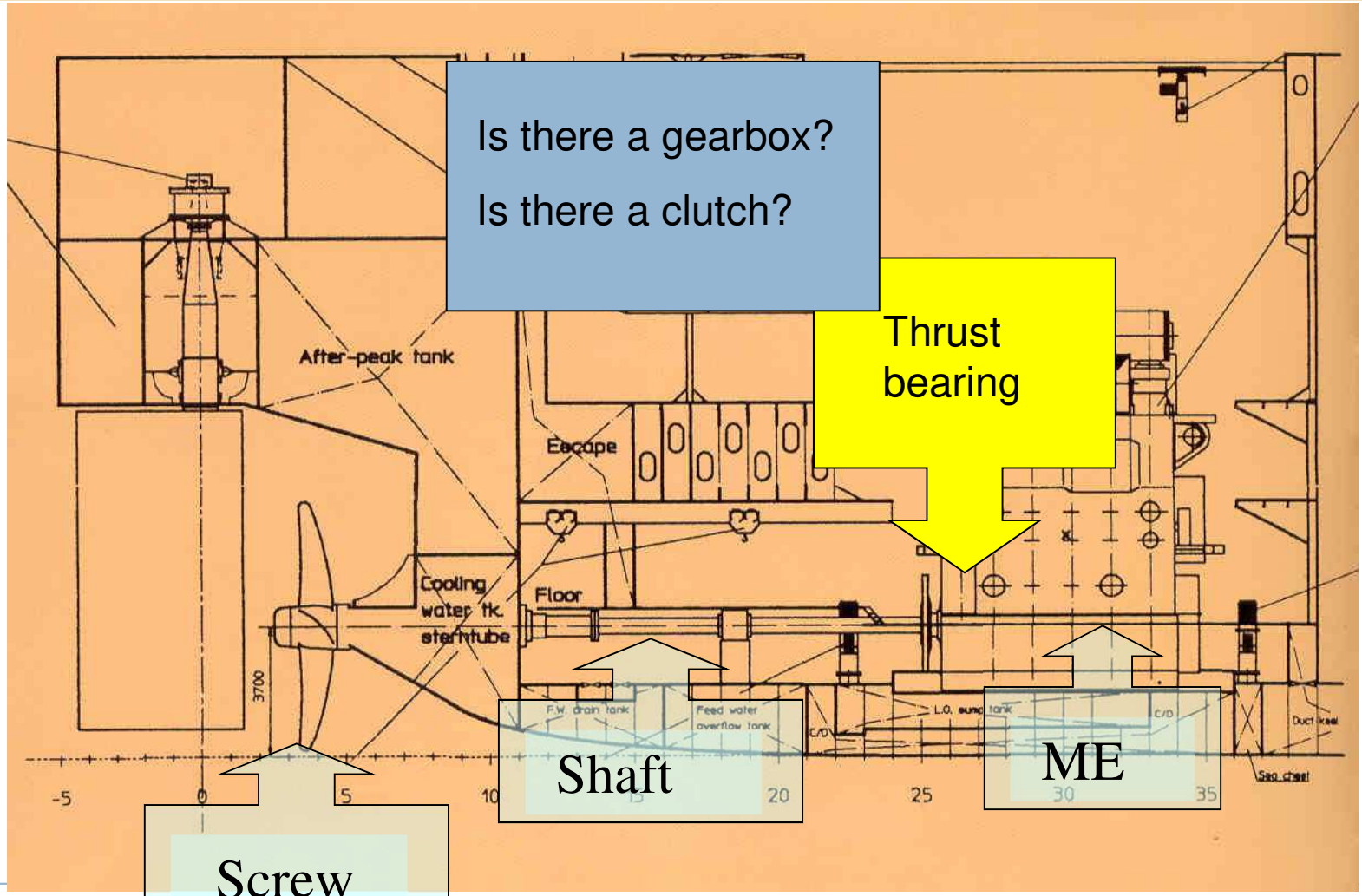
ERASMUS
MARINE ENGINEERING SYSTEMS
(propulsion systems and engines)

Propulsion systems

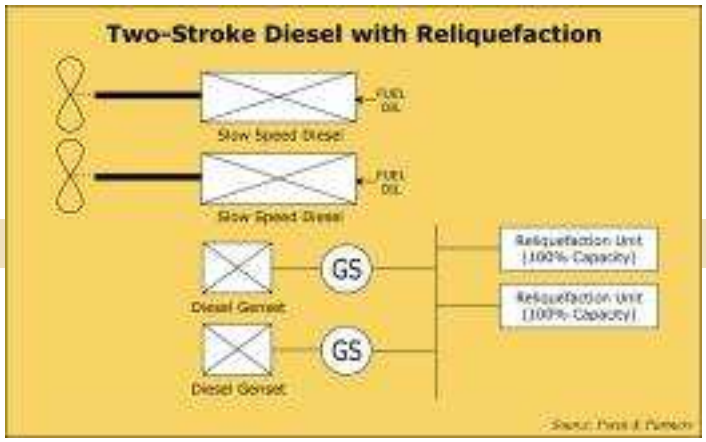
- diesel engine propulsioned
  - 95% of ships are propulsioned with slow speed d.e.
- steam turbine propulsioned
- gas turbine propulsioned
- electric motor propulsioned
  - AC/DC
  - AC/AC
- combination
  - CODOG, CODAG, COGES, CODLAG...

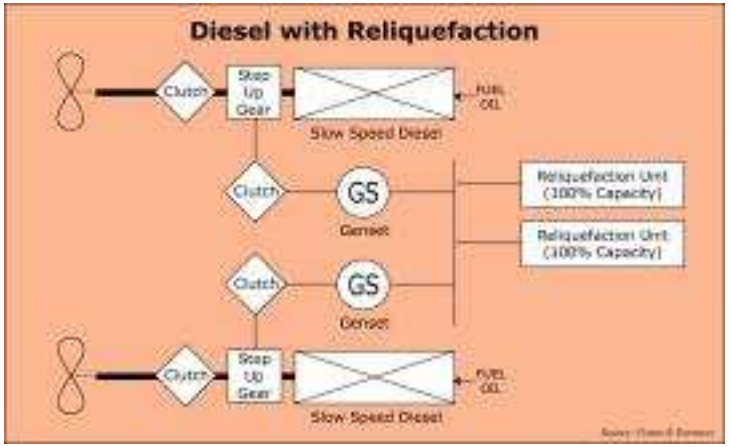
Engine room cross-section

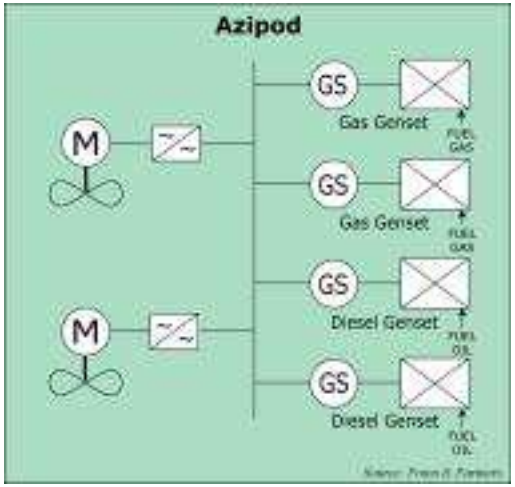


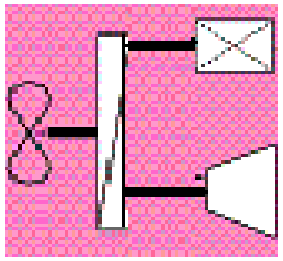
Typical arrangements

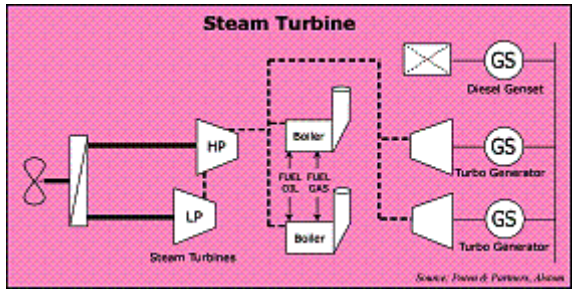
- one or two ME, several DG
- multi casing steam turbine
- AC/AC
- CODOG or CODAG



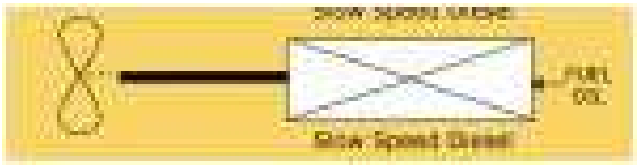


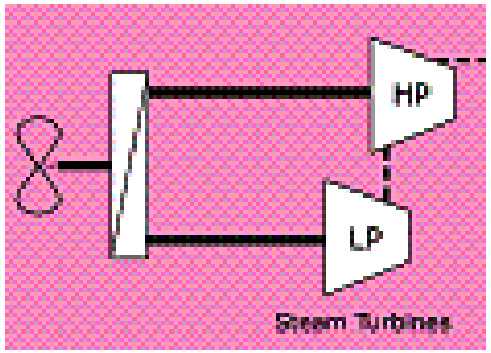


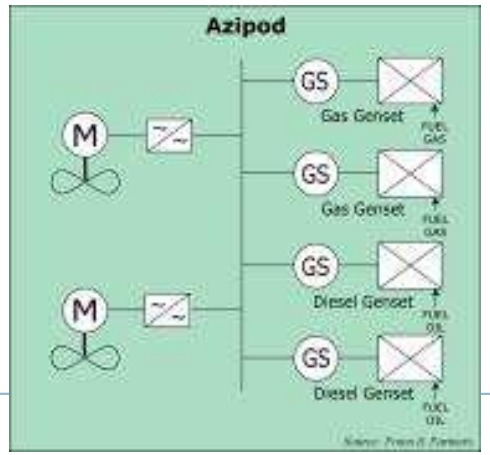


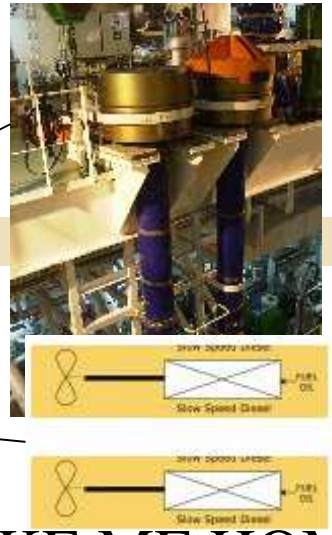


Propulsion power safety?



