Hydroelectric Power Plants

Hydro Power Generation

- Usage of potential (polohové a tlakove) and partly kinetics energy of water flow
- Usage of hydroenergetic potential of water flows has some advantages compare to other power sources:
  - Renewable and clean source of energy
  - Usage of own sources (independancy on other counties)
  - Low investments and operating costs
  - Low failure rate, long life-time and high number of operating hours

Classification

- With respect to installed power
  - **smal** with installed power up to 10 MW
  - **medium** with instaelled power from 10 MW to 200 MW
  - **large** with installed power more than 200 MW
- With respect to method of needed high creation
  - **run of river** the water head is created by a weir on river
  - **derivative** artificial channel or pipe
  - **reservoir** head is created by a dam
  - **pump of storage** pump water over upper reservoir
  - **taidal** sea ebb and flow
- According to availability of water head
  - **low head** up to 20 m
  - **medium head** from 20 m to 100 m
  - **high head** more than 100 m

Hydroelectric potential energy

- Can be estimated according to formula

$$P = Q\rho g H$$

where P is the power (W), Q is the water flow (m^3/s), ρ is the specific weight of water, H is the hydraulic head (m)

- The real potential energy is smaller and for prelliminary estimation can be determined as:

$$P = k_T Q H$$

where k_T is a multiplicative factor,k_T=8 for low pressure turbines of larger dimensions, k_T=7 for low pressure turbines of small dimensions, k_T=6,5 for low pressure unregulated turbines of micro sources

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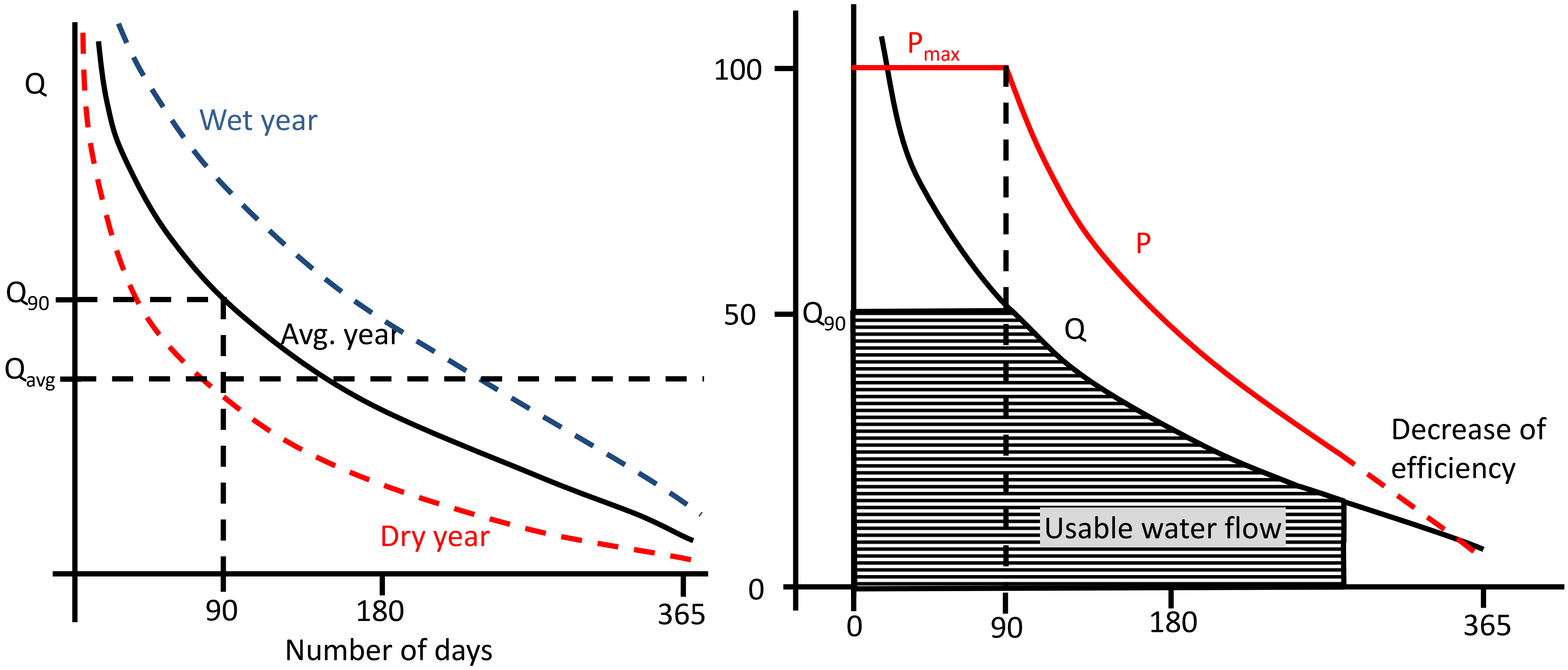
Hydroelectric potential energy



