POLITECNICO DI MILANO

FLUID-MACHINES

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Classification and description of Fluid-Machines

Classification criteria

Direction of energy transfer

- Motor machines convert the fluid energy in mechanical energy (P, h ↓; $l < 0$)
- Operating machines convert mechanical energy in fluid energy (P, h ↑; $l > 0$

Thermal and volumetric behavior of the working fluid

- Incompressible flow machines (also called hydraulic machines), if the fluid does not exhibit its compressibility throughout the transformation
- Compressible flow machines (also called thermal machines), if the fluid compressibility (i.e., thermal effects) are relevant for the transformation

Operating way

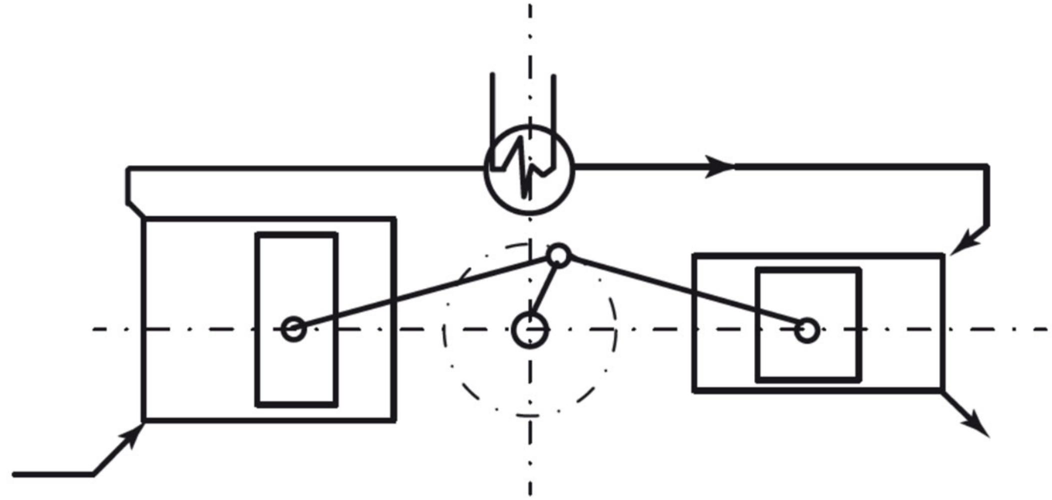
- Volumetric machines exchange energy by a cyclic change of volume or a displacement the fluid; low flow velocity (small flow rate), high work
- Turbomachines exchange energy by the continuous interaction between the fluid and the rotating components of the machine; high flow velocity (high flow rate), limited work (by a single rotor…)

Relevant example: aero-engine vs ICE → turbomachinery vs pistons

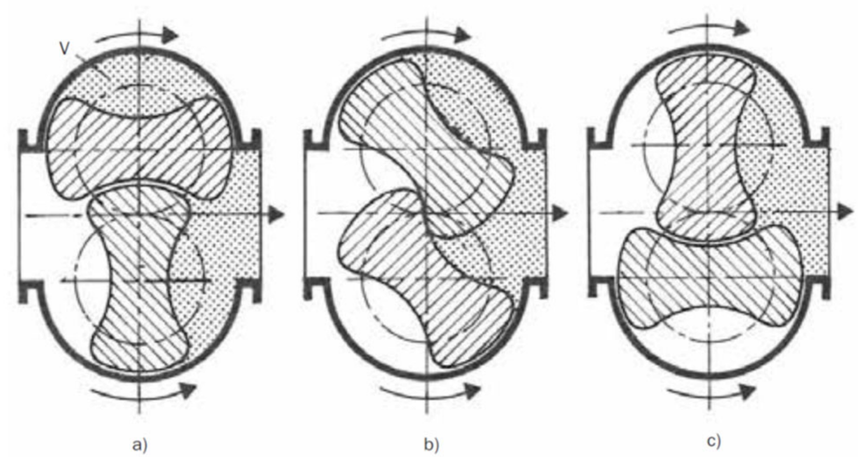
	Hydraulic machines (incompressible flow)		Thermal machines (compressible flow)	
	motor	**operating**	**motor**	**operating**
Volumetric machines	Volumetric actuators	Volumetric pumps	Volumetric expanders (es: I.C.E.)	Volumetric compressors (es: I.C.E.)
Turbomachines	Hydraulic turbines	(Turbo-) pumps, fans	Turbo-expanders or thermal turbines (es: turbogas)	(Turbo-) compressors

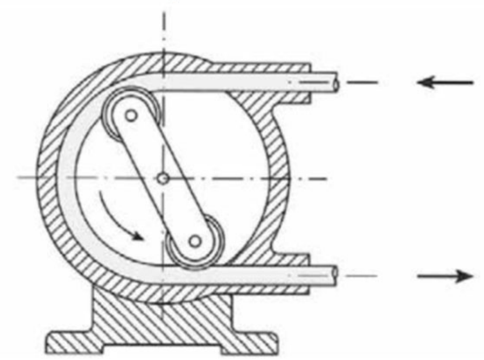
Volumetric machines

Reciprocating compressor/expanders
Piston in reciprocating motion, which during a cycle intakes and discharge the fluid (through valves), possibly compressing/expanding the fluid



Rotative compressors/expanders
Gears that, while rotating, capure the fluid and displace it towards the discharge section possibly inducing a variation of volume





Suitable (→ more efficient than other machine technologies) for:

- **LOW FLOW RATE**
- **HIGH SPECIFIC WORK**

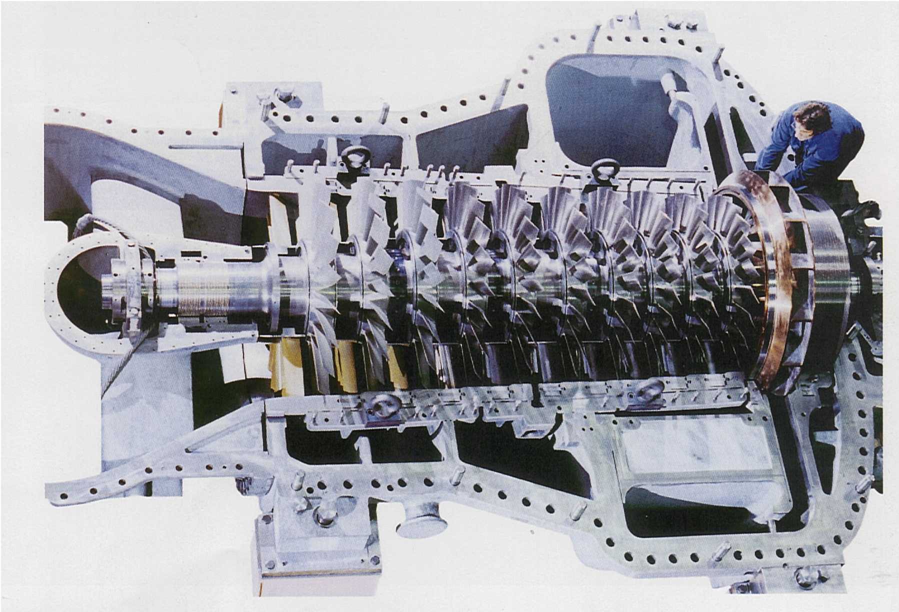
(classification valid for a single device!)

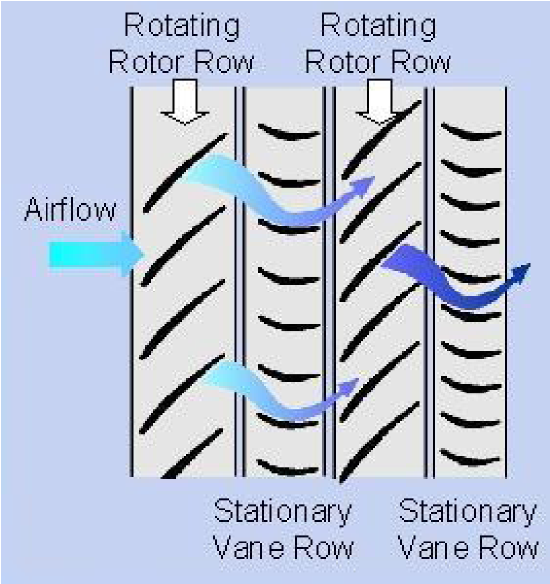
Working principle: aerodynamic forces exchanged between flow and moving blades

→ exchange of mechanical power: cross and transversal velocity components involved

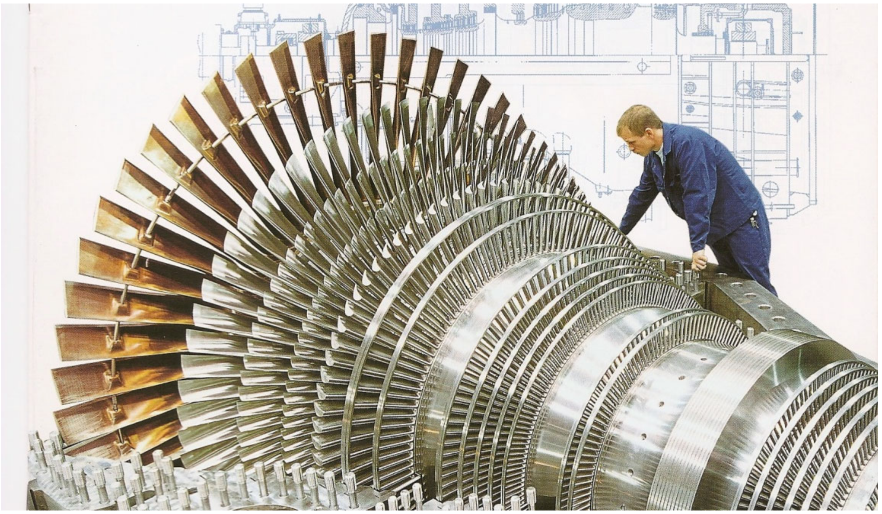
→ blades inclined and cambered, both moving (rotor) and fixed (stator) blade rows