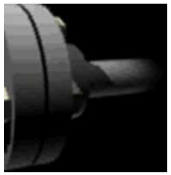


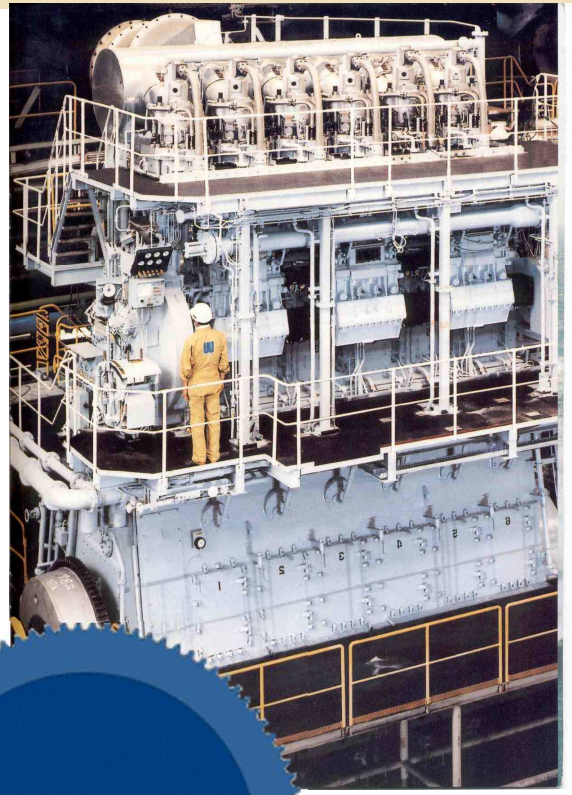


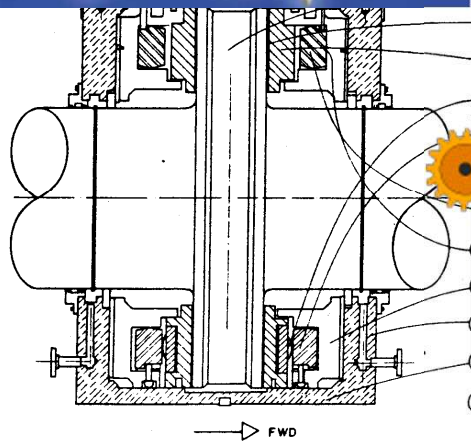


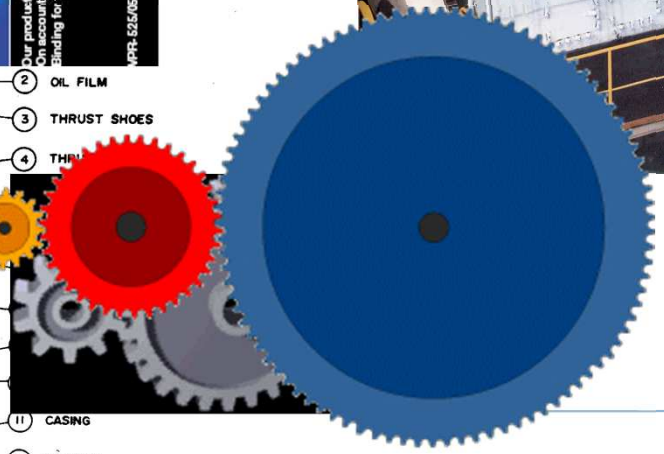
TAKE ME HOME DEVICE

Propulsion system elements



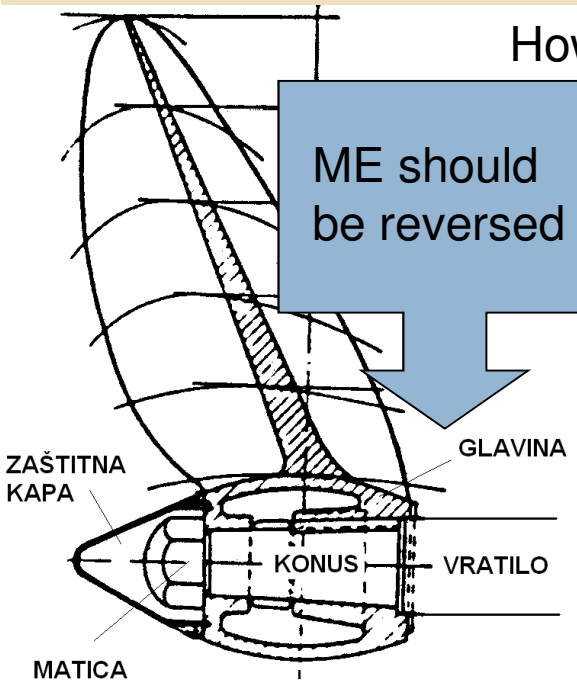




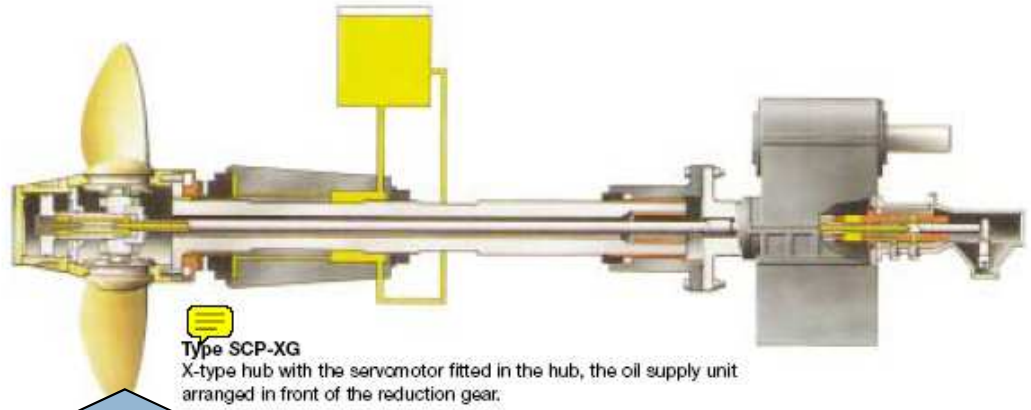


FPP vs. CPP

How could the direction of movement be changed?

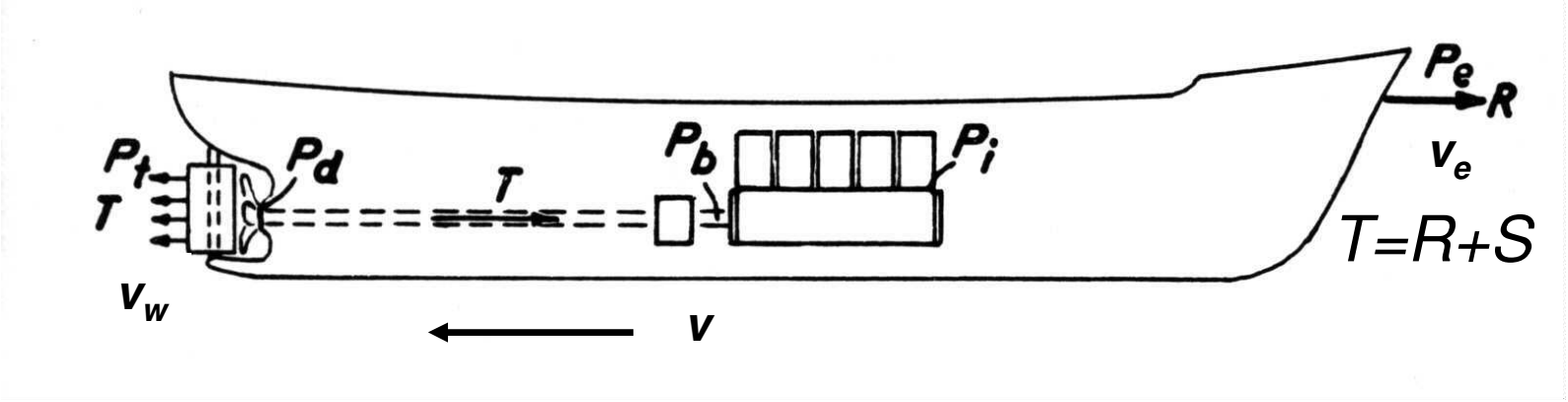


ME should be reversed



Pitch is changed

Propulsion System Coefficient of efficiency



$$\eta_p = \frac{P_b}{P_i} \cdot \frac{P_d}{P_b} \cdot \frac{P_t}{P_d} \cdot (\frac{P_e}{P_t})$$

$$\eta_p = \frac{P_e}{P_i}$$

$$\eta_p = \eta_m \cdot \eta_o \cdot \eta_p \cdot (\eta_h)$$

Slip

$$s_p = \frac{\frac{Hn}{60} - v}{\frac{Hn}{60}} \cdot 100[\%]$$

$$s_p = 1 - \frac{v}{H \cdot n}$$

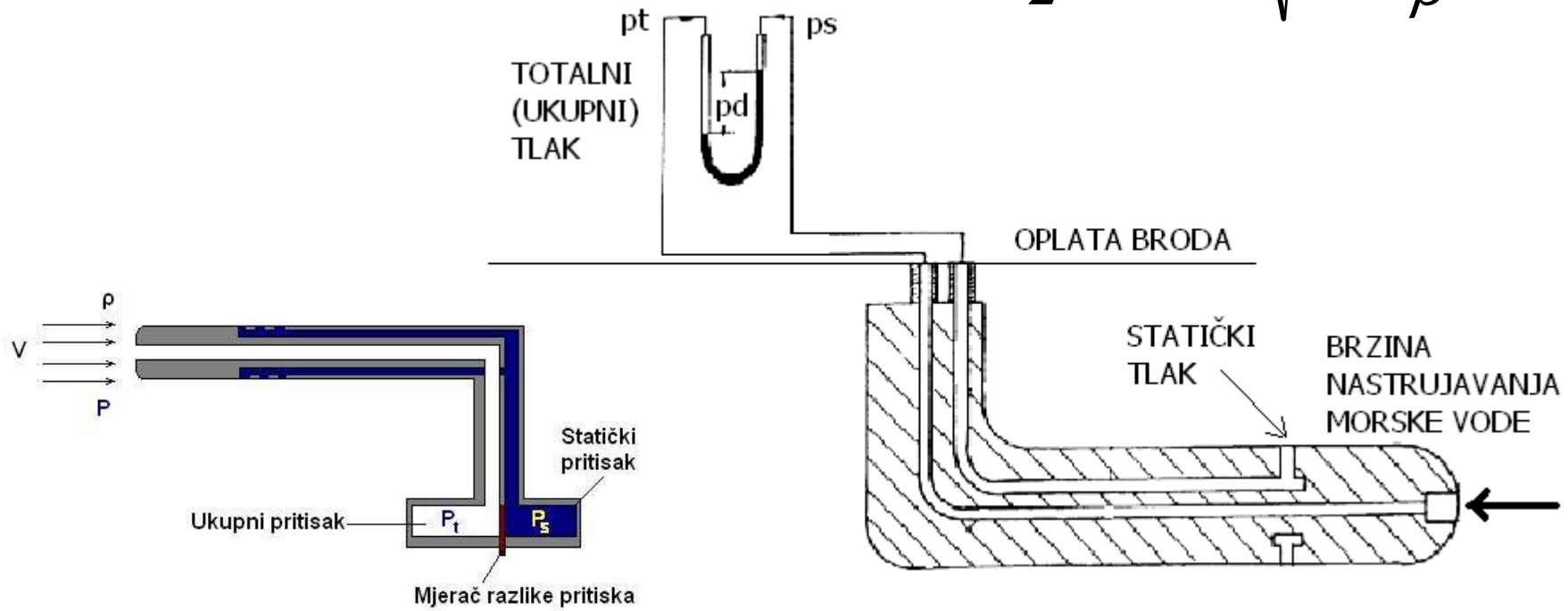
- H, P [m] – pitch of the propeller
- n [min^{-1}] number of the revolutions of the propeller
- v [m/s] speed

The ship's speed measuring

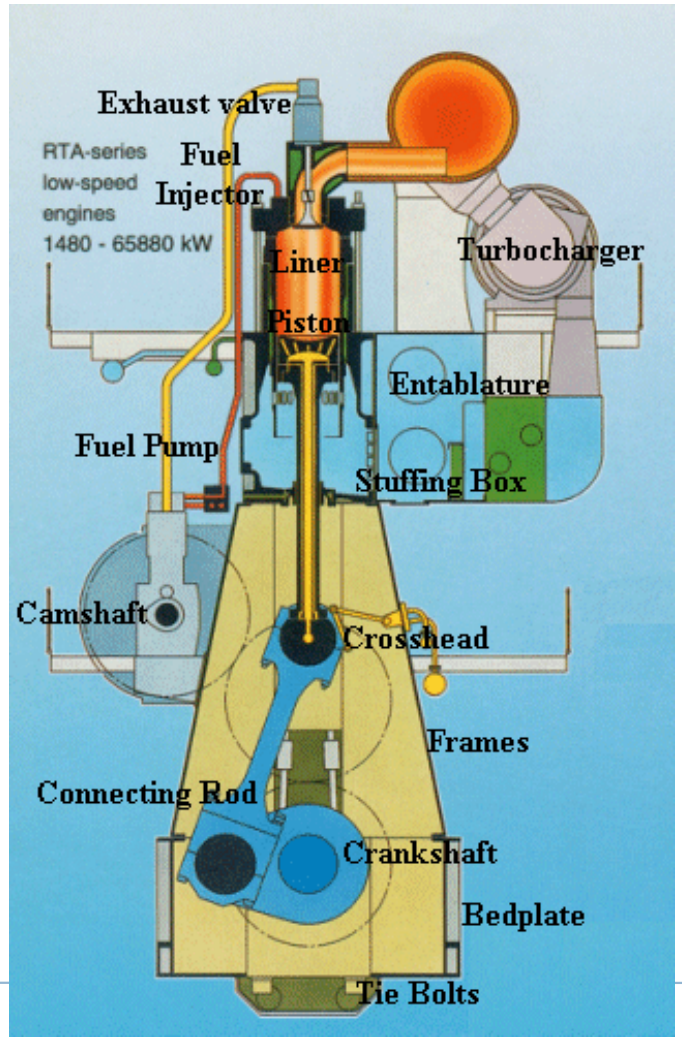
- Pitot's tube (Pitotlog)
- GPS
- sonar...

