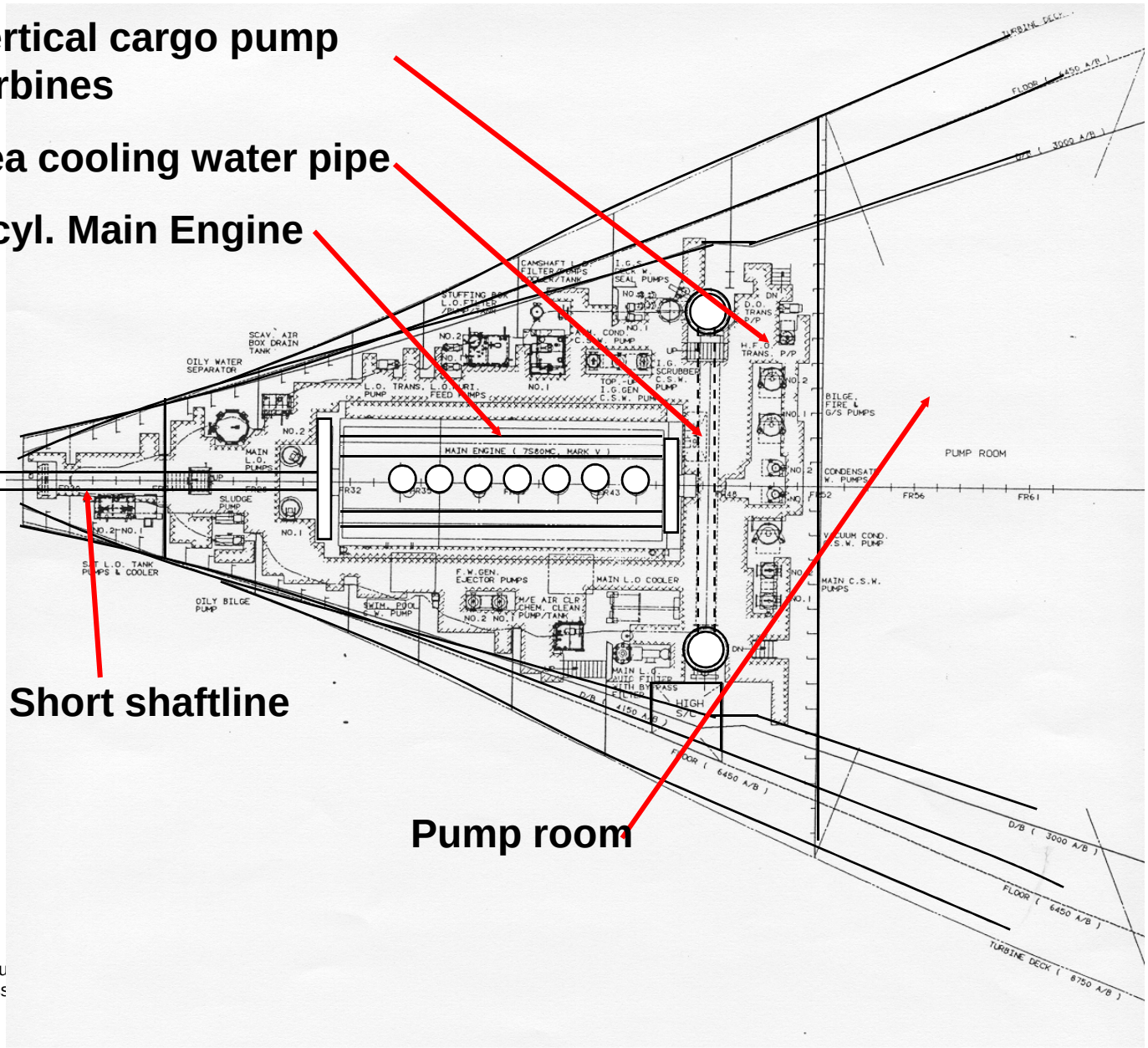
VLCC

VLCC (Very Large Crude Carrier)