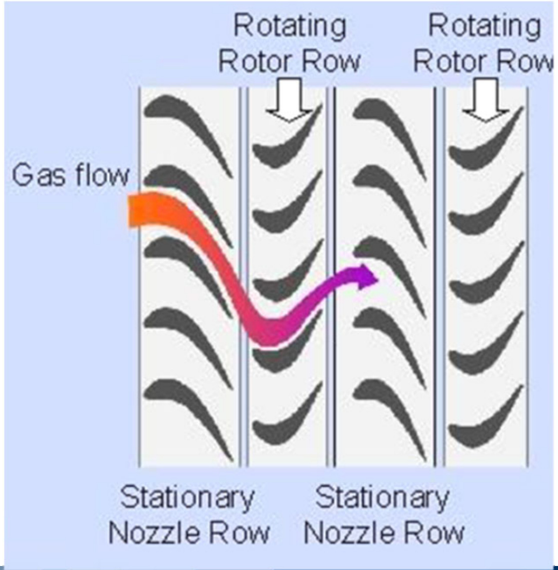
COMPRESSOR



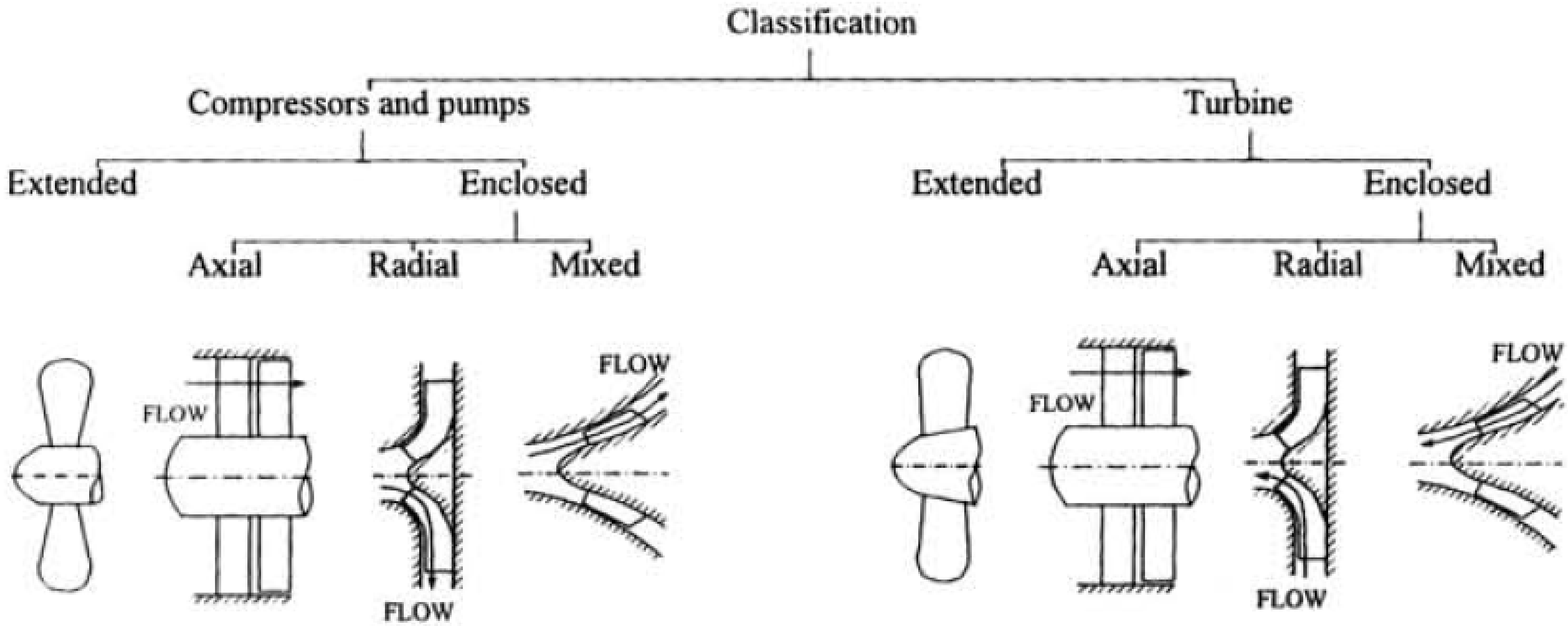


TUBRINE





Turbomachinery architecture and flow implications



→ *Axial machines (rotors):*

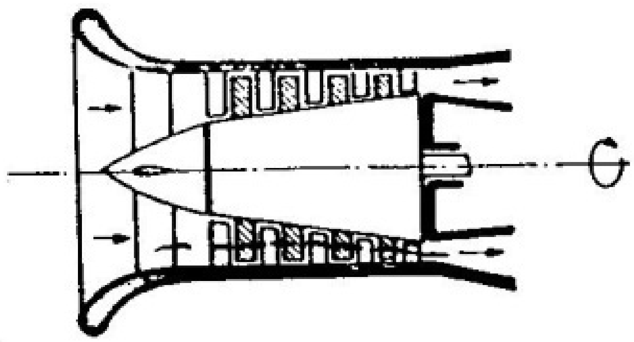
- *the flow passes throughout the machine mainly in <u>axial</u> direction*
- *the flow trajectories lie mainly on cylindrical surfaces*
- *from inlet to outlet the distance between the flow surface and the axis of the machine remains (almost) constant*
- *intrinsically suitable for high flow rates, low specific work exchange*