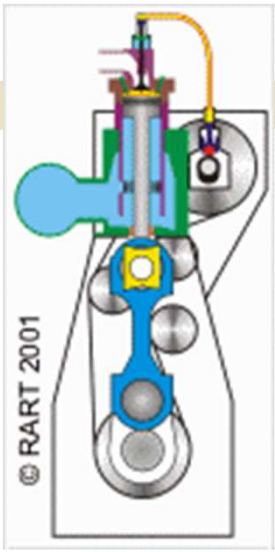
$$p_t = p_s + p_d$$

$$p_d = \frac{\rho v^2}{2} \Rightarrow v = \sqrt{\frac{2(p_t - p_s)}{\rho}}$$



Slow speed engines





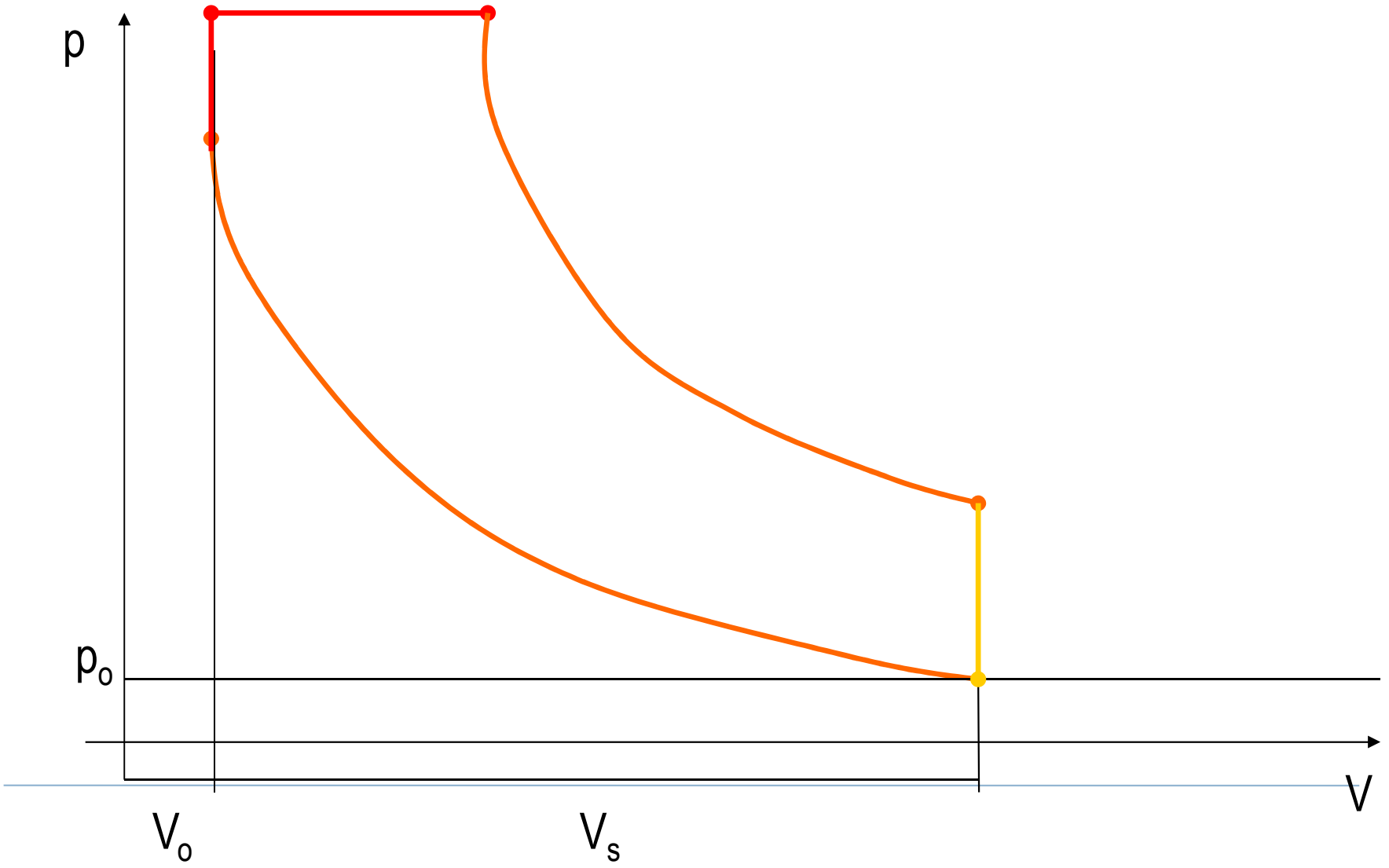
Fuel characteristics

- residual fuel
- HFO, DO, BO
- viscosity (cinematic)
- density
- content of S(ulphur) or V(anadium)
- low flammability
- Self-combustion point
- CETANE number

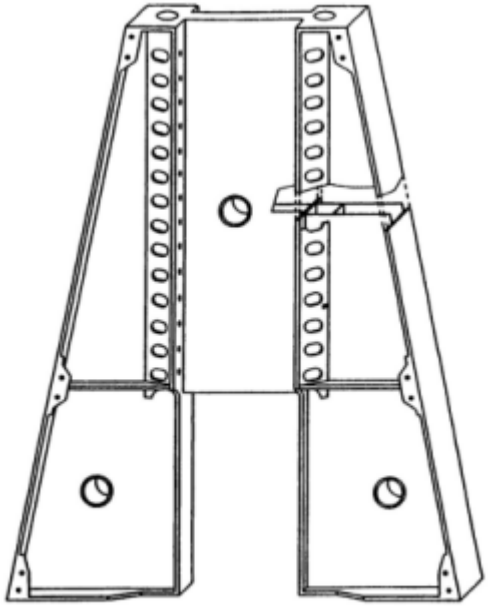
Combustion

- oxygen needed
- theoretical amount of air
- there is always a surplus of air

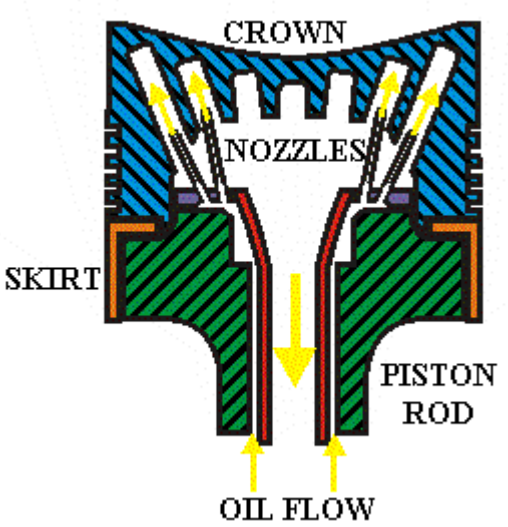
Theoretical process

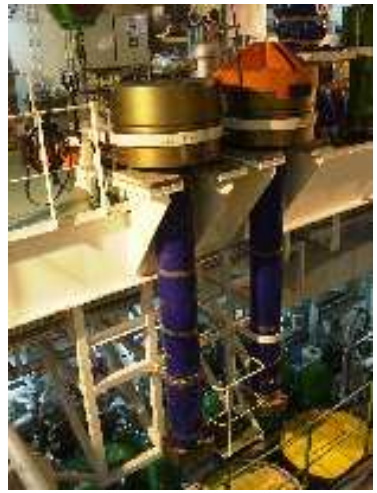


D. engines – construction



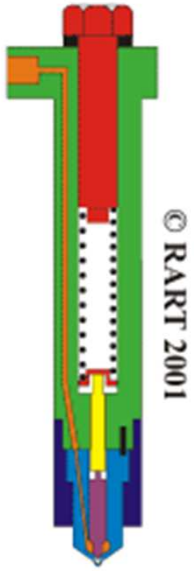
- piston mechanism parts:
  - main bearings
  - crankshaft
  - connecting rod
  - crosshead
  - piston rod and piston





- combustion space
  - piston
  - cylinder liner
  - cylinder head (exhaust, fuel, starting valves)
- camshaft mechanism
- combustion air system
- auxiliary systems (fuel, lubricating oil, compressed air, regulation system etc.)

Common rail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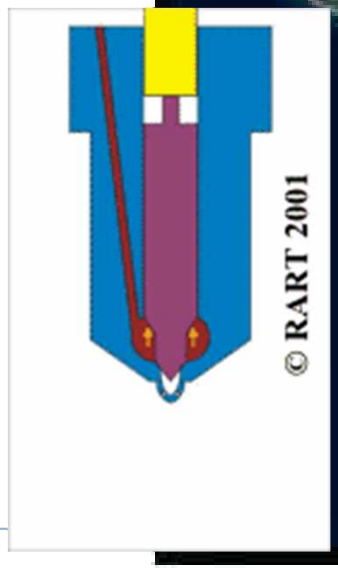
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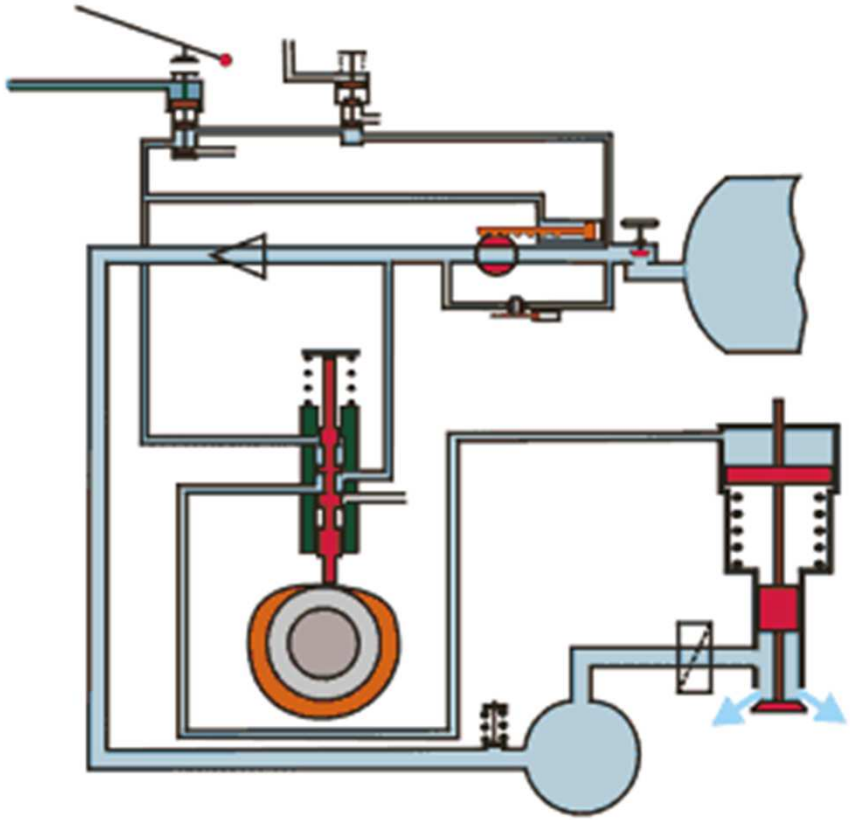
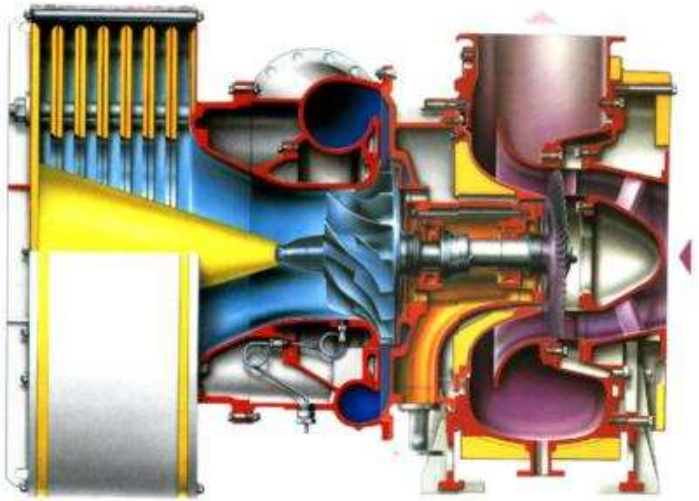
Druckregelventil
Pressure control valve
Injektor
Injector
Common-Rail
Drucksensor
Pressure sensor
Hochdruckpumpe
High-pressure pump