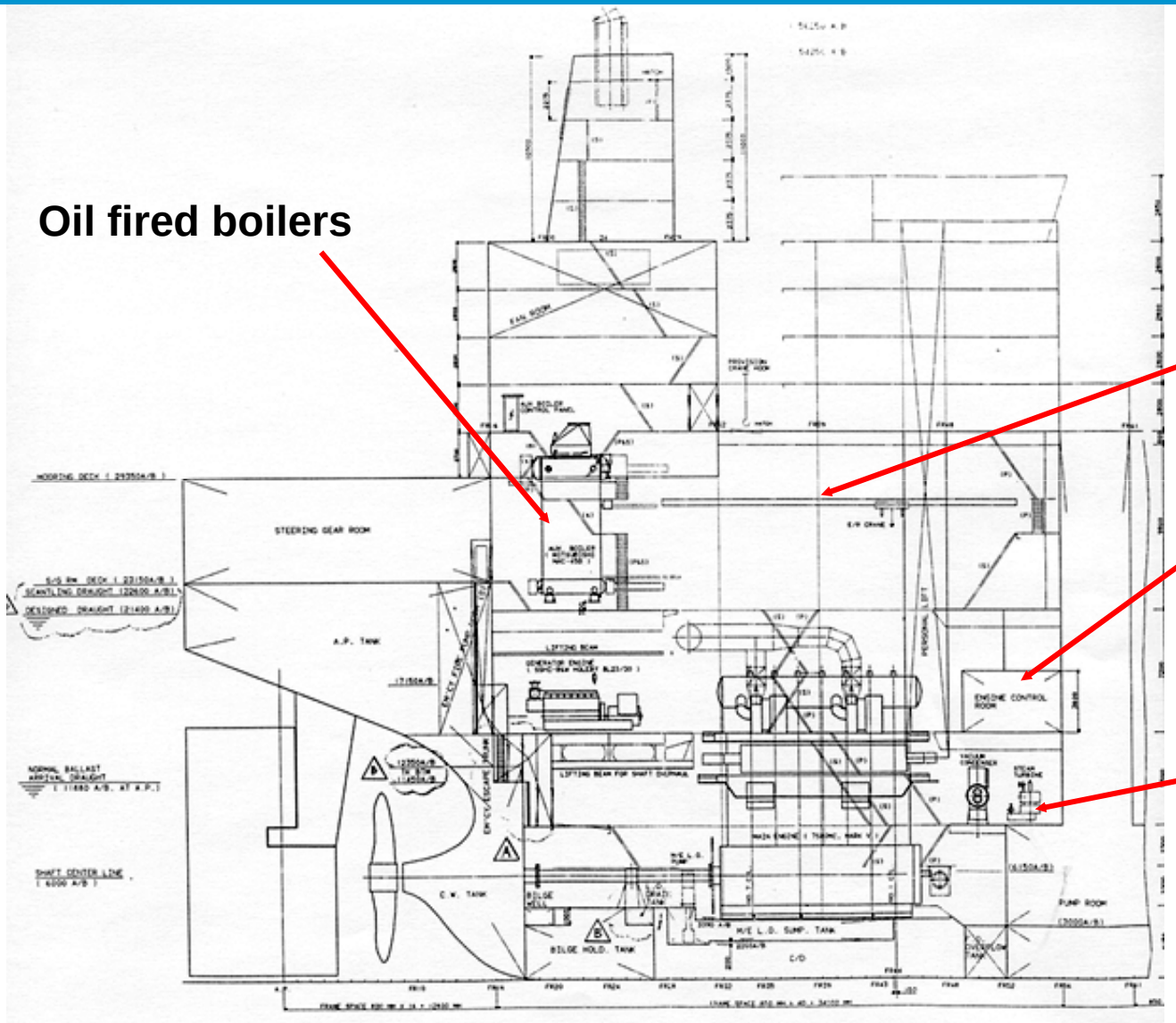
300.000 DWT - Basic features

- Low L/B ratio ships with low sailing speed, 16 kn
- Long voyages
- High ballast water capacity
- High steam boiler capacity for cargo heating, tank washing and inert gas generation
- Low number of segregates: 3 or 4 cargo pumps
- Traditionally steam turbine driven cargo pumps. Only shuttle tankers have very high unloading capacity
- Typically single FPP and 6 … 8 cylinder low speed engine in large volume engine room

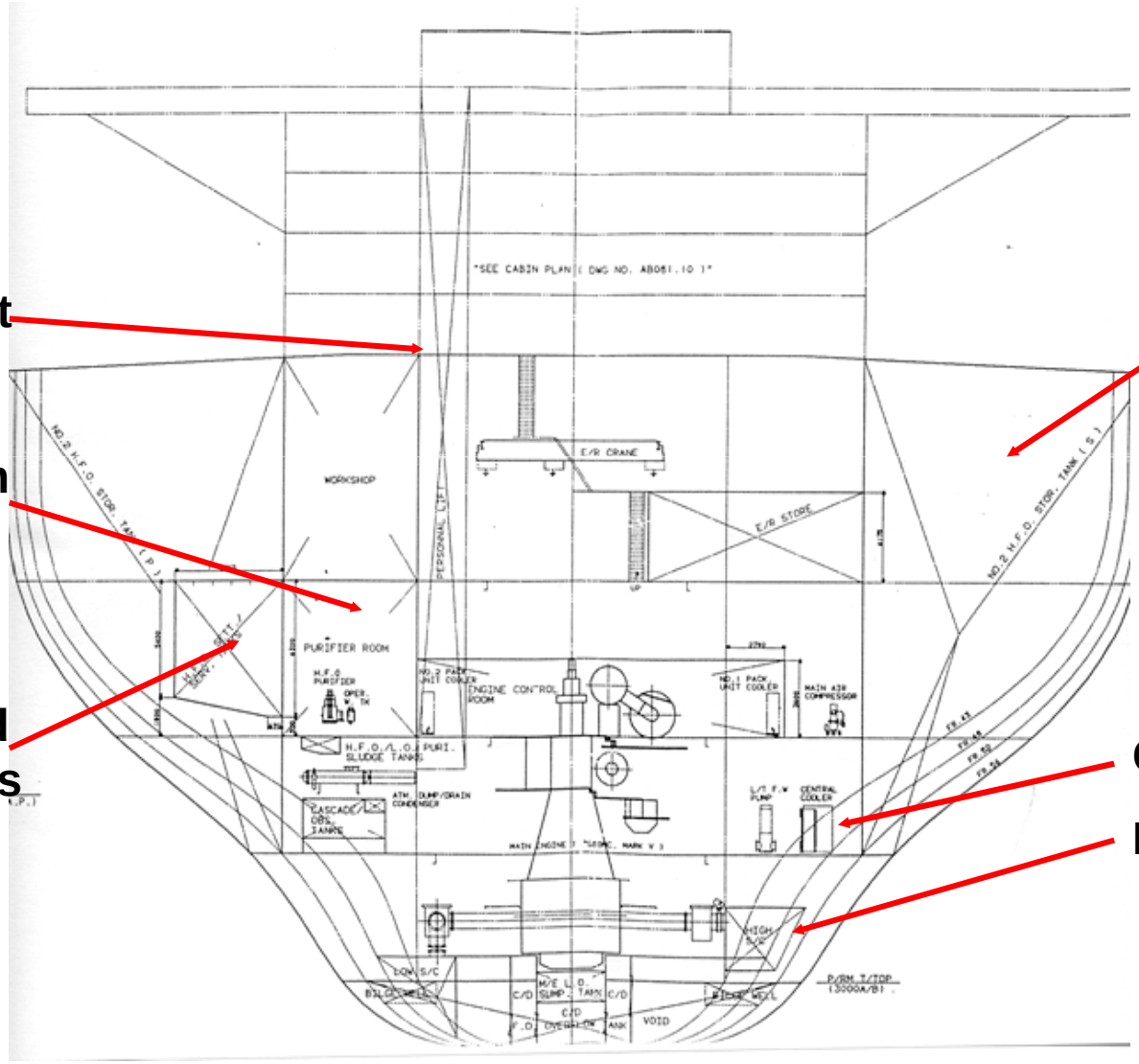
VLCC Engine Room



VLCC Engine Room



VLCC Engine Room



Oil and chemical cargoes

Oil products
Flammable, not particularly chemically aggressive

- **light products** easily pumped, generally tank washing not needed when cargo quality changes. E.g. kerosene (aviation fuel)
- **black products** demand heating, specific density over 900 kg/m^3. E.g. heavy fuel oil, bitumen

- Crude oils – mixtures of many hydrocarbon molecules with various chemical radicals. Some are highly volatile. Density varies, generally is less than 900 kg/m^3.