→ *Radial machines (rotors):*

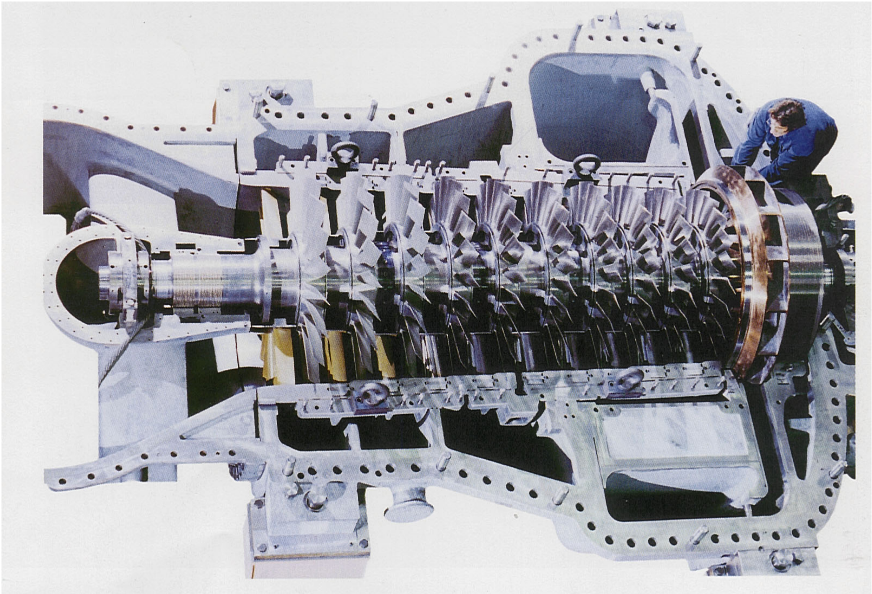
- *the flow passes throughout the machine mainly in radial direction*
- *the flow trajectories lie on conical surfaces and NOT cylindrical*
- *from inlet to outlet the flow changes significantly the distance from the axis: centripetal/centrifugal flow paths*
- *intrinsically suitable for low flow rates, relatively high specific work exchange*

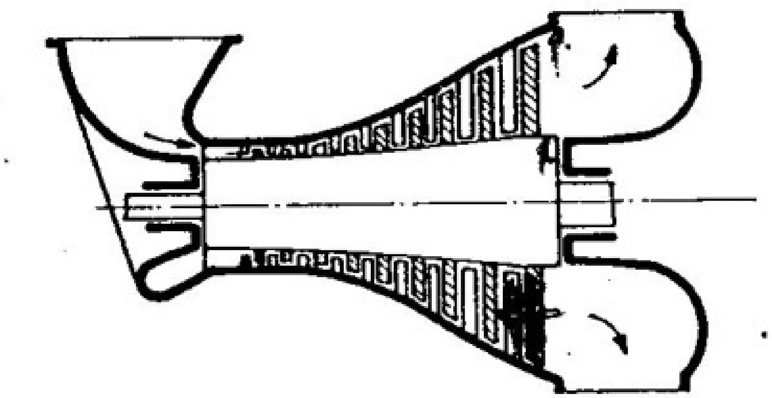
→ *Mixed-flow machines (rotors): intermediate configuration*