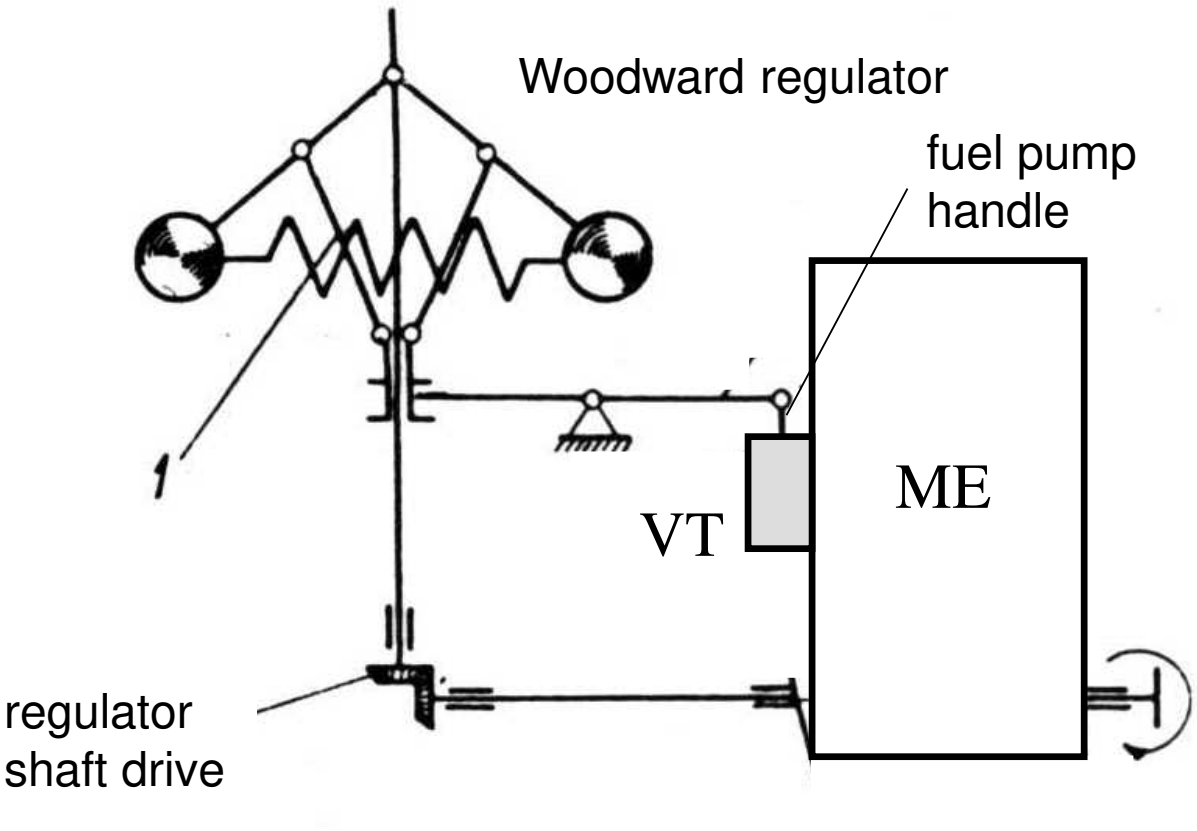
How the engine is started?



Turbocharging – why?



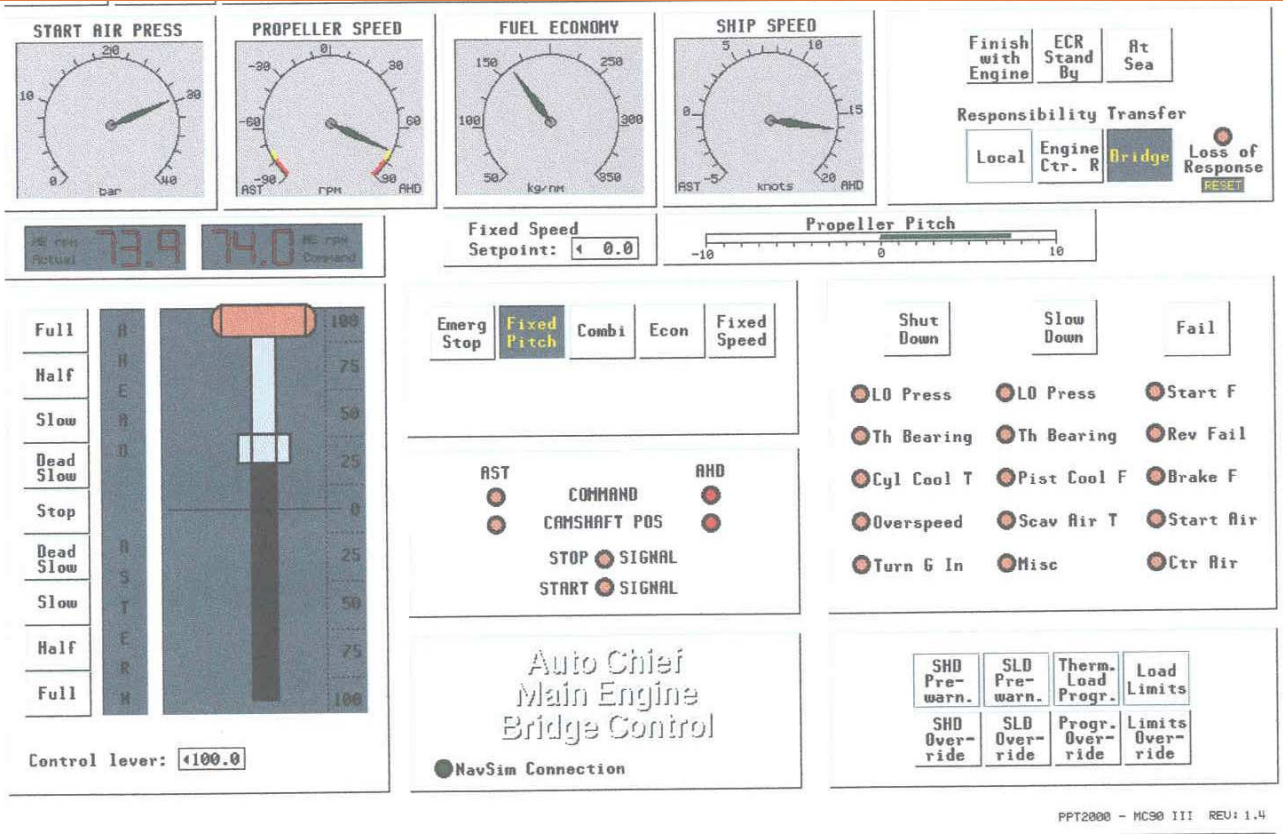
Management - regulation



In case of engine having common rail fuel system there is a common fuel pump, fuel valves are being opened electronically and there has to be an electronic crankshaft position device.

Bridge control panel

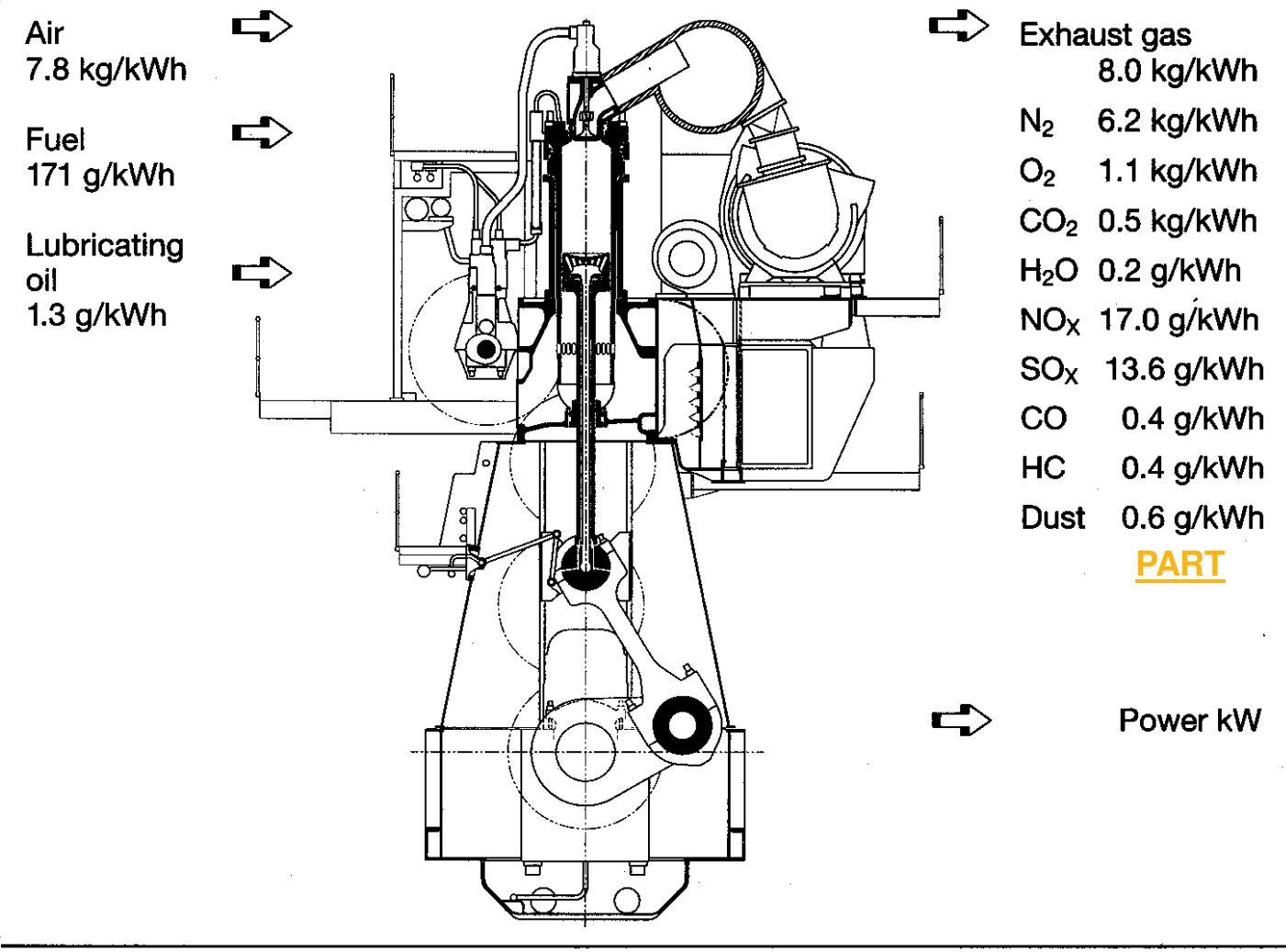
PREPARATION MANAGEMENT
ALARMING PROTECTION



Reasons for starting failure?

- engine is not preheated
- fuel is not preheated
- engine is not turned slowly in order to lubricate it
- there is not enough scavenging air
- safety system activated
- not sufficient starting air pressure
- water hammer in the cylinder

Exhaust gases emission (IMO, annex VI)