- **Chemicals** highly variating compounds, density between 700 – 1600 kg/m^3. Wine, vegetable oils
- Strong acids and bases, e.g. Sulphuric acid and caustic soda.

Materials for tanks and piping

Oil tanks are generally incorporated in hull structure
Without insulation. Generally not agains hull side
In special cases cylindrical separate vessels, small ones can be installed on the diec and can be insulated.

Chemical tankers
Due the chemical aggressive properties or strict purity demands often adic proof steel or special coating. Same ship may have cargo tanks of various materials and coatings.

Products tanker
Steel with epoxy coating to prevent corrosion
Piping of steel, normally coating only outside

Cargo pumping systems

Pump room

When only 1 –3 segregates.
Pumps inside pump room in front of main engine room. Prime mover in the engine room, gas tight shaft penetrations.
Steam turbine, electric motor, sometimew diesel engine.
Pump capacity 500 – 15 000 m^3/h (to obtain 24 h periods)
3 ... 4 pumps

Steam turbine

Horizontal or vertical shaft condenser turbine, 10 000 rpm
Poor efficiency, 17 … 22 % .
Resonable if cargo heating demands steam boilers
Pressure level 16 – 25 bar.

Electric motor drive

Established with inverter frequency control
Easy pump capacity control and simple automation

Pump room system

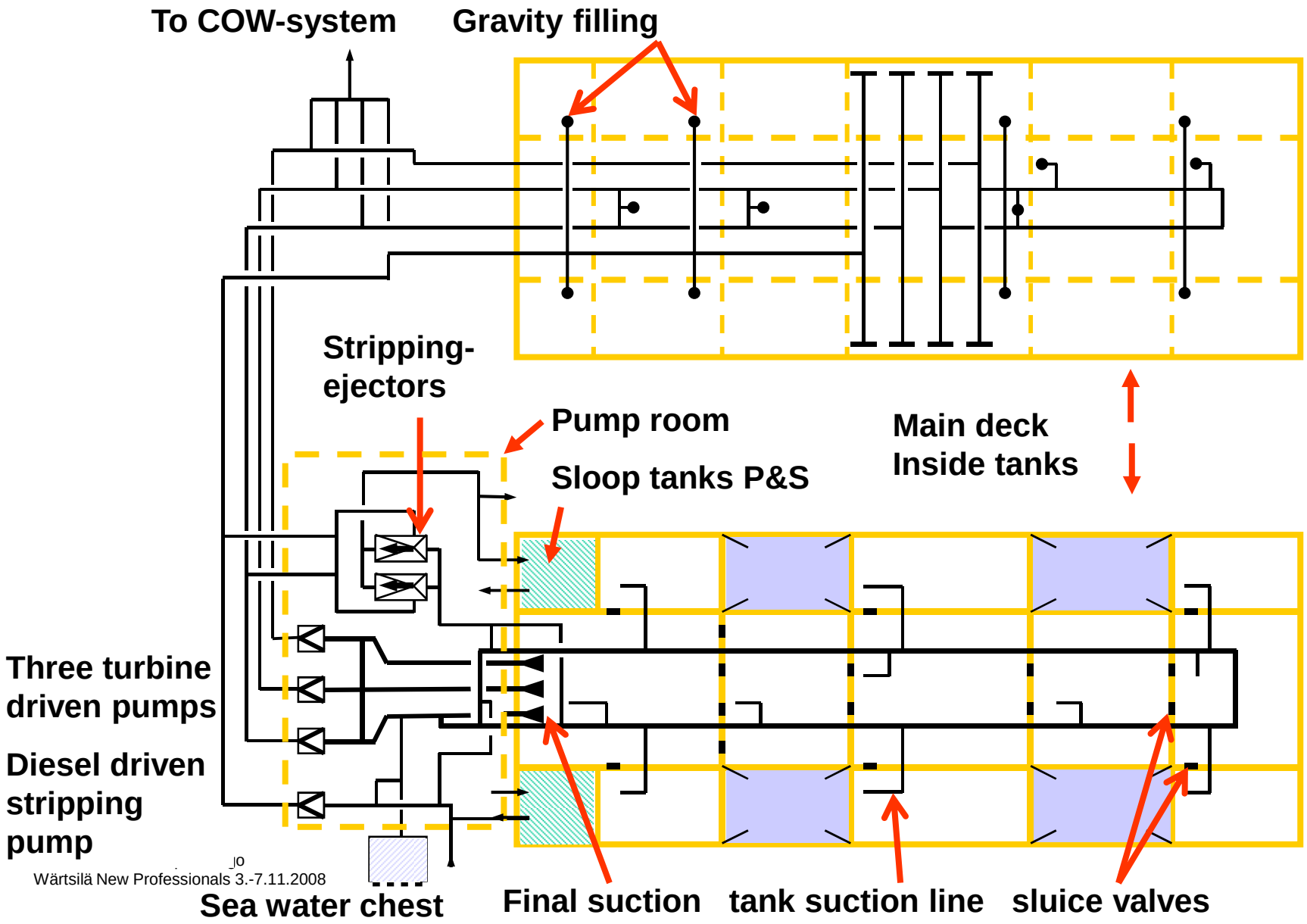
Suitable for low number of segregates. Pumps in the dry compartment. Large suction lines are common to several tanks.

As precaution to pipe/valve failure a ring line has been arranged and sluice valves in bulkheads between tanks, with operation from the deck above.

