Basic knowledge

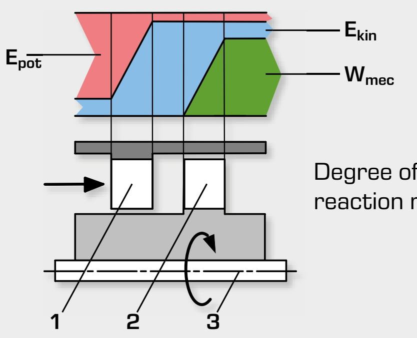
Turbines for gaseous fluids

Turbines for gaseous fluids are designed as gas turbines, steam turbines or expansion turbines. They are used to power vehicles, aeroplanes and ships, or to generate electricity. The turbines in use range from small capacities (a few kWs) to large units (more than 1600 MW) in power plants. The maximum inlet pressure of steam turbines is up to 270 bar. The temperature of the fluid ranges from under 100°C in expansion turbines to over 1500°C in modern gas turbines. As turbomachines, turbines allow high mass flow rates and thus also a high concentration of power, which is why they are a preferred solution for aeroplanes, fast ships or for very high outputs.

While gas turbines only use reaction turbines, steam turbines operate with both reaction turbines and action turbines.

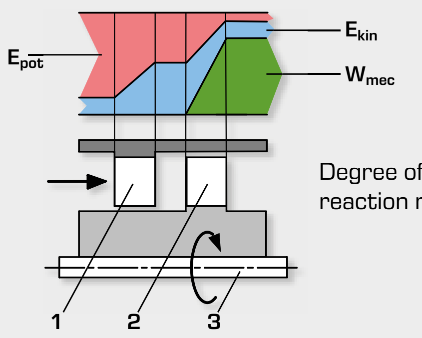
The advantage of action turbines in this case is that they can be designed with a partial admission rotor for use with small volume flow rates (small output, high pressure). This ensures that the diameter of the rotor and the length of the blades remain large enough, and that the speed is comparatively low.

Conversion of energy in action turbines and reaction turbines



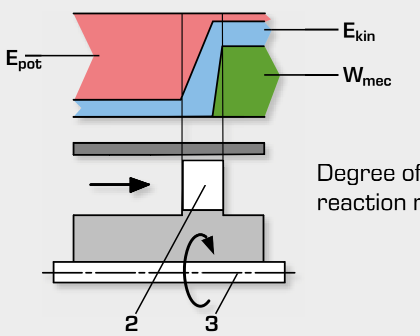
Degree of reaction r = 0

Action turbine: In the distributor, the potential pressure energy is completely converted into kinetic energy. The rotor then converts the kinetic energy into mechanical work.



Degree of reaction r = 0,5

Reaction turbine: The conversion of the potential pressure energy is divided among the distributor and rotor. The kinetic energy is then converted into mechanical work at the rotor.



Degree of reaction r = 1,0

Pure reaction turbine: The conversion of the potential pressure energy into kinetic energy takes place in only one nozzle in the rotor. The recoil of the nozzle then provides the impulse for the mechanical work. Pure reaction turbines are not used in industrial applications. The figure represents an abstract form.

For the purpose of differentiation, the **degree of reaction r** was added as a dimensionless number. The degree of reaction is an indication of the proportion of energy that is converted in the rotor. Thus it is also a measure of the ratio of enthalpy **h** converted in the rotor.

$$r = \frac{h_{1-2}}{h_{1-2} + h_{0-1}} = 0...1$$

h_{0-1} enthalpy gradient over the stator,
h_{1-2} enthalpy gradient over the rotor

1 distributor, **2** blades, **3** rotor;
E$_{pot}$ potential pressure energy, **E$_{kin}$** kinetic energy, **W$_{mec}$** mechanical work

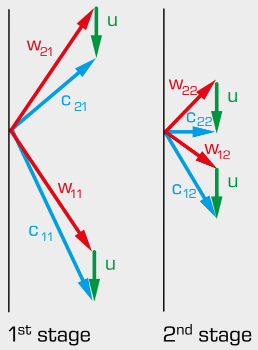
Due to the high enthalpy gradient in gas and steam turbines, the flow velocities during the conversion to kinetic energy are high in comparision to water turbines. Accordingly, the theoretically required circumferential velocity of the rotor is very high. Since the circumferential velocity of the rotors is limited by the strength of the material, the enthalpy gradient is generally divided into several pressure or velocity stages. This is why all steam turbines, and most gas turbines, have multiple stages.