Total hydroelectric potential

- Generated electric power

$$P_s = Qg\rho H\eta_T\eta_P\,\eta_G$$

where η_T is turbine efficiency (0,6-0,9), η_P is efficiency of torque transfer to the generator shaft (0,94-0,97) and η_G is generator efficiency (0,95-0,97 for MW powers)

Hydro turbines speed

- Operating speed of different hydro turbines with various parameters are in the range from 53 to 1500 rpm
- Estimation of nominal turbine speed:

$$n = 1{,}166 \frac{n_s H \sqrt[4]{H}}{\sqrt{P_T}}$$

where n is the nominal speed of turbine (rpm), n_s is the specific speed, H is the head (m), P_T is the power on the shaft of turbine (kW).

Specific speed of hydro turbine

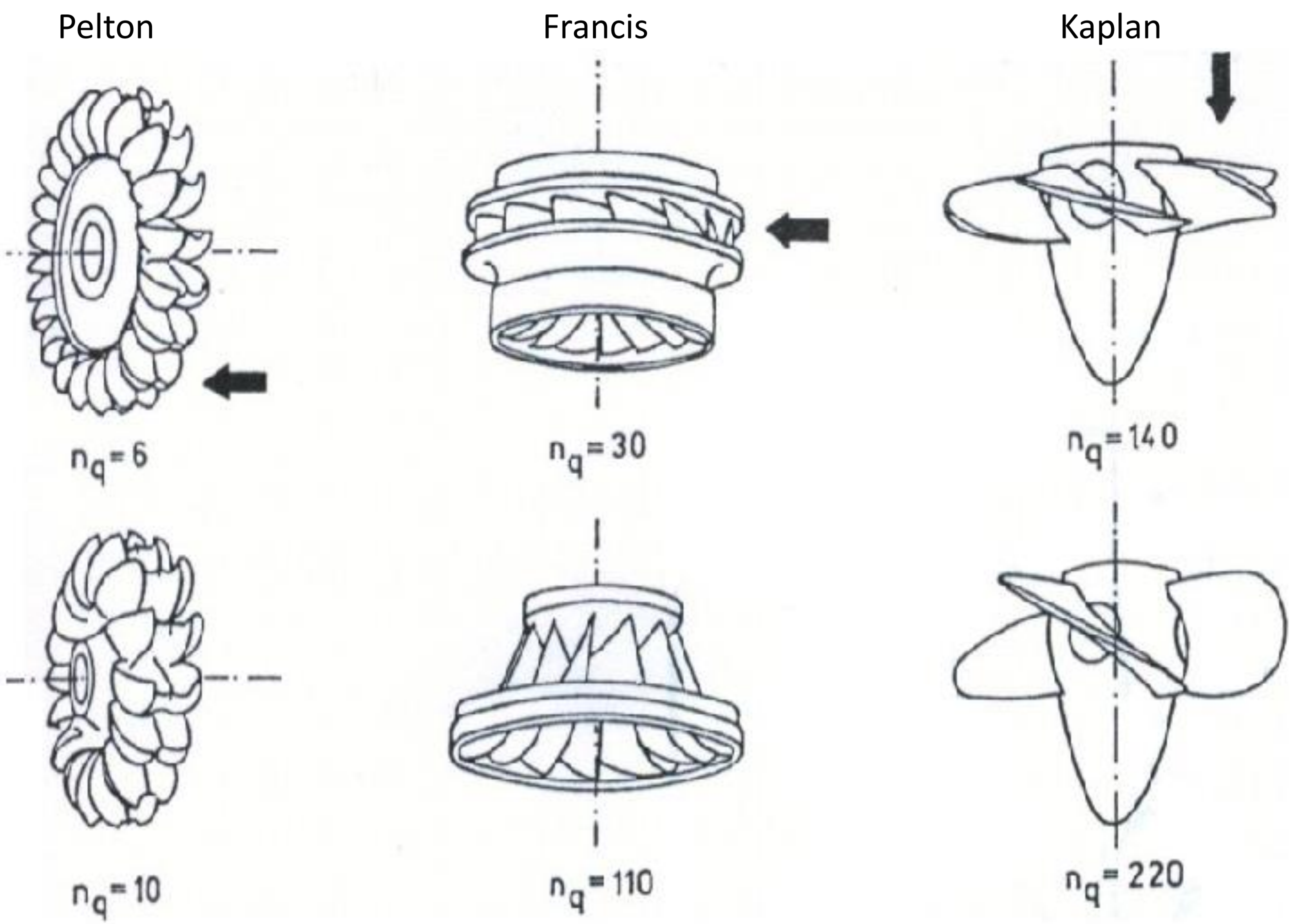
- The specific speed of a turbine is the speed of geometrically similar turbine (model) so that at the head of 1 m a turbine produces the power of 1 kW
- From geometrical similarity the specific speed can be formulated as