Measures to reduce the emissions

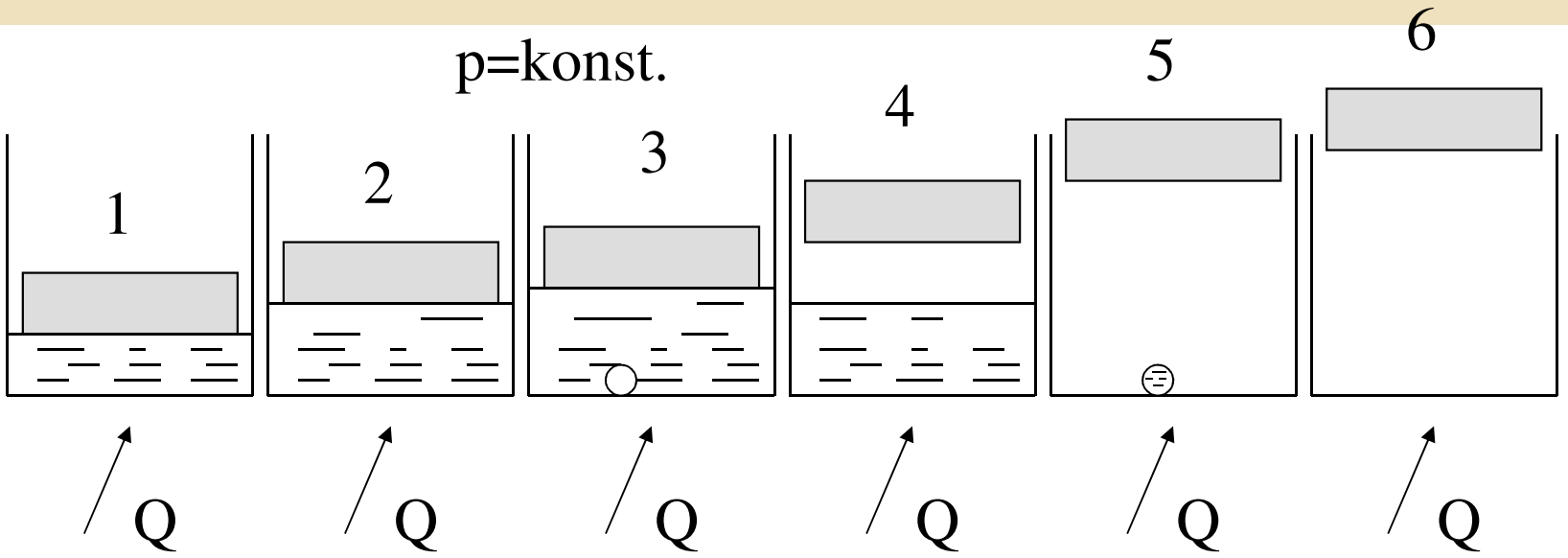
- primary
- secondary

Main engine preparation procedure

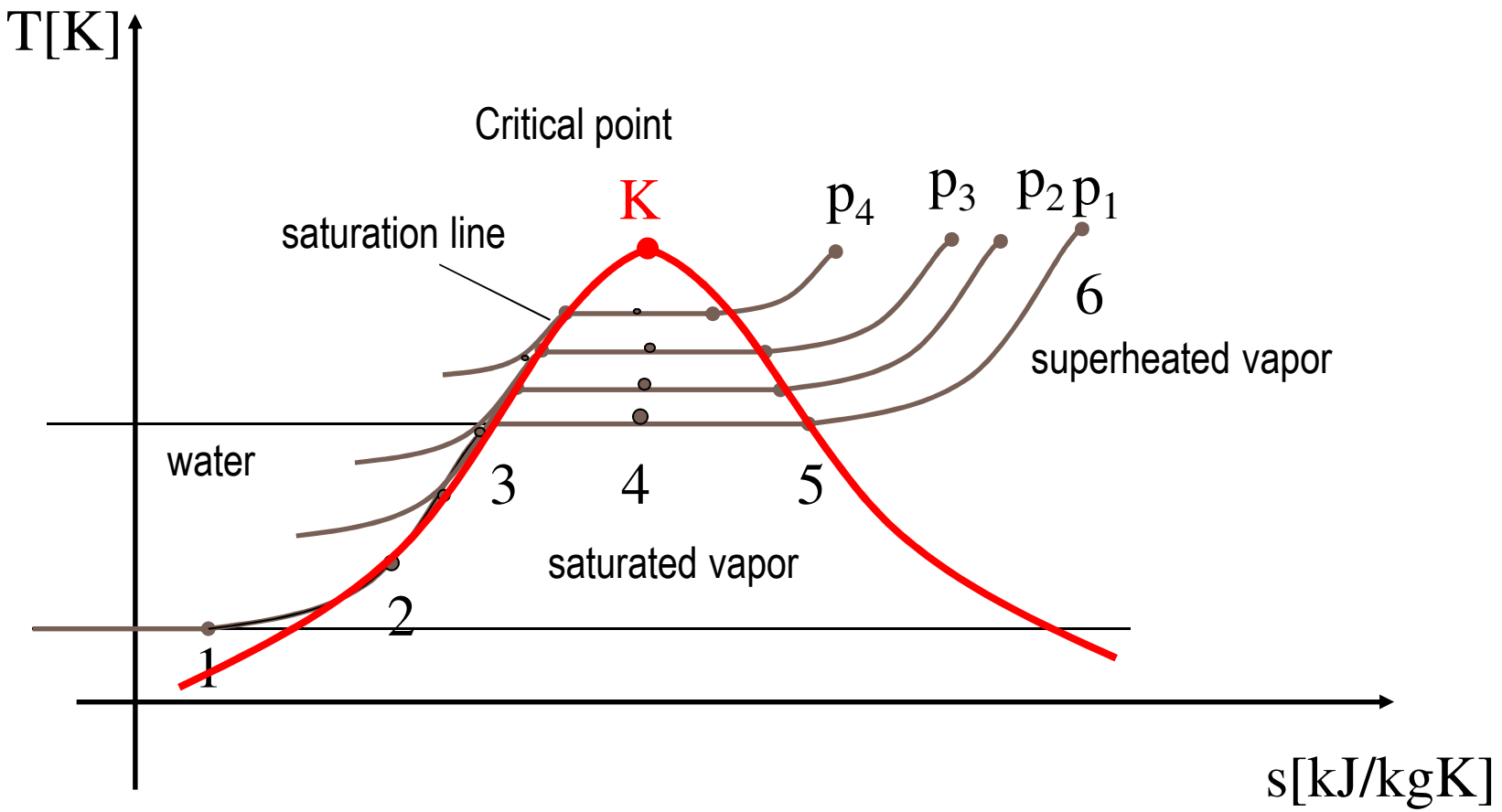
- preheating
- lube oil pumps starting
- starting air system preparation
- turning the engine slowly (on air or by a slowturning mechanism) with the indicating cocks opened
- indicating cocks closing
- setting the auxiliary blowers on ‘auto’
- fuel oil system preparation
- cooling water system preparation
- main engine reversing
- steering gear, anchor etc.

Marine steam generators

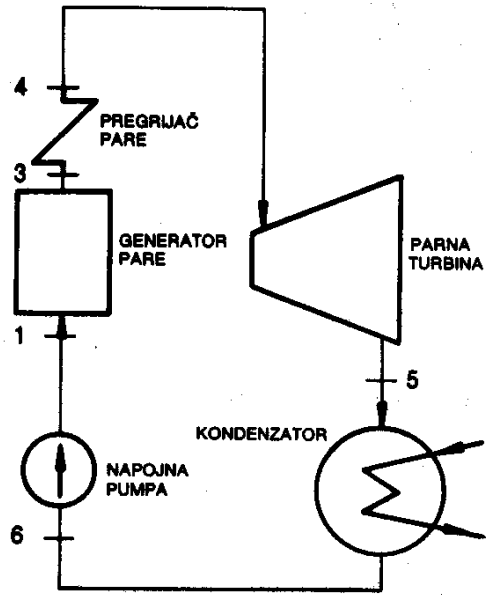
Water to steam (vapor)



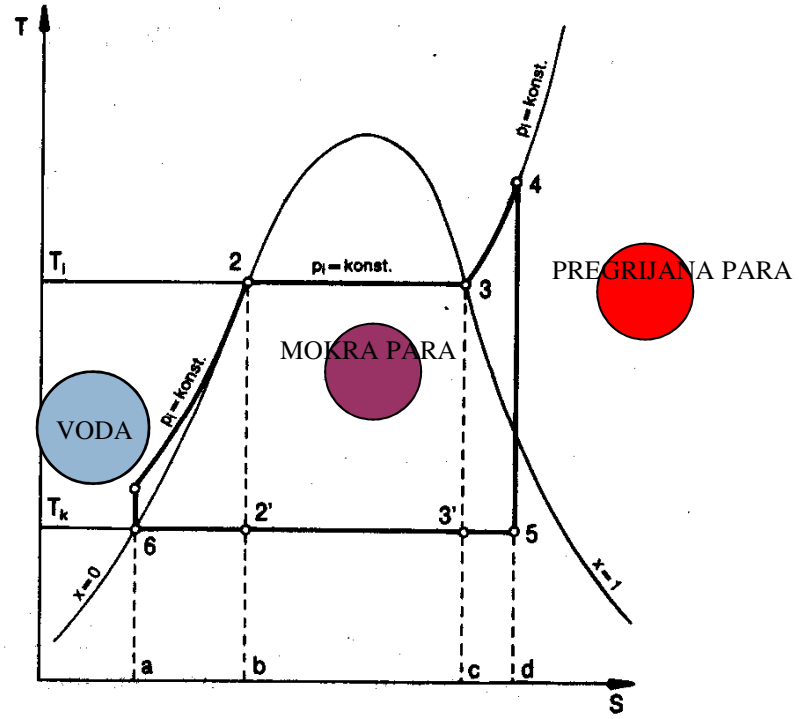
T – s diagram


T[K]
Critical point
K
p_4
p_3
p_2
p_1
saturation line
6
superheated vapor
water
3
4
5
saturated vapor
2
1
s[kJ/kgK]

Steam process



OSNOVNA SHEMA PARNOG PROCESA



T-s DIJAGRAM PARNOG PROCESA

Sea water

- 25000 g/m^3 NaCl + $MgCl_2$, $MgSO_4$, $CaSO_4$…
- around 35000 g/m^3

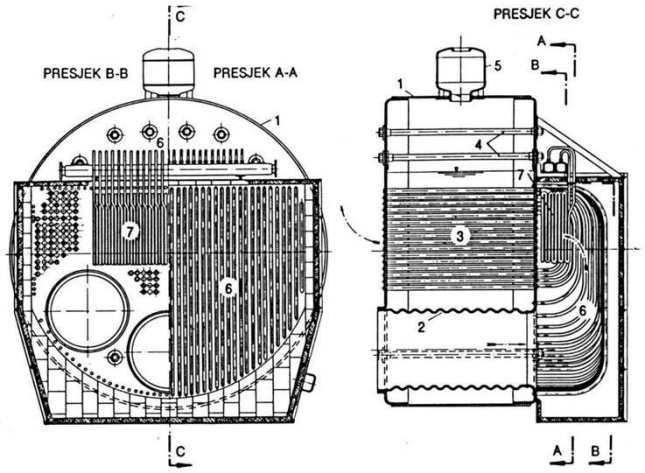
Natural

- water dissolves CO_2 i O_2
- dissolves $CaCO_3$ and other minerals
- $Ca(HCO_3)_2$ i $Mg(HCO_3)_2$ - alkaline
- CO_2 - acidic

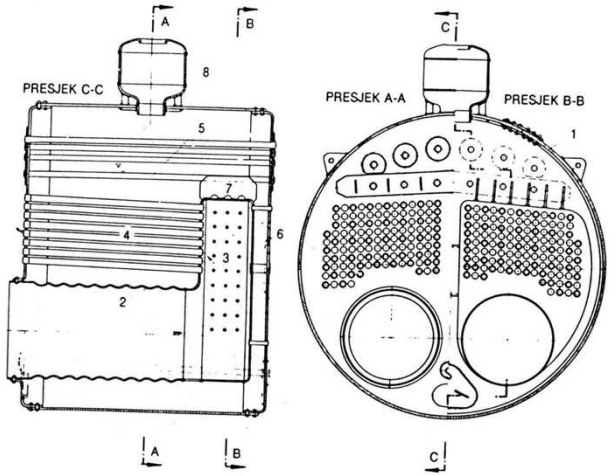
Distilled water

- produced in the ship's fresh water generating equipment
- generates water with 4 mg/l or less
- vacuum evap. - 2 mg/l
- if more quality water is needed (1 mg/l)- ION EXCHANGERS

Cylindrical boiler

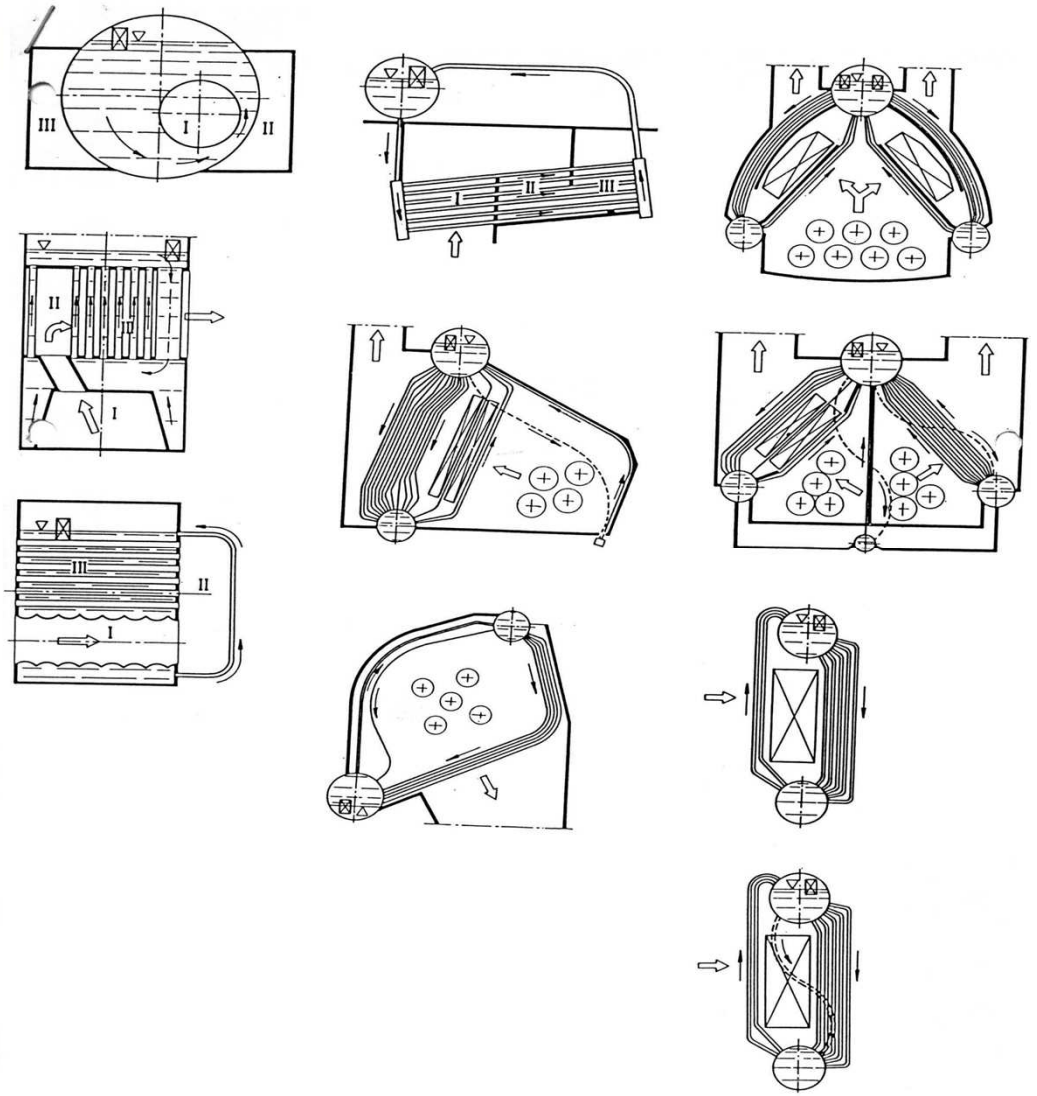


Parni kotao »Howden – Johnson«
Legenda: 1-plašt bubnja, 2-plamenica, 3-dimne cijevi, 4-kotveni vijci, 5-parni dom, 6-konvektivni snop isparivača, 7-pregrijač pare