In spite ot pump speed control, pump capacity may be excessive in the unloading final stage. This has been observed with a smaller capacity **stripping pump** and **stripping ejector**. Ejectors are also used to move wash water to **sloop tanks**.

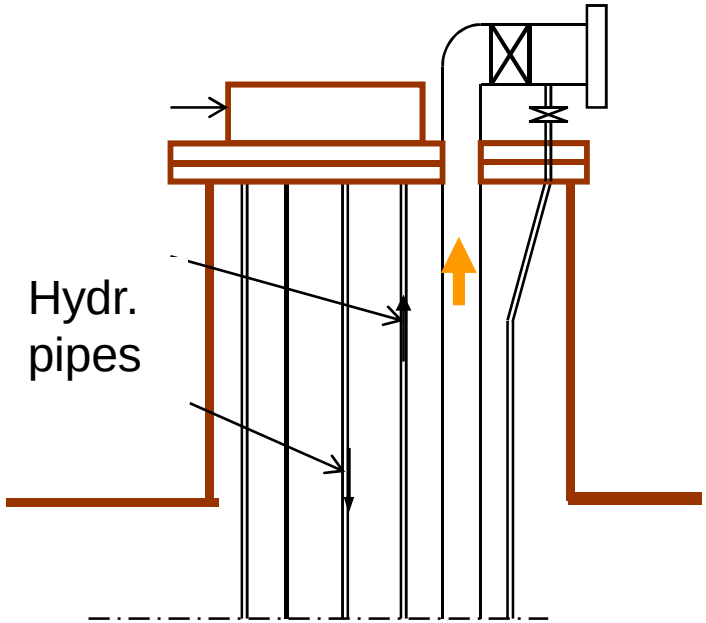
During cargo unloading the ship obtains aft trim. Through sluice valves dirct suction is available from all large cargo pumps from the aftmost middle tanks.
Wash water form sloop tanks removed with stripping pump/ ejector.

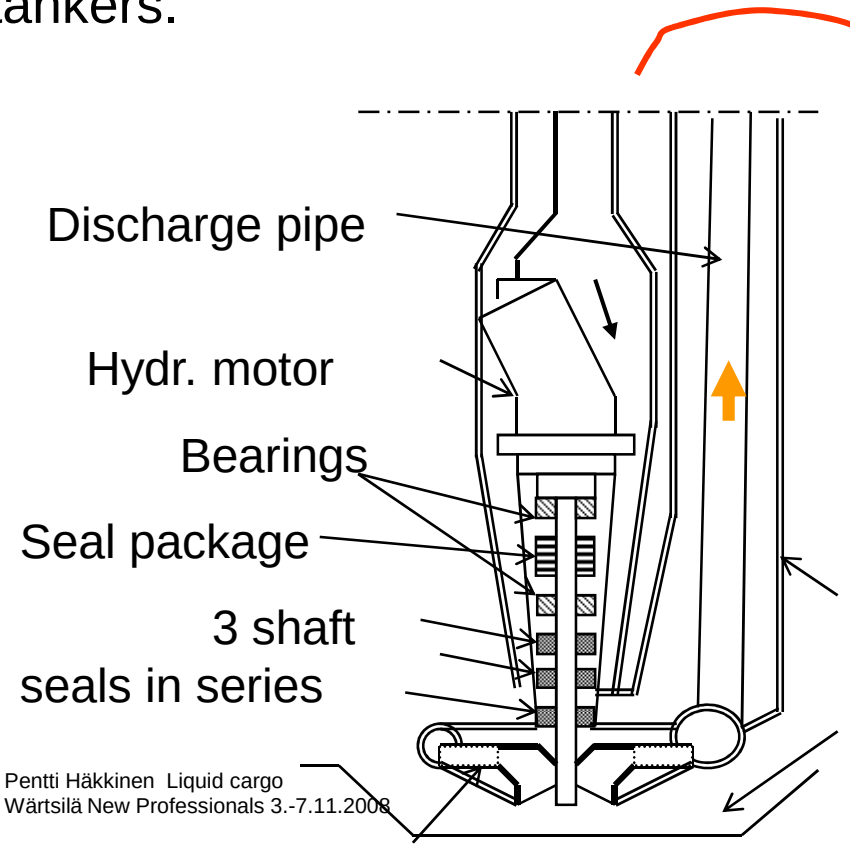
Crude oil tanker with pump room



Submerged pump system

Inside each cargo and sloop water tank a high speed vertical pump. Hydraulic drive motor with stepless speed control.
Low mass equipment, no shaft alignment.
Flexible system in products/chemical tankers.