Examples of Axial Turbomachines
→ typically in multi-stage configuration

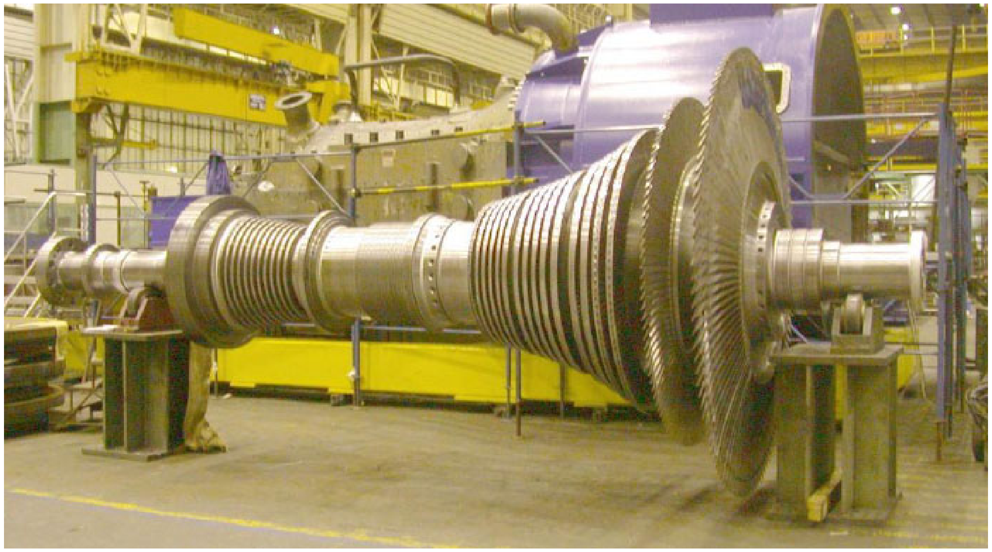


Axial compressor



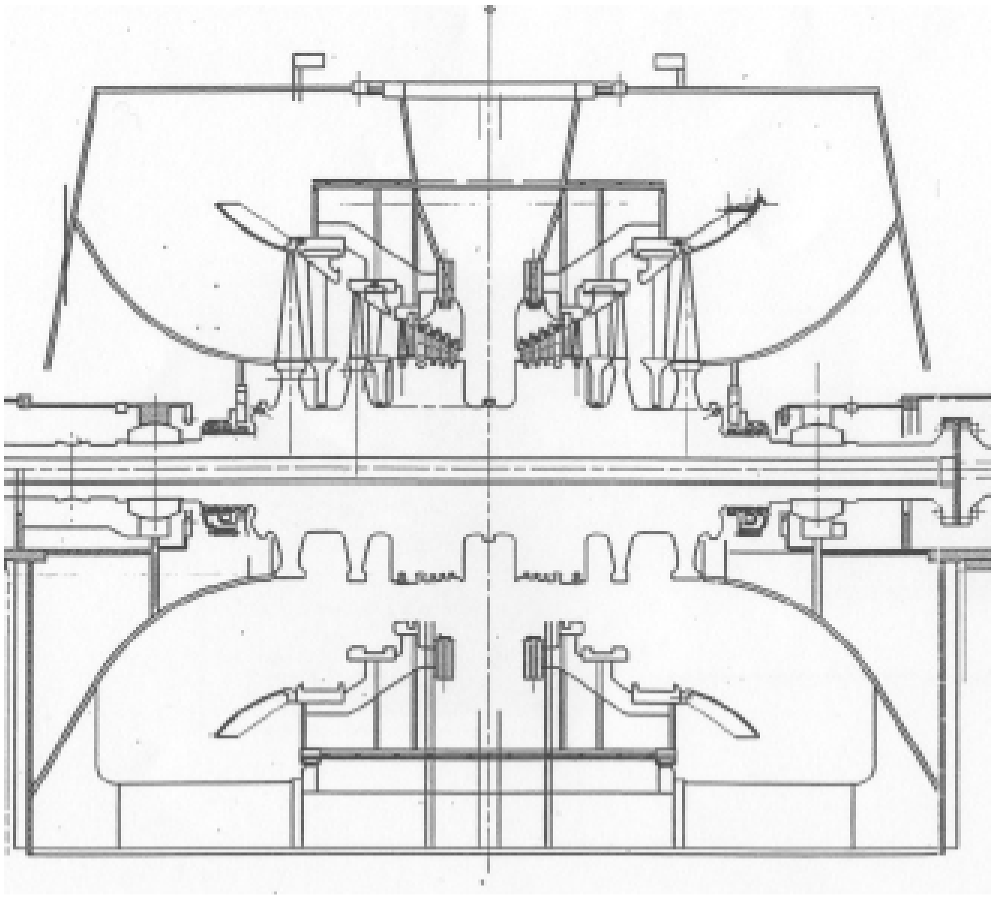


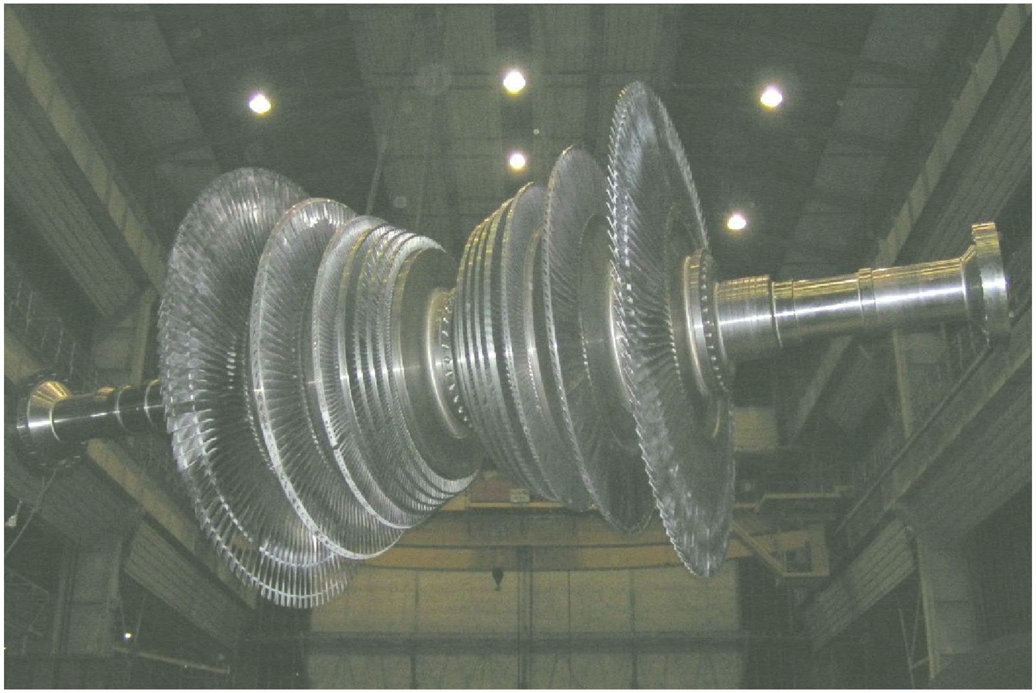
Axial turbine



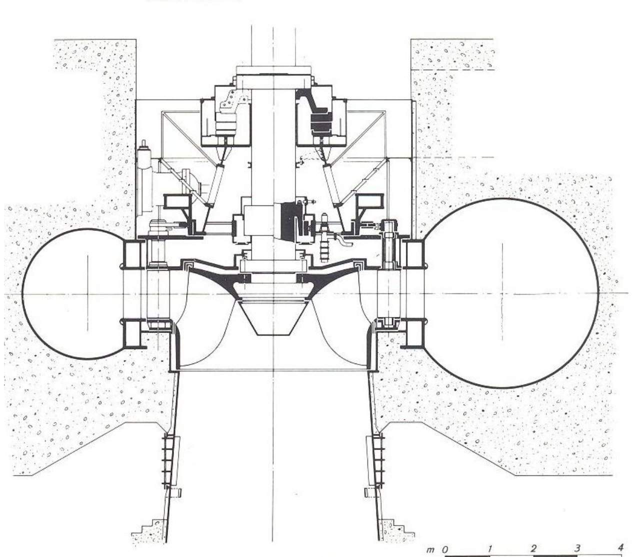
Low pressure axial steam turbine

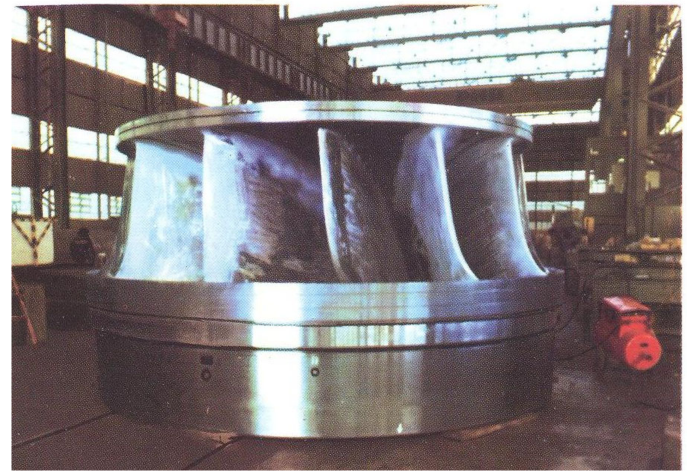
(the dramatic change in mean diameter due to the increase of channel height does not affect the classification, which holds across each single rotor)