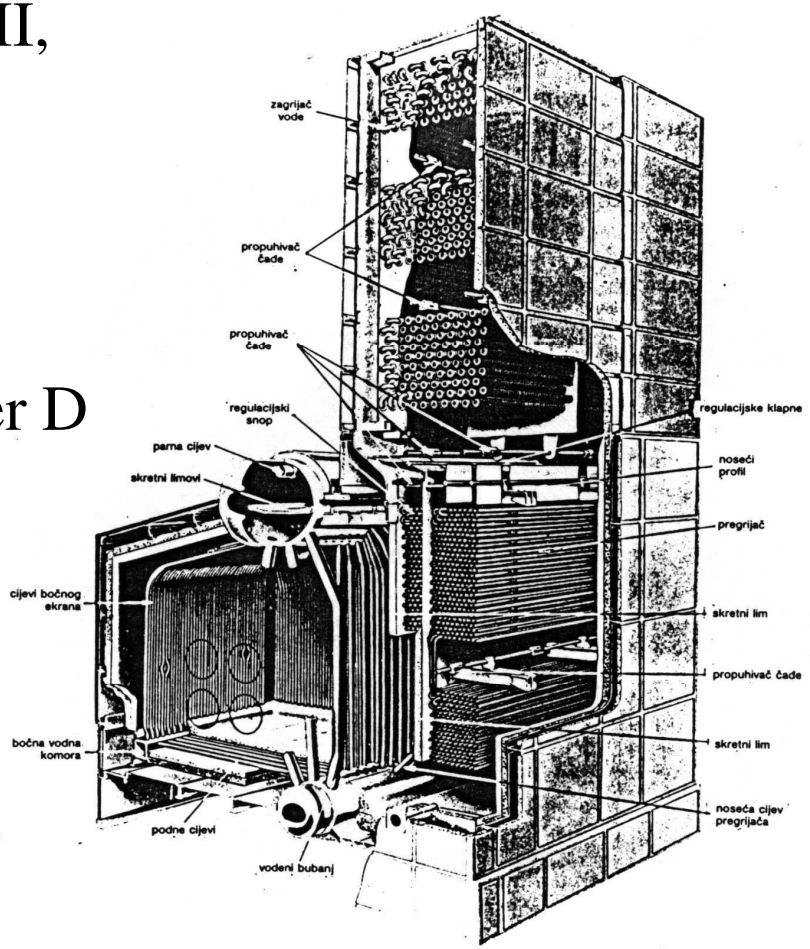
Škotski kotao
Legenda: 1-plašt bubnja, 2-plamenica, 3-skretna komora, 4-dimne cijevi, 5-kotve, 6-sprežnjaci, 7-ukrepe, 8-parni dom

Water circulation



FOSTER WHEELER

- D, ESD I, ESD II, ESD III, ESD IV, ESRD
- *D*- 40-55 t/h, 40-70 bar, T_{pp}=723-773 K
- ESD=external superheater D



Sl. 1.19. Brodski »D« generator pare (»Foster Wheeler«)

Heat coefficient of efficiency

INTRODUCED $: Q_{dov} = B \cdot H_d$

REMOVED $: Q_{odv} = D \cdot (h_{p,izl} - h_{v,ul})$

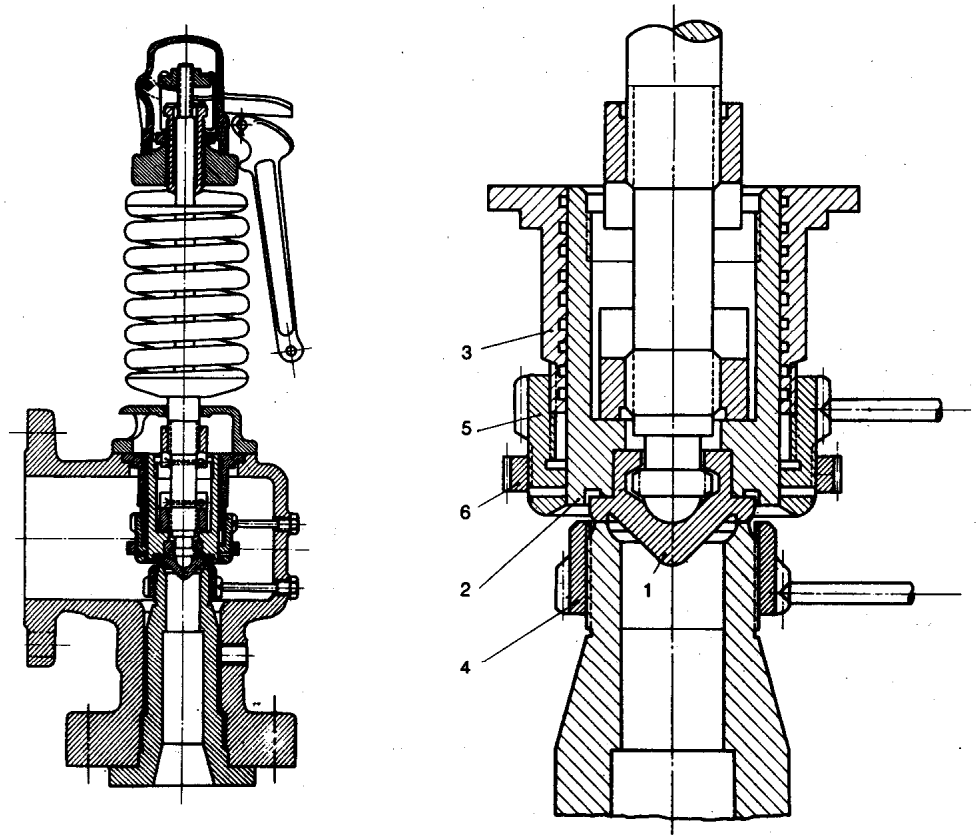
$$\eta_t = \frac{Q_{odv}}{Q_{dov}}$$

$$\eta = \frac{D(h_{p,izl} - h_{v,ul})}{BH_d}$$

Dangers

- pipes overheating and bursting
- to high pressures – steam drum explosion
- furnace explosion
- safety equipment

Safety valves

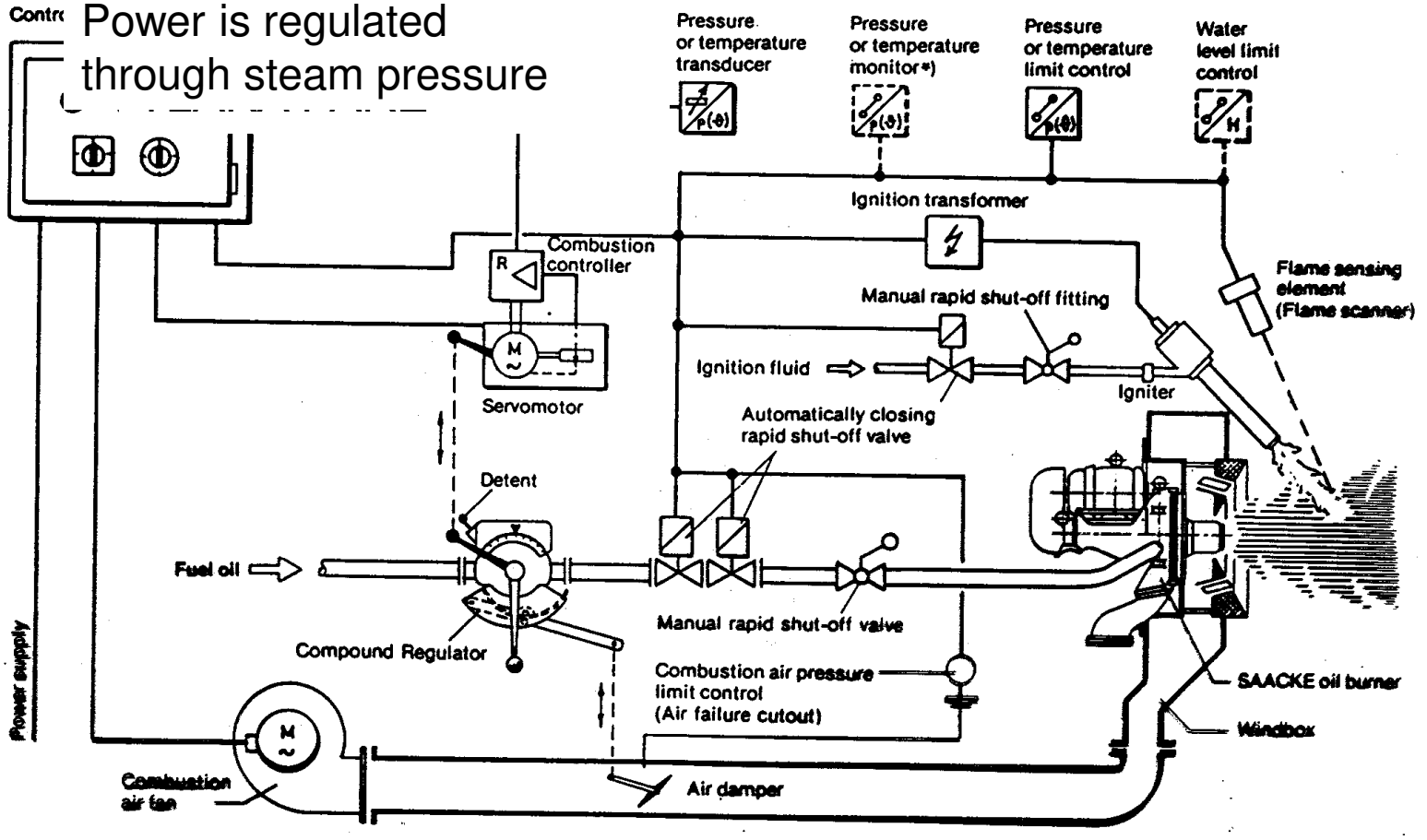


Sl. 9.11. Sigurnosni ventil s direktnim djelovanjem
Legenda: 1-pladanj, 2-klip, 3-cilindar za vođenje, 4-regulacijski prsten za prigušivanje zatvaranja, 5-regulacijski prsten, 6-regulacijski prsten
Izvor: 6, I/156

Burner management

PURGING IS ESSENTIAL!