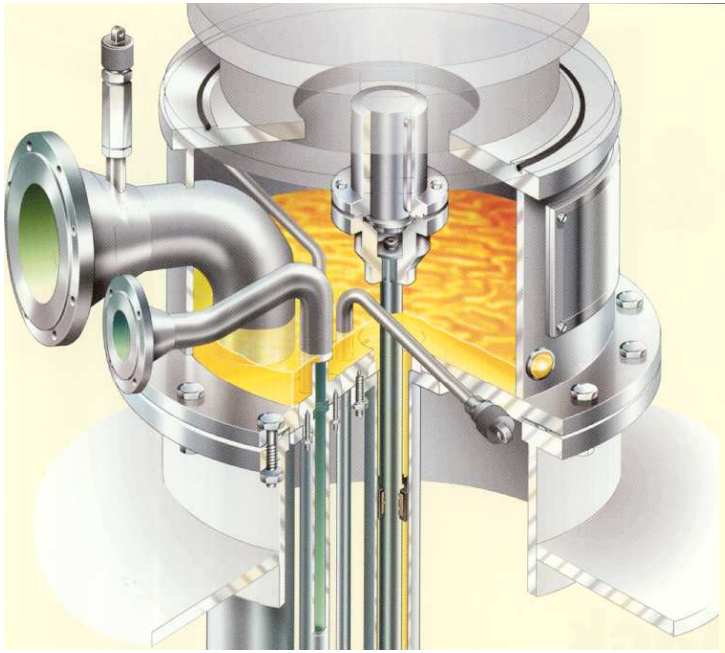




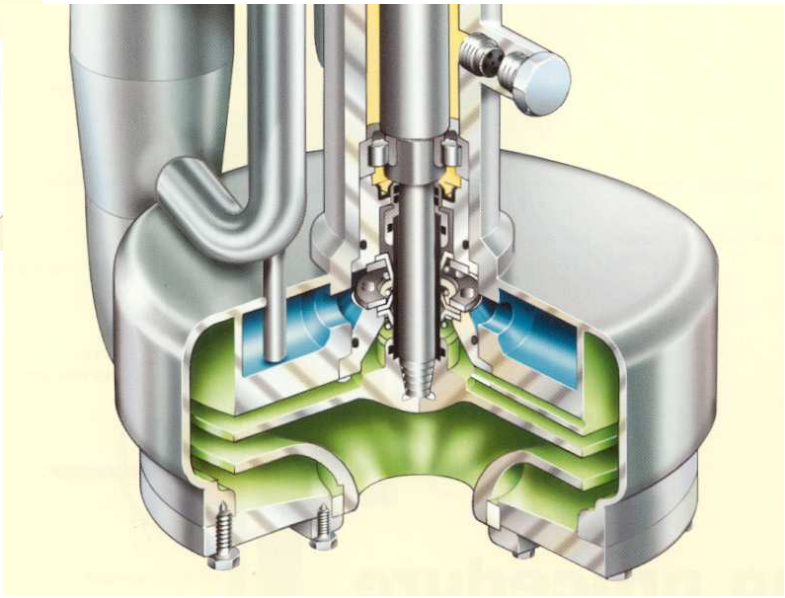
Gas evacuation suction pipe

Suction well in tank bottom

Deepwell pump system



Explosion proof electric motors on deck
Separate portable spare pump stored on deck.



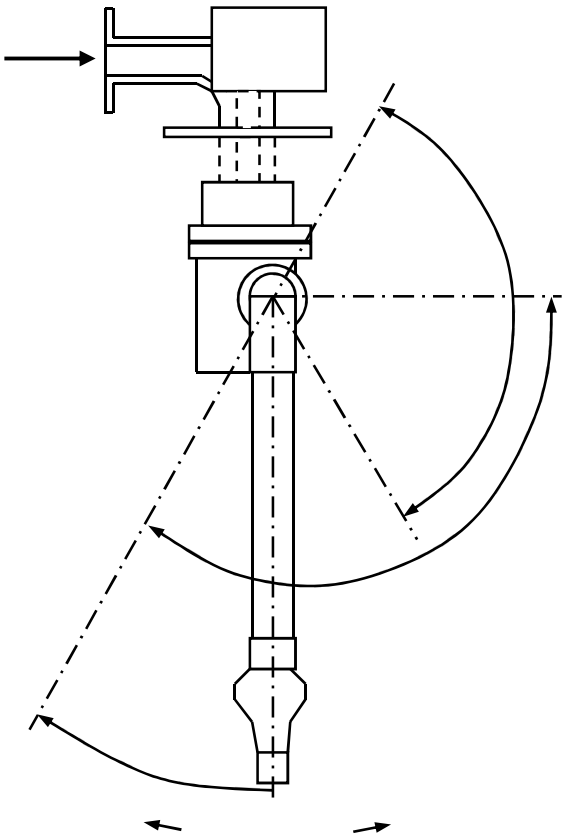
Inert gas equipment

inert gas generator, IGG is required for tankers with capacity over limit - depending on cargo.
HFO or MDO incinerated with small air ratio, residual oxygen content in flue gas < 5%.
Sulphur & other impurities removed in *scrubber*, preventing chemical problems.
Flue gas then cooled and blown into cargo tanks.
Automatic control and atmosphere measurement.
IGG is large unit, located in engine room.

The burner/scrubber unit

Cargo tank washing

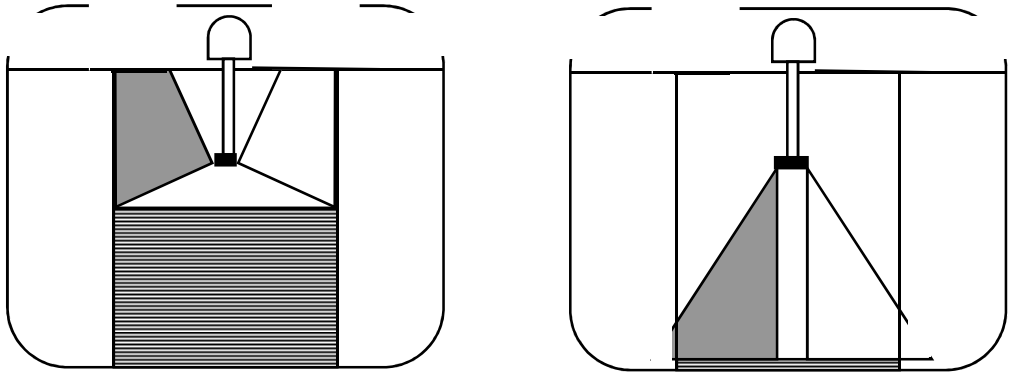
Tanks are washed when cargo grade or type is changed.
Fresh hot water 60–80 ^{o}C is injected through rotating nozzles at 10 bar pressure.
Number, capacity and position of nozzles is selected so that all surfaces are cleaned. Contaminated wash water is pumped to sloop tank, usually two tanks.
In crude oil tanker the sloop-tanks are also used for cargo oil.
Sea water is used for the sticky crude oil. Then finally steam is blown on the tank walls, it condenses rinsing aways the salt crystals.



Cargo tank washing

Crude oil tankers above 20 000 TDW must have *COW (Crude Oil Washing)*. Heated cargo oil is used to wash the tank that is being unloaded.

Finally oily wash water is pumped to sloop tank. Sloop tank water may be pumped to sea through a high capacity (up to 300 m^3/h) oil separator. Figure shows tank washing machine position at start and at end of the unloading sequence.