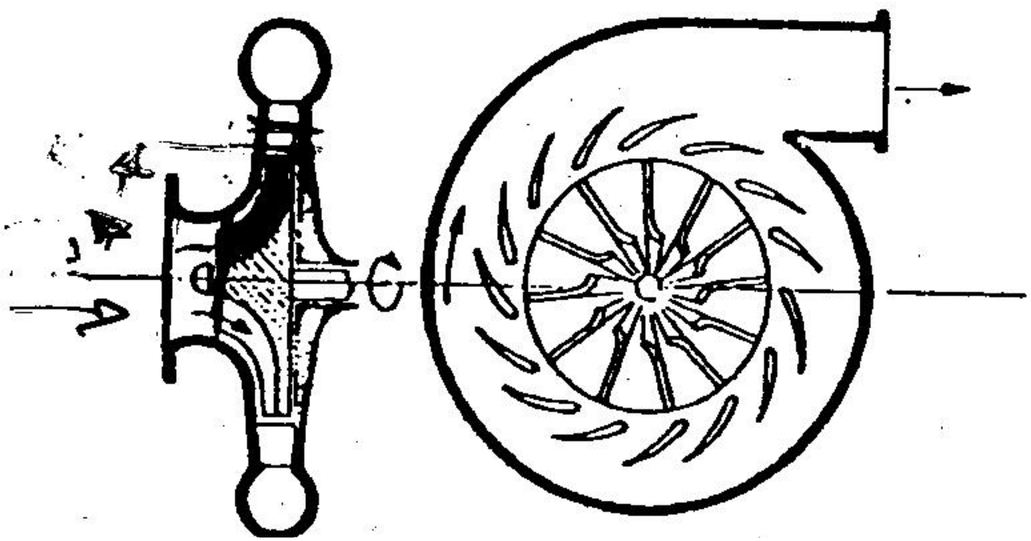


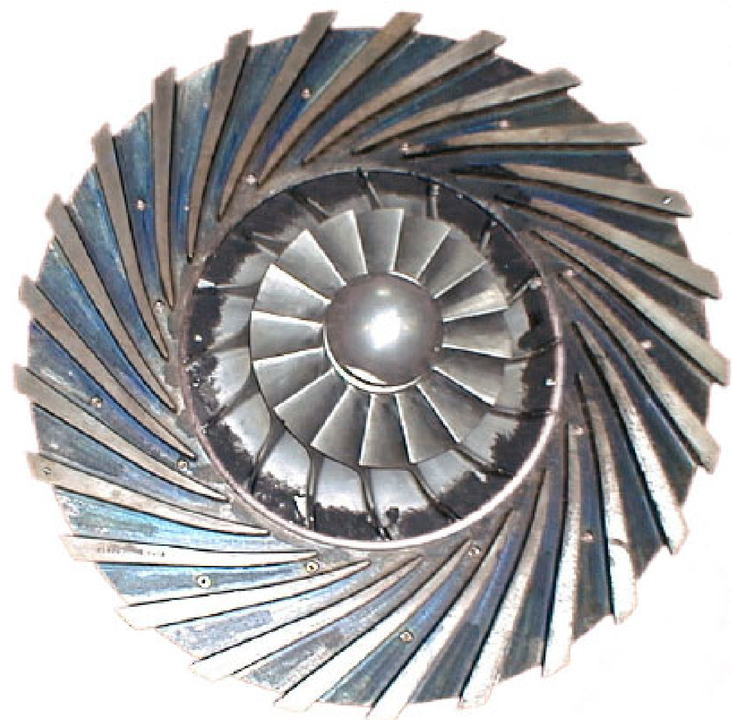
Examples of radial turbomachinery





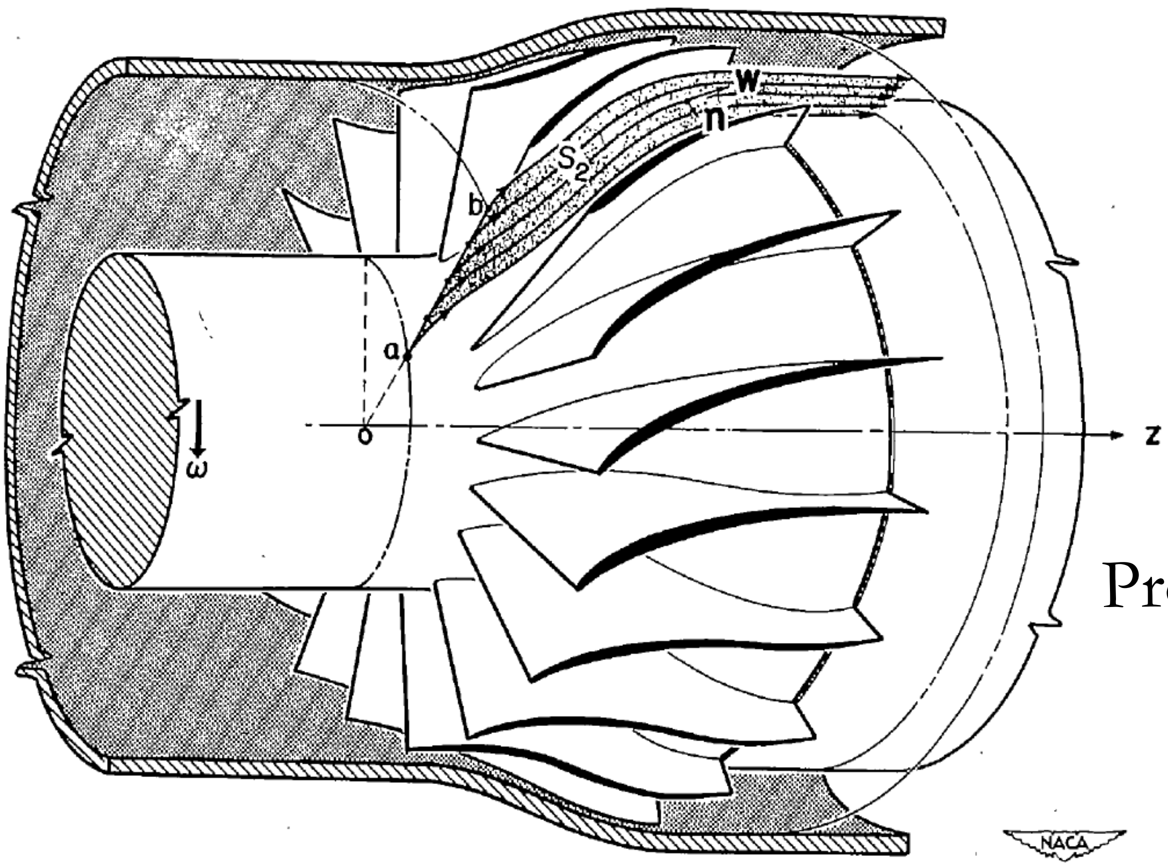
Centripetal turbine

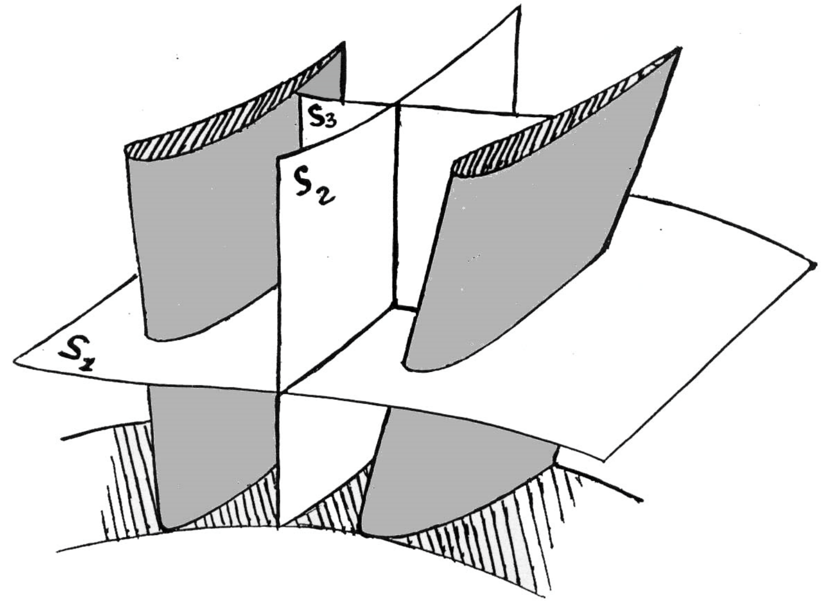




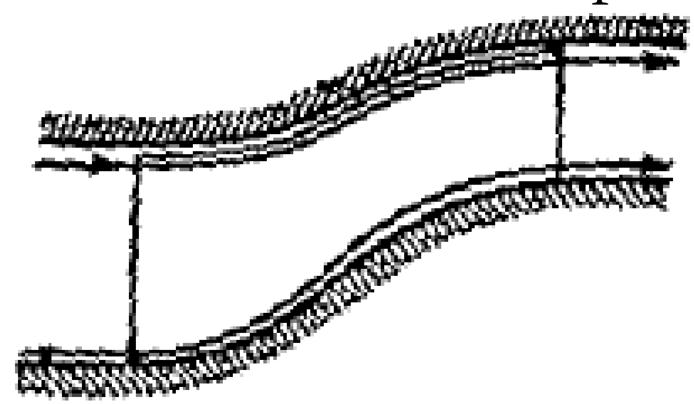