$$n_s = \frac{n}{H^{\frac{5}{4}}}\sqrt{P}$$

where n is turbine speed, P is the turbine power and H is the hydraulic head.

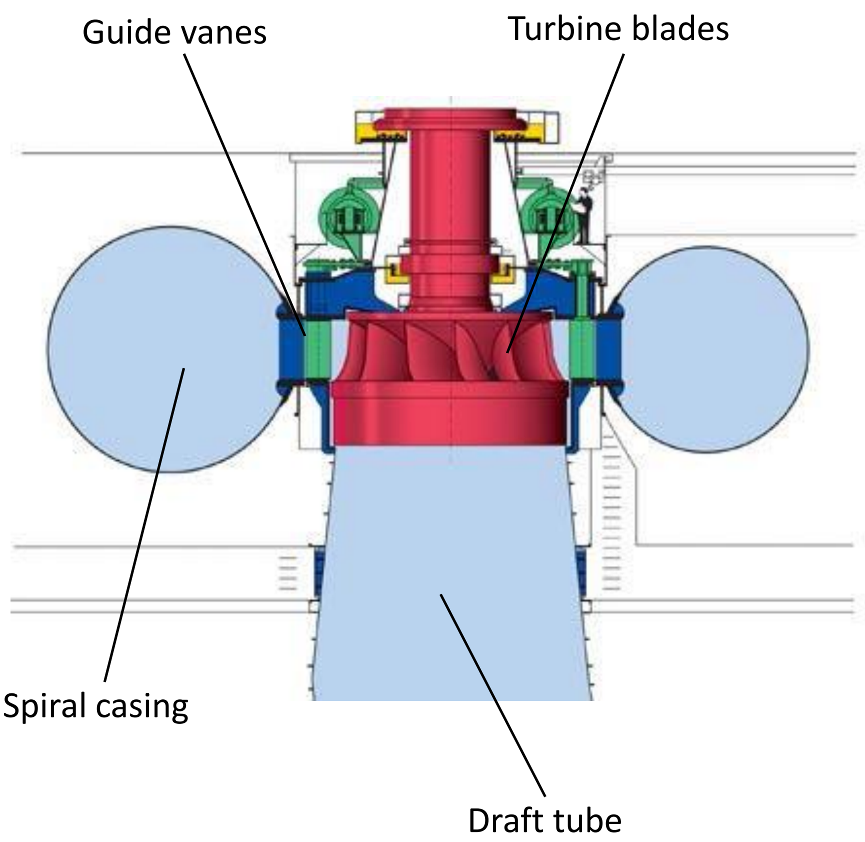
Specific speeds of turbines	
Type of turbine	Usual range of n_s (1/min)
Pelton	4 - 32
Banki	70 - 150
Francis	50 - 450
Kaplan	300 - 1000