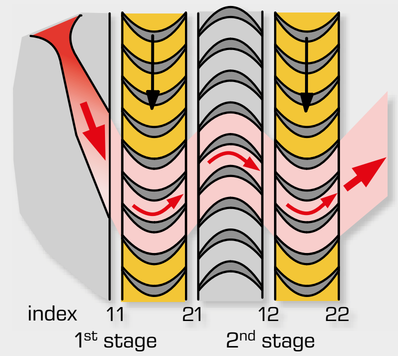
When energy conversion is accompanied by a release of energy and a corresponding pressure drop, this is called expansion. Due to the increase in volume that occurs when gaseous fluids expand, the flow cross-sections become larger from stage to stage. In the low pressure stages of large steam power plants the diameter of the last stage can be up to 3,7 m and the length of the blades more than 1,4 m (n = 3000 min^{-1}).

Velocity triangles and multiple stages

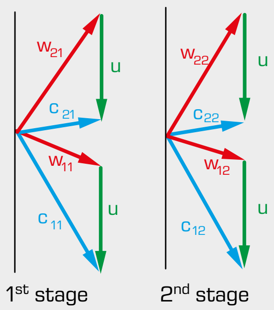
Action turbine
with **velocity** stages:
Ratio c_{11}/u, very large

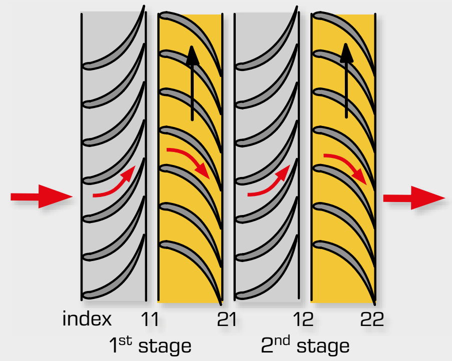
rotor stator
index 11 rotor inlet, 1st stage,
index 21 rotor outlet, 1st stage,
index 12 rotor inlet, 2nd stage,
index 22 rotor outlet, 2nd stage





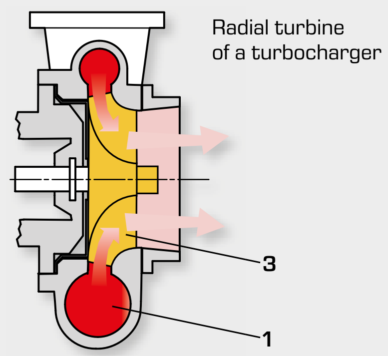
Reaction turbine
with **pressure** stages:
Ratio c_{11}/u, medium

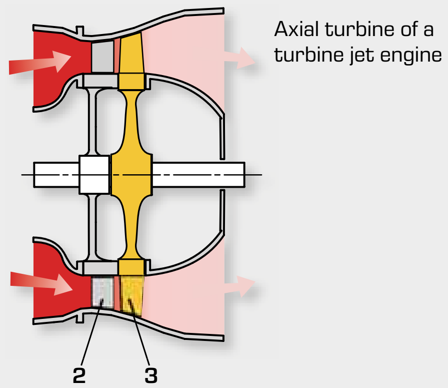




Velocity triangles and multiple stages

As with other turbomachines, we differentiate between radial and axial turbines by the direction of flow.





1 spiral housing as distributor,
2 distributor, **3** rotor