Centrifugal compressor

(a): Meridional surface, representing the channel between the endwalls

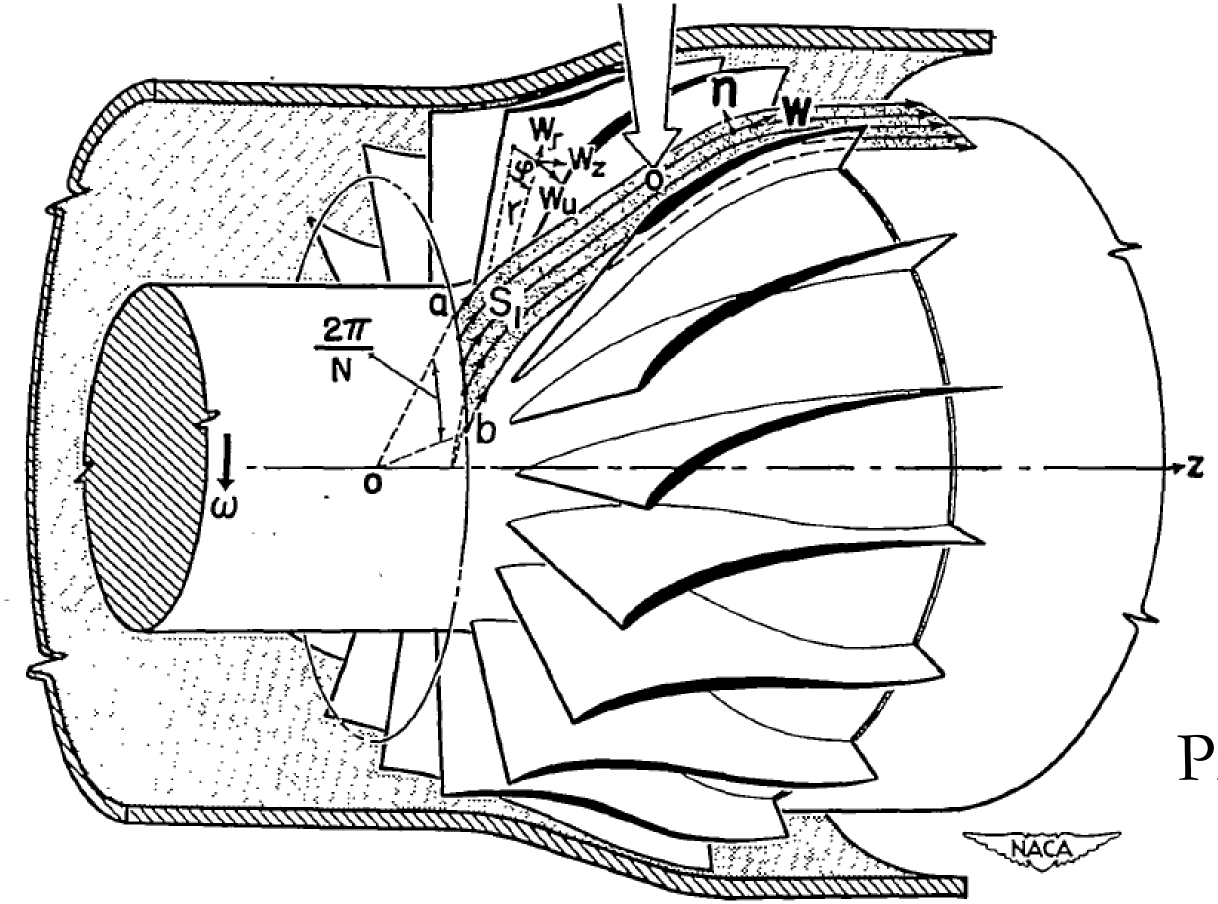


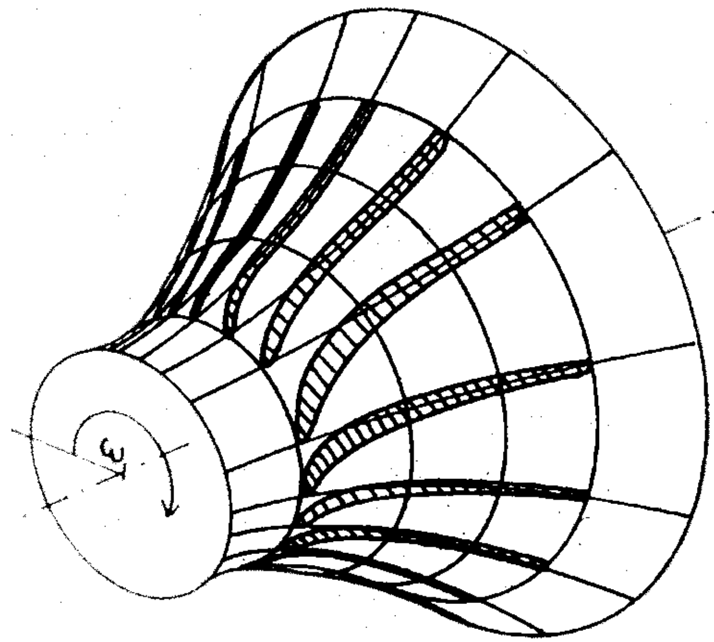


Projected on the meridional plane

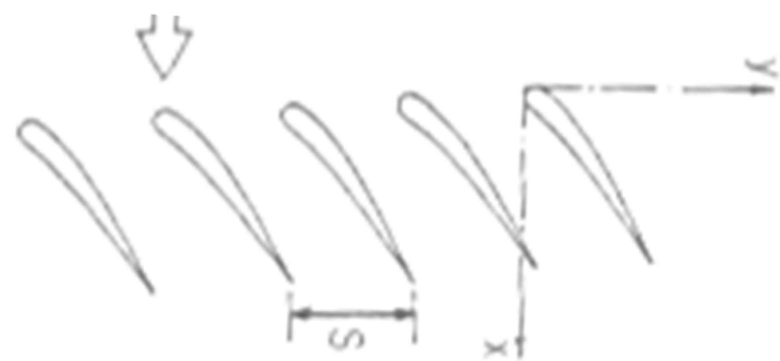


(b): Blade-to-blade surface, containing the blade profiles





Projected on the bl-to-bl plane



Two velocity components in turbomachinery

V_m: normal to in/out → flow rate

V_t: azimuthal flow → deflection

$$\mathbf{V} = V_m\, \mathbf{i_m} + V_t\, \mathbf{i_t}$$