Types of hydro turbine



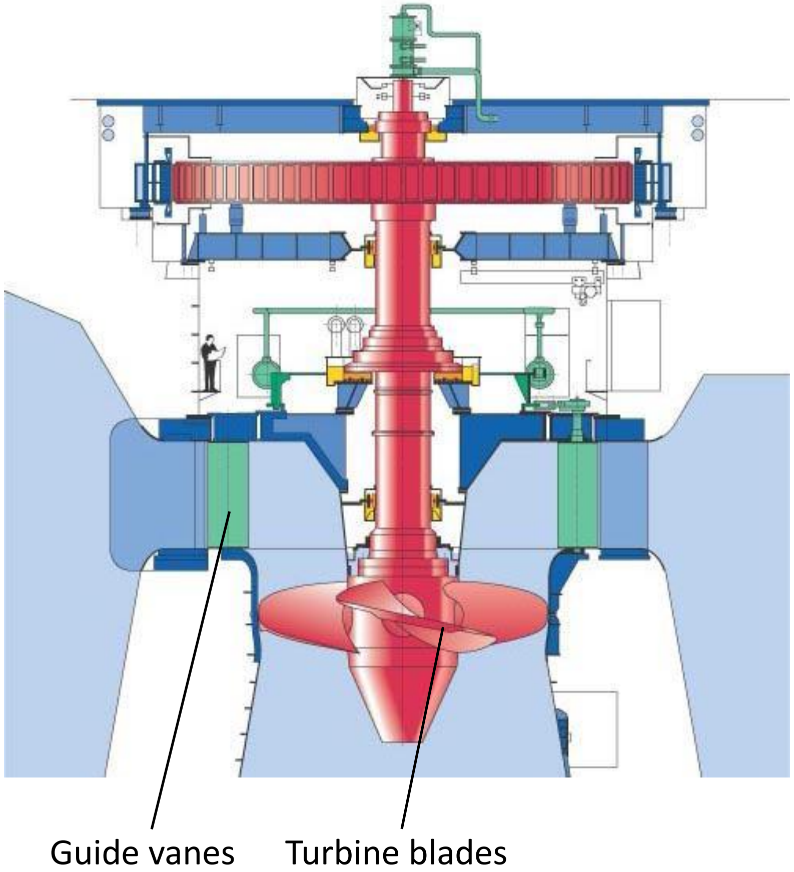
Francis turbine

- Reaction turbine
- The water is directed to blades by guide vanes
- The water output is draft tube with conical shape to create low pressure (vacuum)



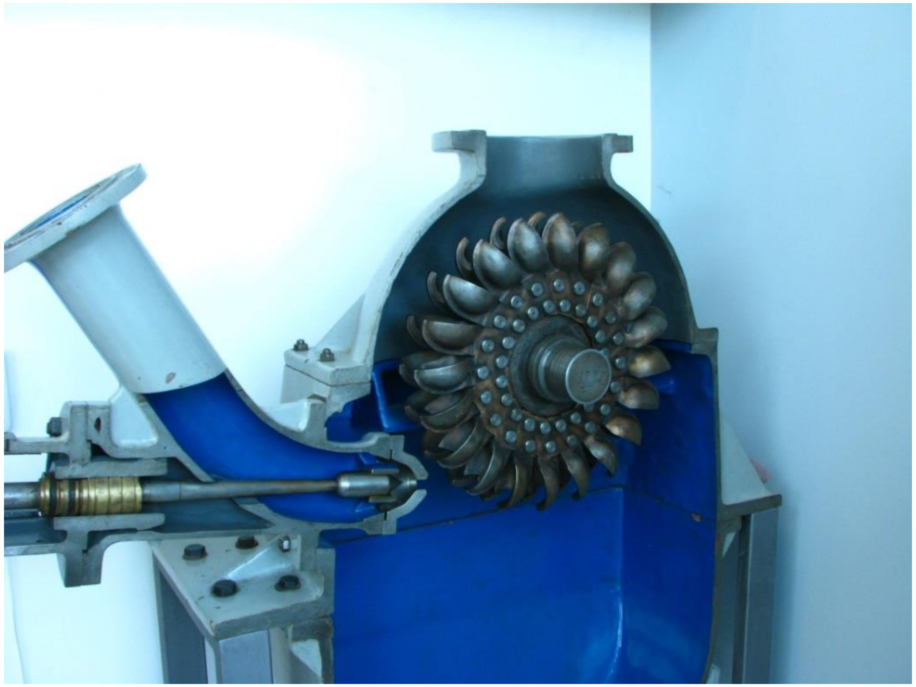
Kaplan turbine

- Axial reaction turbine with lower number of blades
- The power can be controlled by rotation of blades and guide vanes
- Usually is used for large water flows and small hydraulic heads