Liquified gas cargoes

Hydrocarbons that are transported in ambient pressure and cooled into liquid phase. For propane and butane also semi-refrigerated systems have been built, pressure 7 –12 bar.
These cargoes are chemically clean, even when containing some foreign gases. Therefore cargo piping is basically simple, high number of small pipes.

LPG cargoes (Liquefied Petroleum Gas) carried at –50 … -30 ^{o}C temperature. Same ships also carry ammonium.
Longer routes operated with 75 000 m^3 ship, shorter distances also 10 000 m^3.
Tanks and piping generally of stainless steel. Ammonium cannot be in contact with alloys containing copper.
Foam insulated tanks with deepwell pumps, tank cooling nozzles and safety equipment.
Evaporated cargo is reliquefied and returned to the tank. Electric drive – hydraulic systems not suitable in low temperature.

Liquidified natural gas

Liquidified Natural Gas cargo transported at -162 ^{o}C. Mainly methane CH_4. Traces of ethane and nitrogen evaporated first. Ship size standardized accoring to the terminals. Earlier 125 000, now 150 000 m^3. Smaller ships for special transport routes.

Tanks of aluminium, piping of special steel alloy.
In spite of insulation some cargo 0.15 % /d (Boil Off Rate, BOR) is evaporated. This also keeps tanks in low temperature. Some cargo left to evaporate also during the return (ballast) leg. Evaporated cargo is fed to machinery as fuel. Strict safety regulations and systems. Generally high reliability proven.

Earlier gas burners in the main boiler posed no problems.
First dual fuel diesel ships were contracted in 2006. Now great majority with dual fuel diesel engines.
Reliquefaction is not profitable due to high energy consumption. Yet some ships with such a plant.

LNG Carriers

Standard ship size, 135.000 m^3, single fixed pitch propeller

Moderate service speed 21 kn

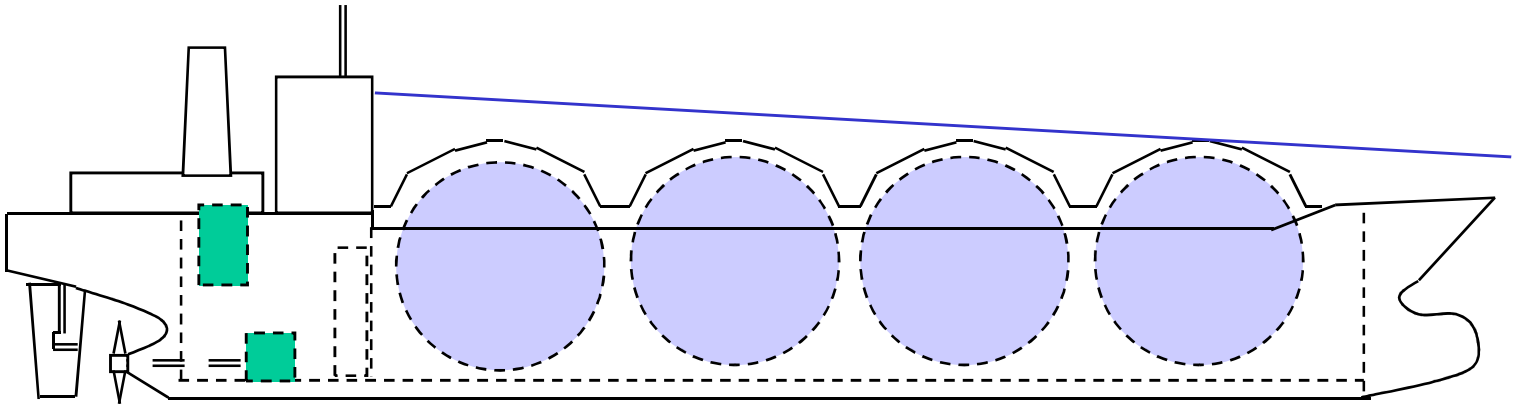
All ships are tied on long term contracts as part of LNG supply chain