SIMPLEST WAY:
Power is regulated
through steam pressure



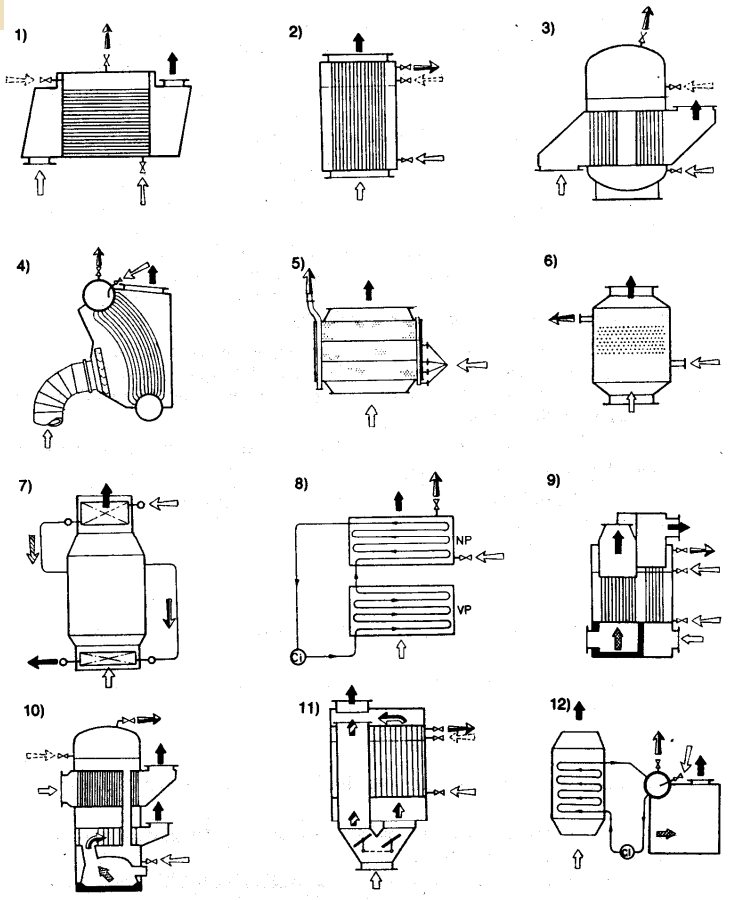
Starting procedure

- combustion air ventilator starting
- fuel pump starting – fuel preparation
- furnace purging
- fuel/air mixture setting
- ignition
- working pressure

Exhaust gases boilers

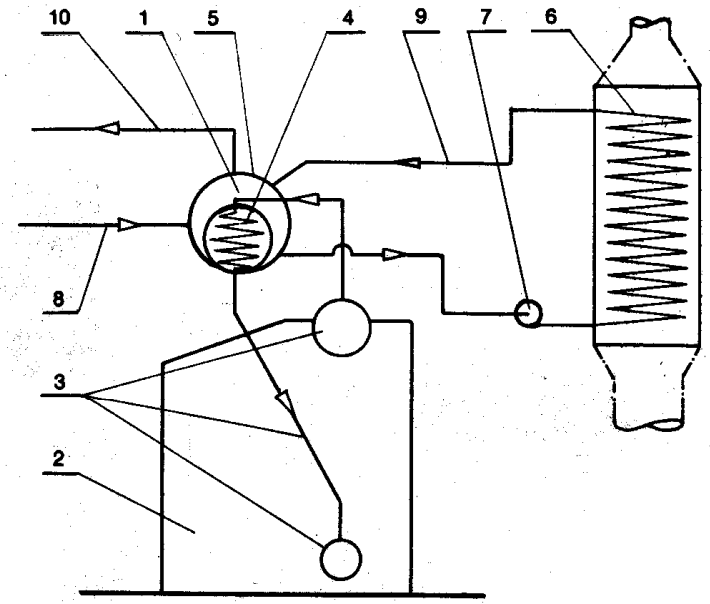
PRESSURES UP TO 20 bar

FORCED WATER CIRCULATION – SMALL DIMENSIONS



Sl. 11.22. Glavni tipovi brodskih utilizatora
1. cilindrični utilizator s horizontalnim dimnim cijevima, 2. cilindrični utilizator s vertikalnim dimnim cijevima, 3. utilizator s vertikalnim vodnim cijevima i prirodnom cirkulacijom, 4. utilizator sa strmim vodnim cijevima i prirodnom cirkulacijom, 5. utilizator sa prisilnom optočnom cirkulacijom, 6. utilizator sa prisilnom protočnom cirkulacijom, 7. utilizator s pregrijačem i zagrijačem vode, 8. utilizator sa dva tlaka, 9. kombinirani utilizator s dimnim cijevima, 10. kombinirani utilizator sa vodnim cijevima, 11. utilizator s obilaznim vodom, 12. utilizator u spoju s loženim generatorom pare
Izvor: 3, 22

Fuel and exhaust gas boilers connection



Exhaust gases boiler has a tube bundle with forced water circulation (pump 7). The pump sucks water from steam drum or secondary steam generator. Fuel boiler produces primary steam having higher pressure and temperature when compared to secondary steam. Consequently, primary steam is used only to produce secondary steam.

4-cijevni
lizatora,
10-izlaz

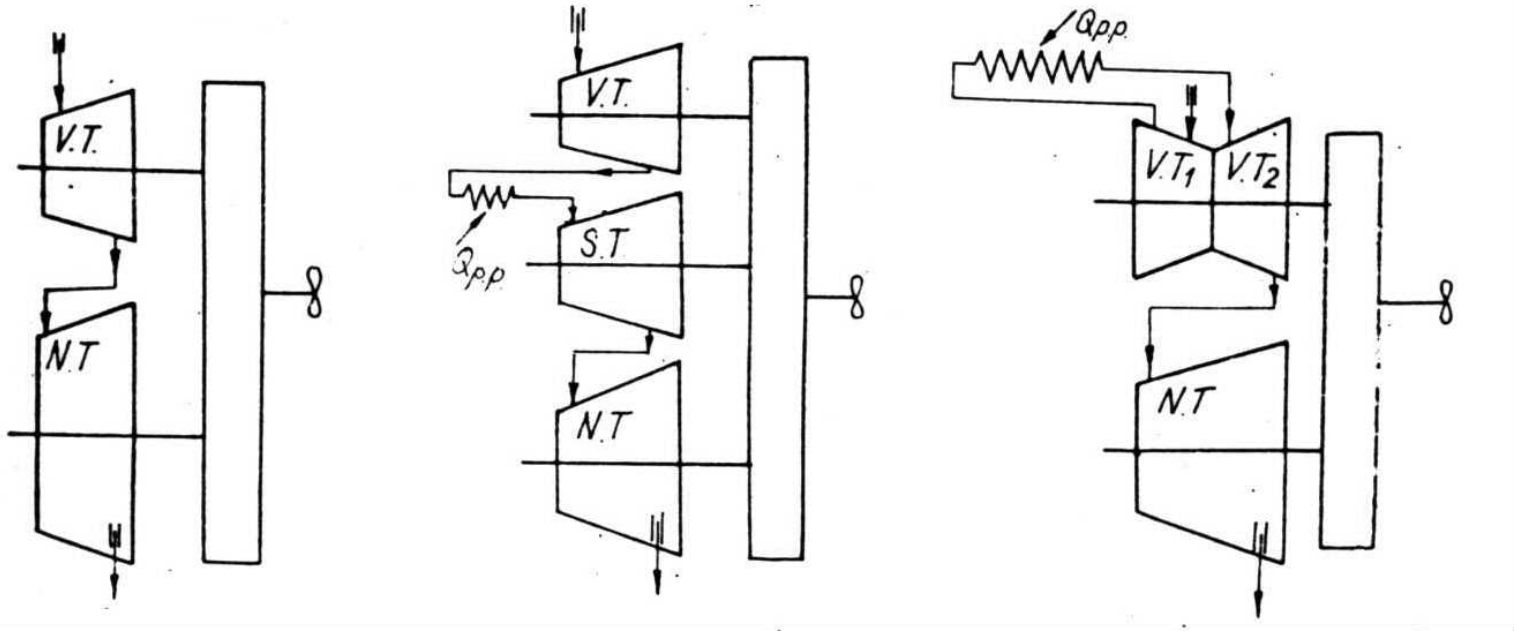
/AČ TOPLINE

Marine steam turbines

Propulsion turbines

- Several casings
- Several stages - Parsons
- Curtis type for reversed drive
- Gas turbine combinations

