Kaplan turbine
The diagram illustrates the power output (P) in megawatts (MW) as a function of discharge (Q, measured in cubic meters per second [m³/sec]) and head (H, measured in meters [m]). The equation for power output is given as:

\[ P = \frac{HQ}{102} \cdot 0.9 \text{ MW} \]

The diagram shows curves for different types of turbine designs, including Pelton, Francis, and Kaplan turbines, each with distinct performance characteristics at various discharge rates and heads.
Jebba, Nigeria

- $Q = 376 \, m^3/s$
- $H = 27.6 \, m$
- $P = 96 \, MW$

$D_0 = 8.5 \, m$
$D_e = 7.1 \, m$
$D_i = 3.1 \, m$
$B_0 = 2.8 \, m$
Machicura, CHILE

*Q = 144 m³/s
*H = 36,7 m
*P = 48 MW

$D_0 = 7,2 \text{ m}$
$D_c = 4,2 \text{ m}$
$D_i = 1,9 \text{ m}$
$B_0 = 1,3 \text{ m}$
Hydraulic efficiency

Hydraulic efficiency $\eta_h$ vs. Flow rate $Q$ for different Runner blade angles $\phi = \text{constant}$.
Hill chart
\[ \eta_h = \frac{u_1 \cdot c_{u1} - u_2 \cdot c_{u2}}{g \cdot H} \]
Pressure distribution and torque
\[ F_L = C_L \frac{1}{2} \rho V^2 \cdot A \]

\[ F_D = C_D \frac{1}{2} \rho V^2 \cdot A \]
Blade profile data

\[ \frac{C_D}{C_L} \]

\[ \delta \]

Average relative velocity

Angle of attack

Gottingen 480
Pressure distribution and torque

The pressure at the outlet is lower for a cascade than for a single profile. The cavitation performance will therefore be reduced in a cascade.
Radial distribution of the blade profile

The ratio $t/l$ influences the lift coefficient in a cascade. The cord length for a blade will therefore increase when the radius becomes increase.
Radial distribution of the blade profile
Flow in the axial plane

The figure shows blades with two different design of the blade in radial direction. This is because it will influence the secondary flow in the radial direction.
Main dimension of a Kaplan turbine
Diameter of the runner

\[ ^{0}\Omega = \omega \cdot \sqrt{Q_n} \]

\[ Q_n = \frac{\Pi \cdot (D^2 - d^2)}{4} \cdot c_{1m} \]

\[ D = \sqrt{\frac{Q_n \cdot 4}{\Pi \cdot c_{1m}}} \]
Height of the guide vanes and runner diameter

\[ n_s = n \cdot \frac{\sqrt{P}}{H_n^{5/4}} \]
Gap between hub and ring and the runner blades

- Gap between the blade and ring
- Gap between the blade and hub

![Graph showing efficiency vs. gap](image)

\[ s = 10^{-1} d \]

\[ \text{Efficiency} \]

\[ \text{Gap} \ x = 1000s/D \]
The figure shows different runaway speed at different runner blade openings. The runaway speed is dependent of the cavitation as shown in the figure

\[ \sigma = \frac{10 - H_S}{H} \]
Hill chart

\[ \frac{Q}{Q^*} \]

\[ \frac{\varphi}{\varphi^*} = \text{Konst.} \]

\[ \eta \]

\[ \eta = 0 \]

\[ \frac{\omega}{\omega^*} \]
Example

- Find the dimensions $D$, $d$ and $B_0$

- Given data:
  - $P = 16.8$ MW
  - $H = 16$ m
  - $Q_n = 120$ m$^3$/s
  - $n = 125$ rpm
Speed number:

\[ \sqrt{2 \cdot g \cdot H} = \sqrt{2 \cdot 9,82 \cdot 16} = 17,7 \text{ m/s} \]

\[ \omega = \frac{n \cdot 2 \cdot \Pi}{60} = \frac{125 \cdot 2 \cdot \Pi}{60} = 13,1 \text{ rad/s} \]

\[ \frac{\omega}{\sqrt{2 \cdot g \cdot H}} = \frac{13,1 \text{ rad/s}}{17,7 \text{ m/s}} = 0,74 \text{ m}^{-1} \]

\[ Q_n = \frac{Q}{\sqrt{2 \cdot g \cdot H}} = \frac{120 \text{ m}^3}{17,7 \text{ m/s}} = 6,78 \text{ m}^2 \]

\[ \text{o} \Omega = \omega \cdot \sqrt{Q_n} = 0,74 \cdot \sqrt{6,78} = 1,93 \]
Diameter, $D$:

$$c_{1m} = 0,12 + 0,18 \cdot ^{o}\Omega = 0,467$$

$$D = \sqrt{\frac{Q}{\Pi \cdot c_{1m}}} = \sqrt{\frac{6,78 \cdot 4}{\Pi \cdot 0,467}} = 4,3 \, m$$
Diameter, d:

\[ n_s = n \cdot \frac{\sqrt{P}}{H_n^{5/4}} = 125 \text{rpm} \cdot \frac{\sqrt{22826 \, Hp}}{16m^{5/4}} = 590 \]

\[ \frac{d}{D} = 0.45 \quad \Rightarrow \quad d = D \cdot 0.45 = 1.9 \, \text{m} \]
Height, B:

\[ \frac{B_o}{D} = 0.41 \quad \Rightarrow \quad B_o = D \cdot 0.41 = 1.76 \text{ m} \]
Number of vanes, z:

\[ \frac{1}{t} = 0.95 \]

\[ z = 5 \]