Refrigerated tanks, membrane or spherical design

Submerged electrically driven cargo pumps

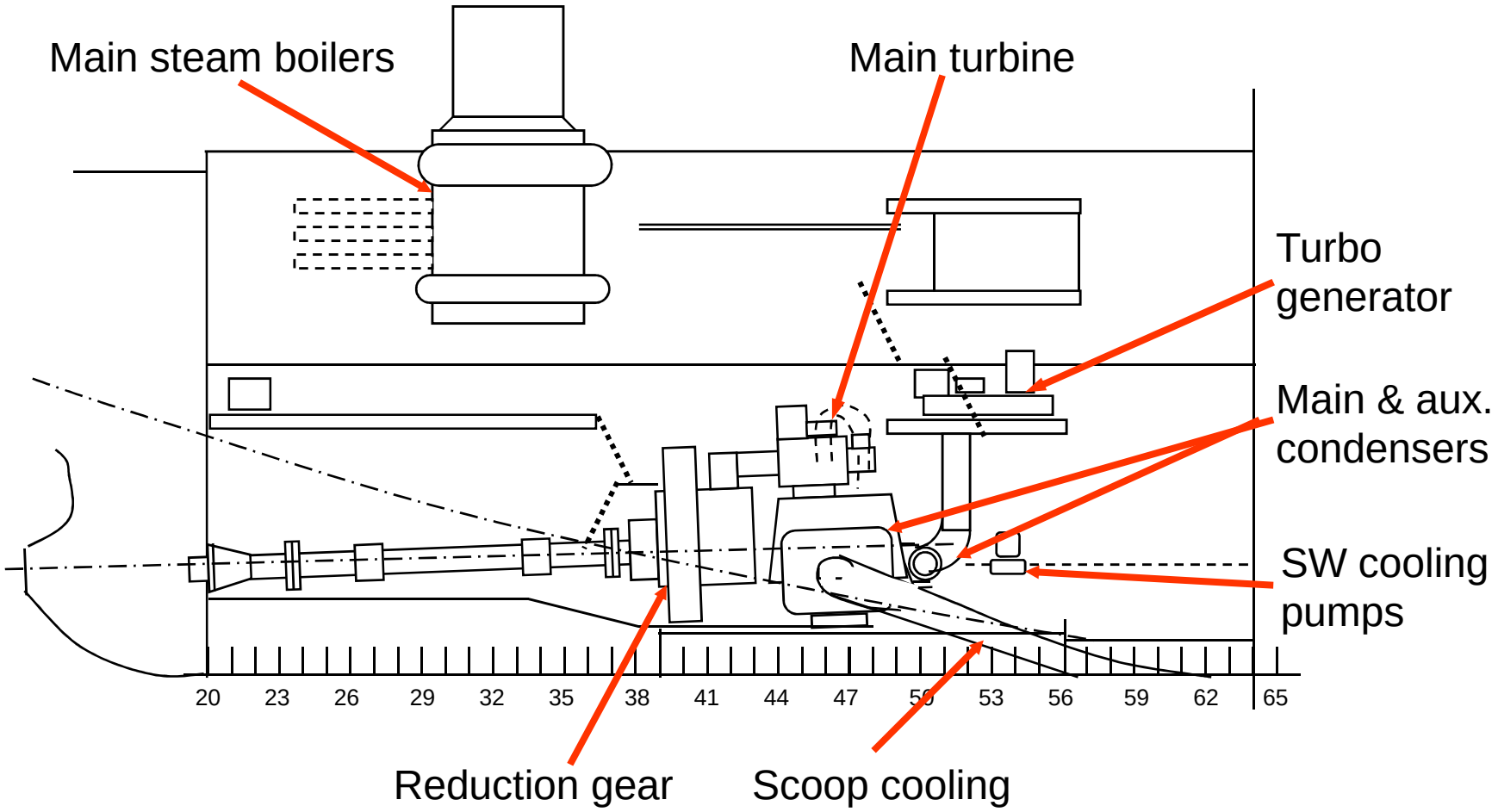
Boil-off gas is generally utilised in main boiler as propulsion fuel.

Reliquefaction plants are considered.



Steam turbine driven LNG Carrier

Engine room arrangement



Machinery selection criteria

- Proven reliability is important, rather than fuel economy. All vessels engaged in up to 15 year contracts. High penalty for off-hire time.
- Large engine room volume where machinery dimensions and mass have less significance.
- Extreme safety in cargo handling and boil-off fuel treatment
- Low electric power demand (except if reliquefaction plant is fitted)

Machinery alternatives

Steam turbine beats low speed diesel & medium speed diesel in total economy if boil-off is not reliquefied. Dual fuel diesel engine has high power demand for gas fuel compressors

COGAS turbine plant is feasible! Boil-off is ideal gas turbine fuel.

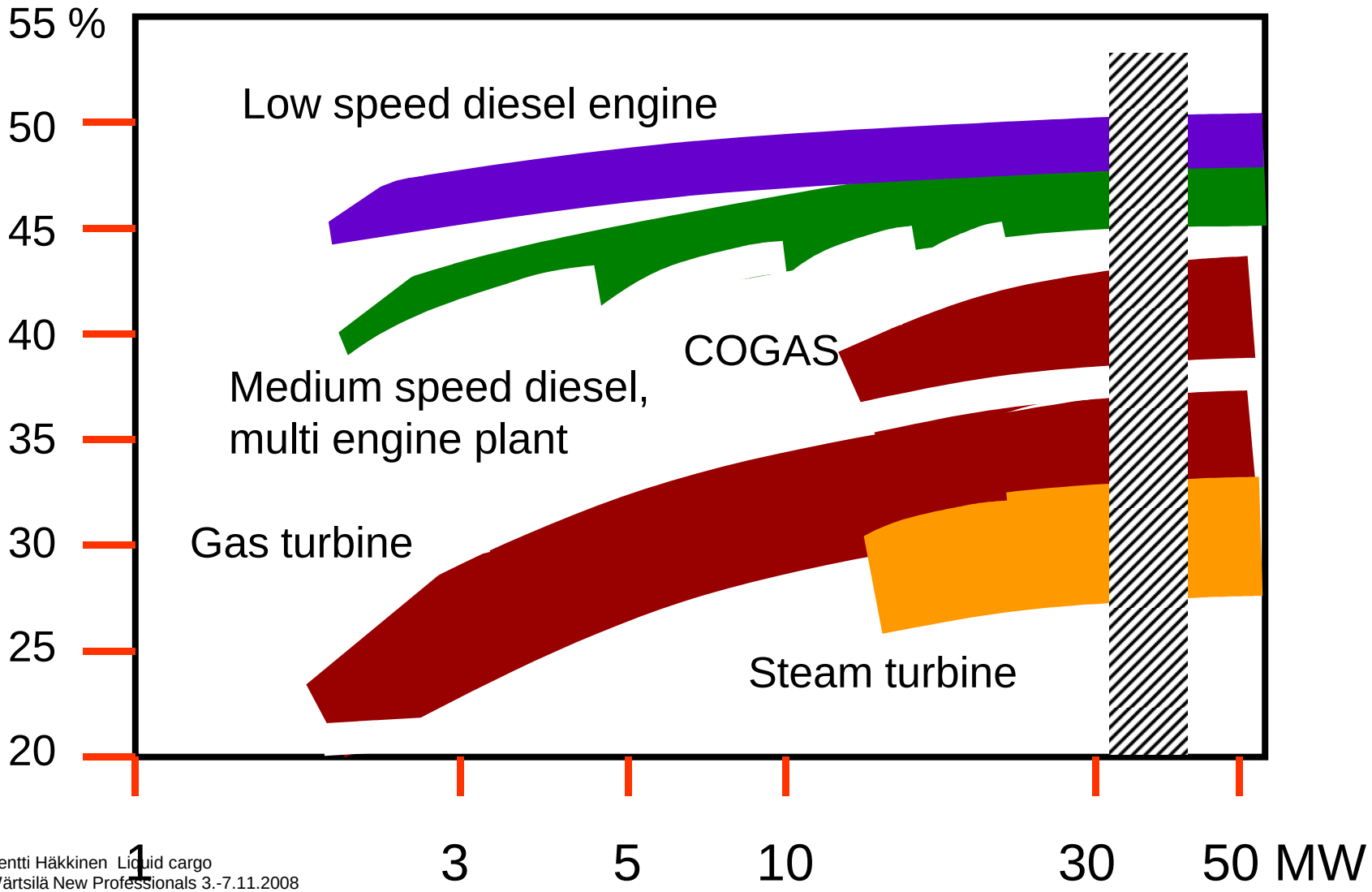
Diesel-electric ship? Reasonable with boil-off reliquefaction. Can twin pod-plant compensate electric losses by propulsion efficiency improvement?