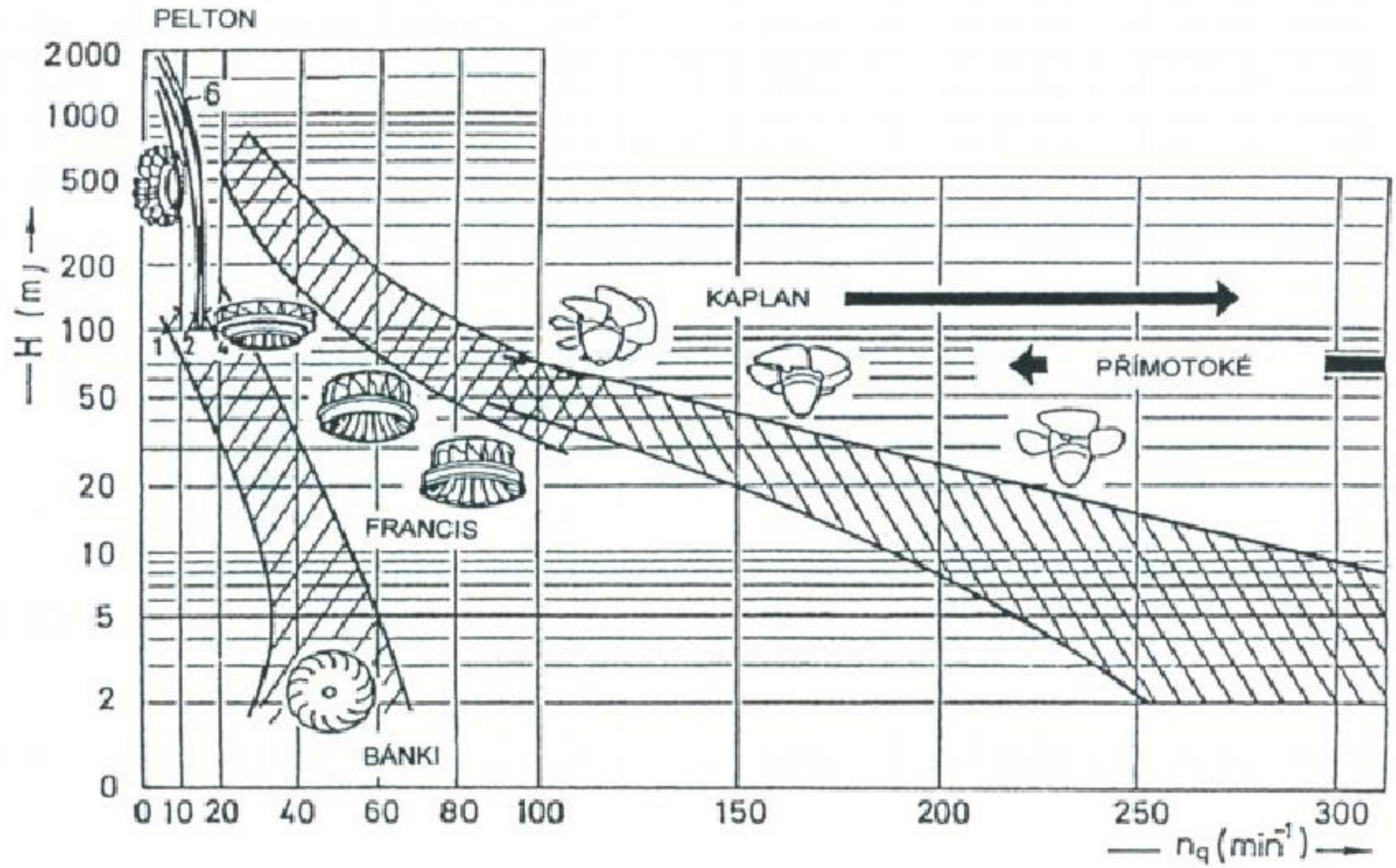


Pelton turbine

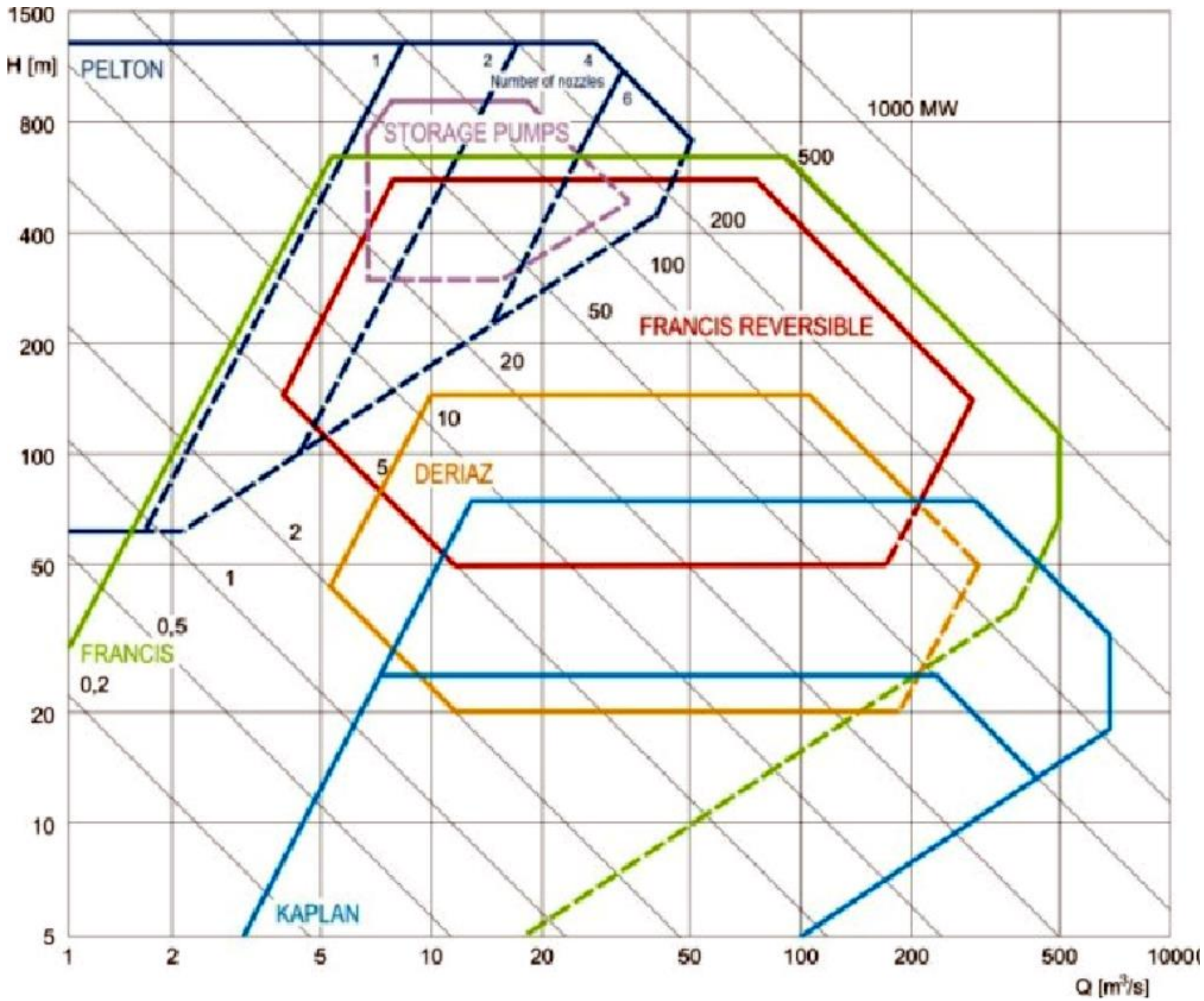
- Impulse turbine, the water from nozzel tangentially enters turbine blades
- The turbine power can be controlled by change of nozzles cross section,
- The fast drop of power can be realized by deflection of water beam.