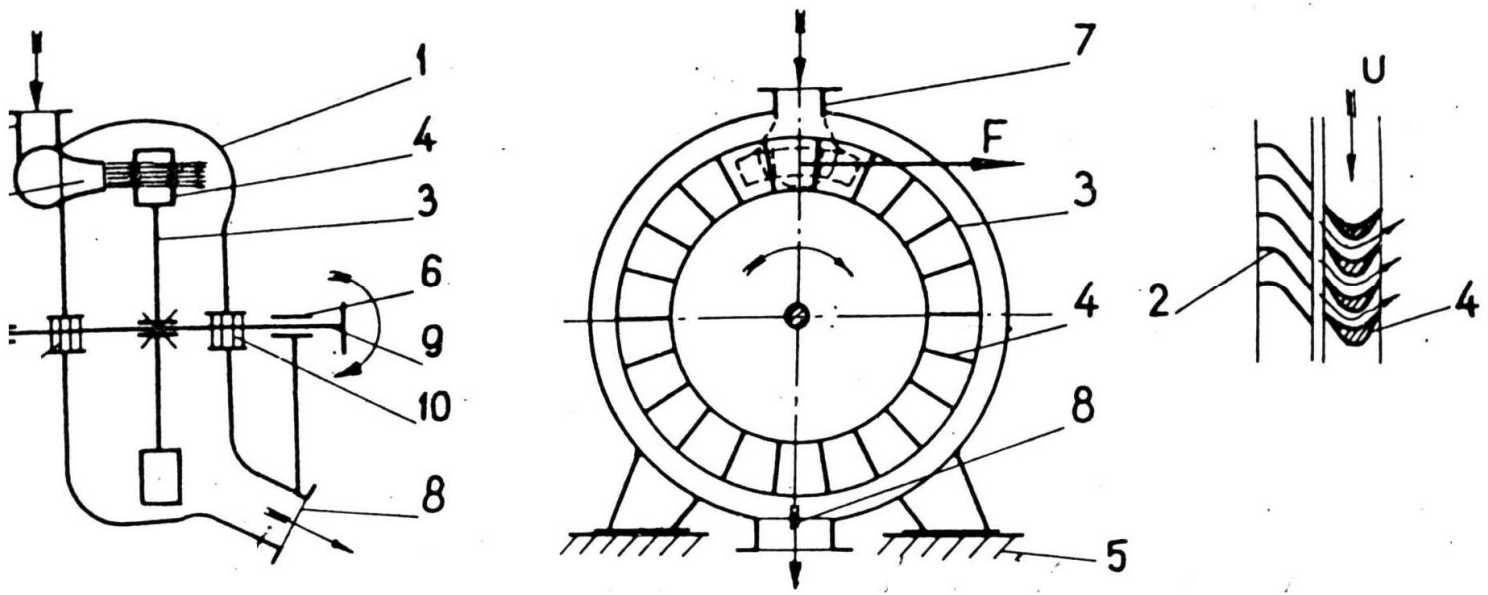
Propulsion turbines



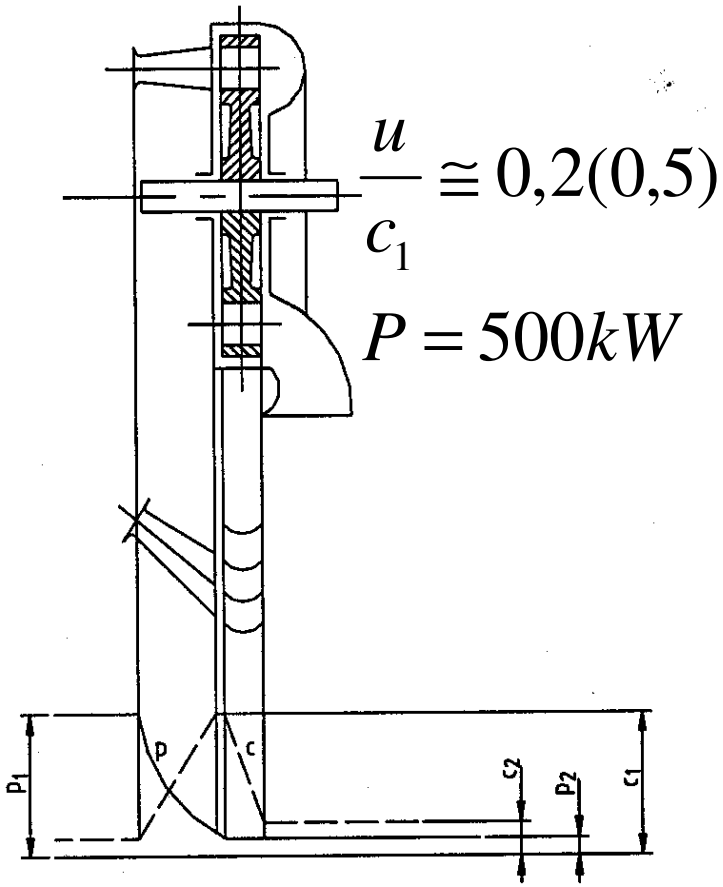
De Laval type

Small power
Pump and e. generators

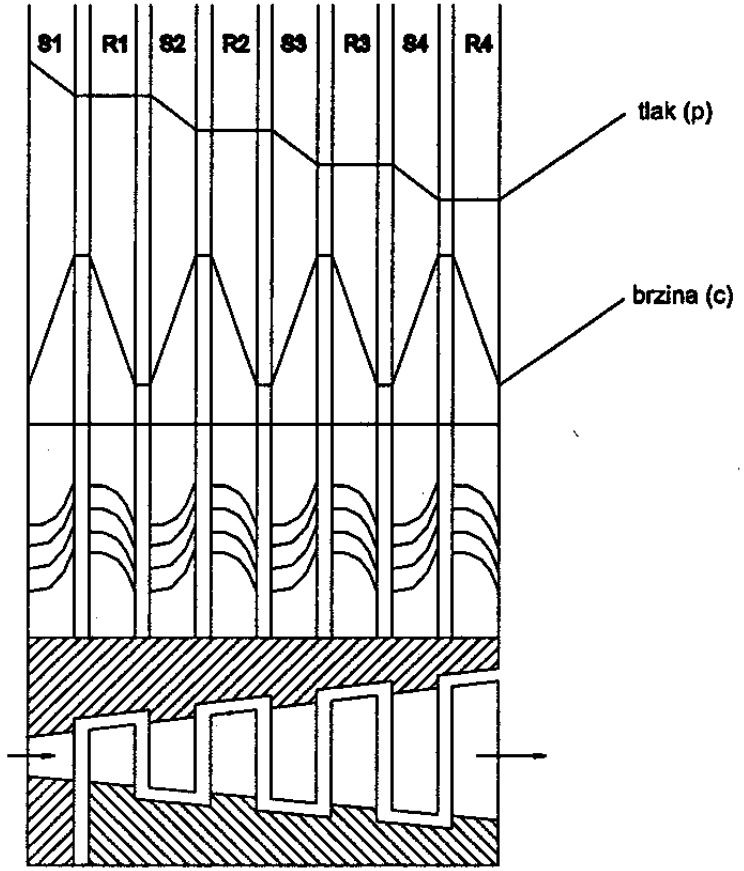
10000-30000 min^{-1}, η_e=0,3-0.4



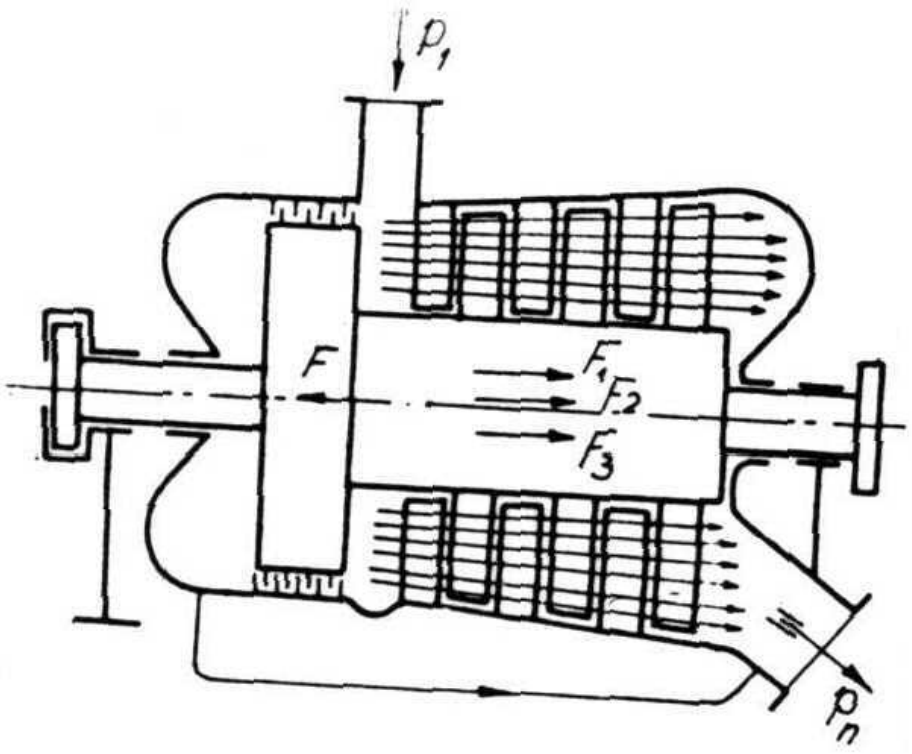
De Laval



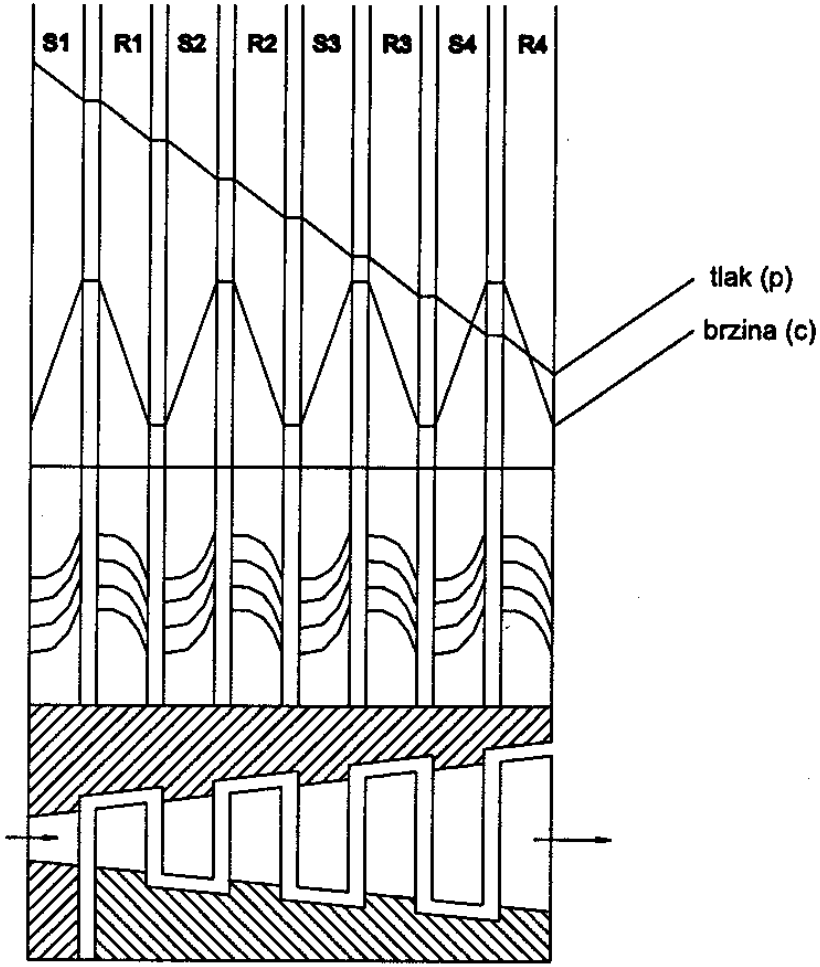
De Laval - multistage



Parsons type

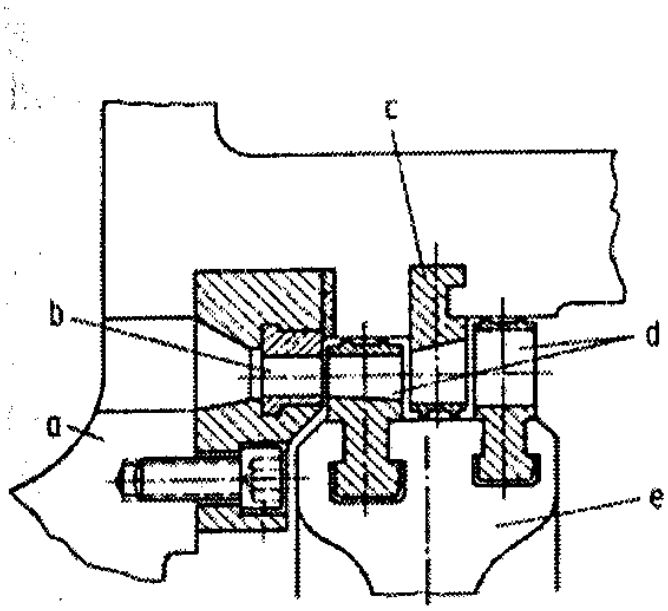


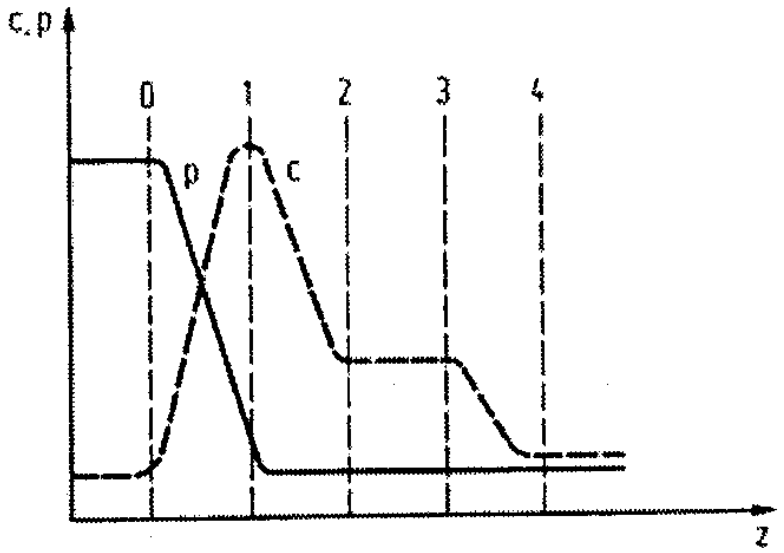
Parsons - multistage



Curtis type – 1900.

3000-10000 min^{-1}, η_e =0,4 i više

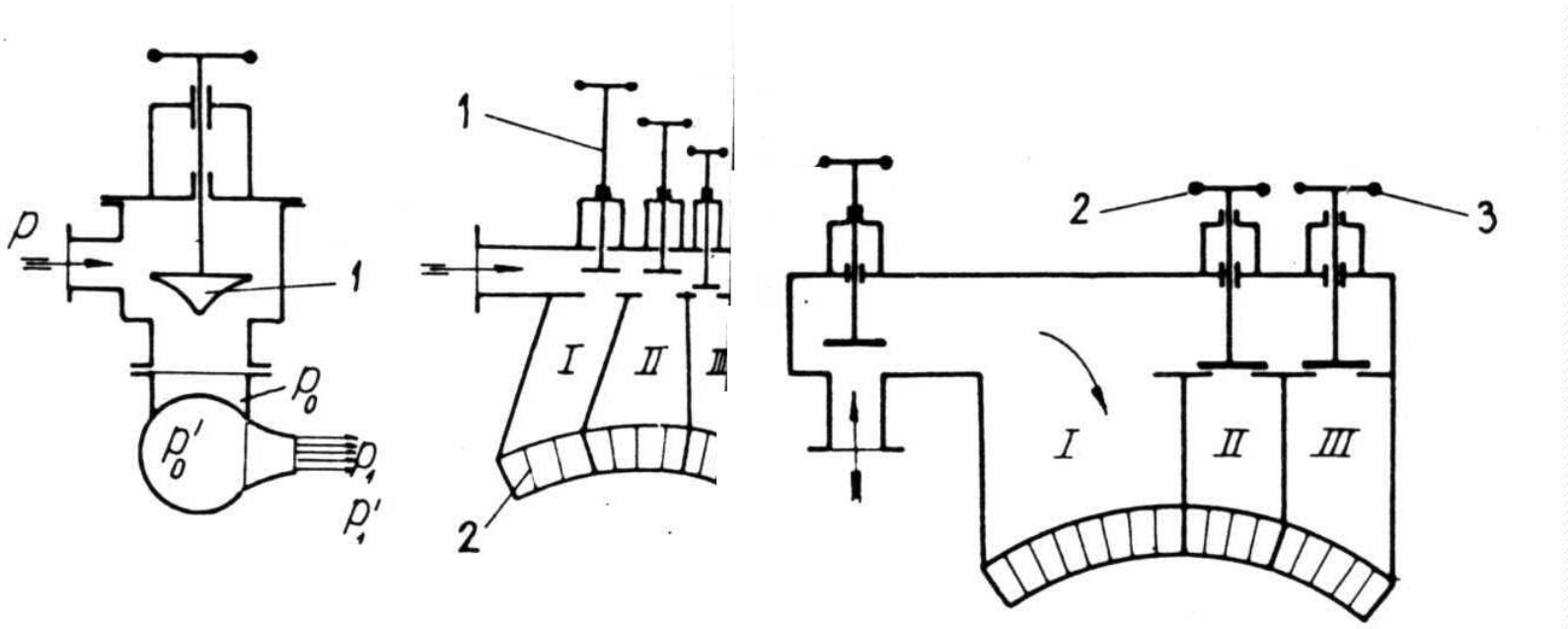




REGULATION

- CHOKING (PRESSURE)
- VAPOR QUANTITY
- COMBINED

REGULATION



REGULATION