- LNG and HFO **price relation** is not simple to define!
- Liquid fuel is still required for emergency conditions
- Boil-off rate = Heat losses cannot be further reduced
- Boiling LNG keeps the tanks cool during ballast trip

LNG ship propulsion alternatives

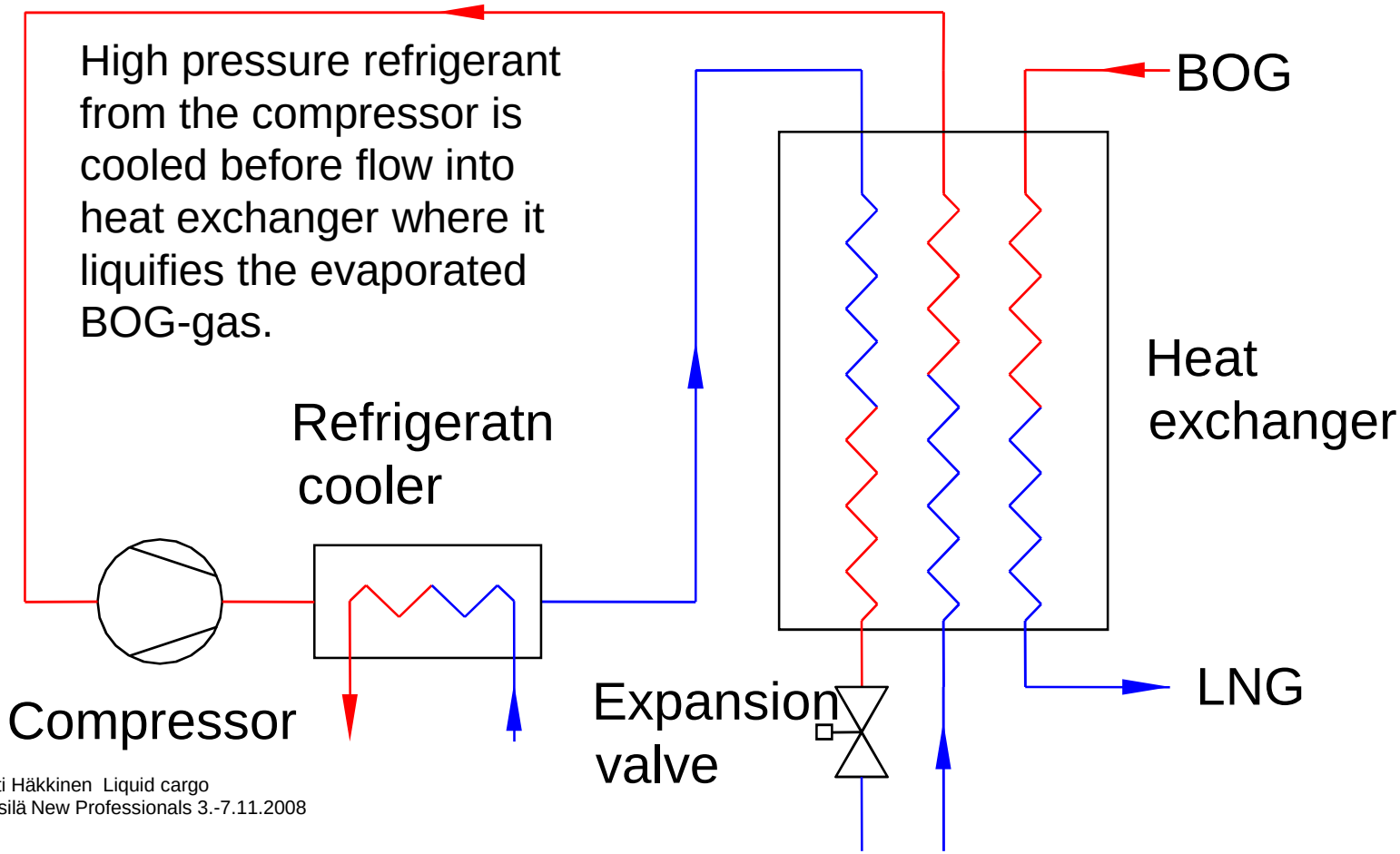
Propulsion plant	Steam turbine	DF Diesel plant	Diesel plant+ reliquefaction	Gas turbine combi cycle
Prime mover	HP, LP turbine	Low pressure gas feeding	low speed diesel	AED gas t. + steam turbine
Advantages	Proven reliable full BOG cons.	High efficiency BOG as fuel	High efficiency Separate gas	Rather high efficiency
Dis-advantages	Poor fuel economy	MDO needed for liquid fuel	High electric power demand	High quality liquid fuel, DF not completed
Relative plant capital costs	100	105 medium speed diesel = 100	110 medium speed diesel = 105	104
Relative fuel costs	100	67	65 ?	79
Relative NOx emissions	4 (3 if BOG only)	100	99	10 (?)
Relative CO2 emissions	150 (130 if BOG only)	100	110	140

Efficiences



Reliquefaction plant

In single stage MRC cycle the refrigeration fluid is mixture of nitrogen, methanen, ethanve, propane and butane. Single compressor is sufficient.



Motor Ship Jan 2004.

Reliquefaction