Areas of use of hydro turbines

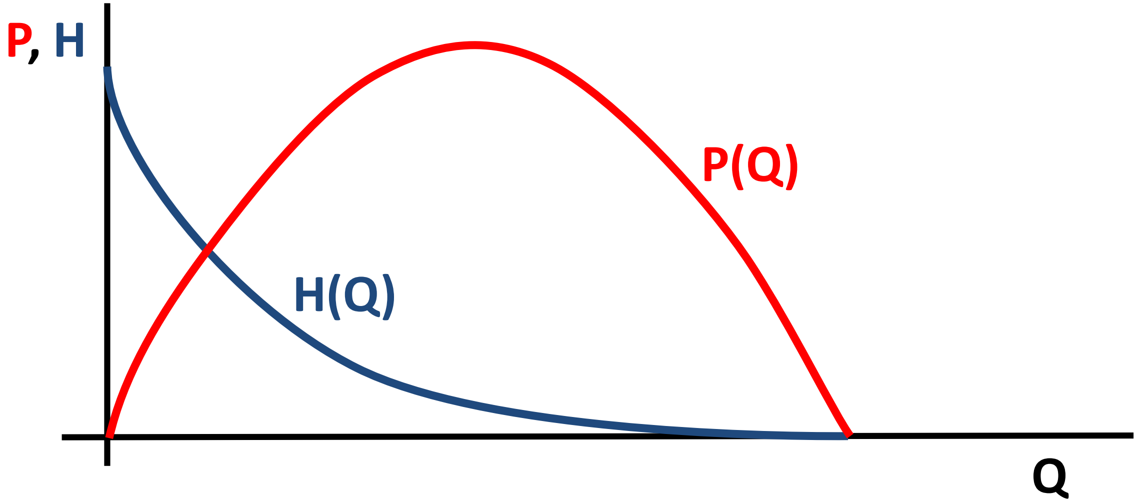


Areas of use of hydro turbines Q/H diagram



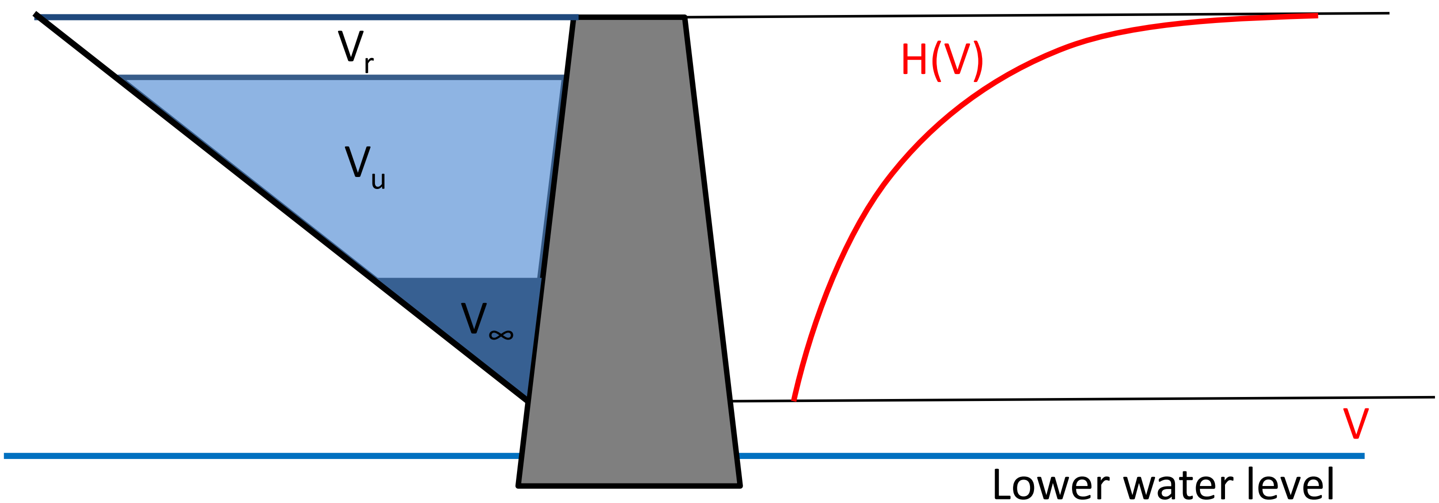
Run-of-River hydro power plants

- Small or no water storage is provided
- Energy generation mainly for the base load
- For low heads the head depends on the water flow, for a big amount of water (high flows) the low level of water can be equalized with higher level
- The power is first increasing with water flow, then after the maximum is reached, the power starts to decline to zero value



Reservoir (Dam) hydro power plants

- Typically a large hydropower system, uses a dam to store river water in a reservoir (artificial or natural)
- Energy generation mainly for peak or intermediate load (ability of wide power control)
- Volume of resovoir has to assure energy accumulation for some time
- The volume of reservoir is splitted into three parts: V_{∞} volume of permanent retention, V_u useable volume and V_r protective volume



Pump-storage hydro power plants

- Three vertically arranged maschines: turbine-motor-pump or two vertically arranged maschines with reversal turbine (turbine/pump) –nowadays more frequent configuration
- Manly for the load diagram balancing, fast synchronization to grid and increasing of power, efficiency 60-70%