Kaplan Bulbs

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Background and History

- A Kaplan turbine is defined by having automatically adjustable propeller blades with automatically adjustable wicket gates.
  - This allows for the turbine to achieve high efficiencies over a wide range of flow and water levels
- The Kaplan turbine was developed by professor Viktor Kaplan in 1913 and is an evolution of the Francis turbine developed in 1858
Overview

- Kaplan turbines can operate with heads as low as 1.5 meters and as high as 50 meters
- Optimal range is 1.5 meters to 20 meters
- Rotor sizes range from 800 mm to 10 meters in diameter
- Kaplan turbines are most suited for high flow and low head situations
- The image to the left is part of a kaplan bulb and the generator
Overview

Kaplan bulb turbines have 3-, 4-, 5-, or 6-blade runners

Some Kaplan bulb turbines are producing outputs of up to 75,000 kW

The turbine speed can reach 500 rpm

The turbines can spin slow enough to allow fish passage
Mechanisms

The inlet is a scroll-shaped tube that directs water tangentially through the wicket gate. The water spirals on to the runner, resulting in the propeller spinning.

The outlet is a draft tube that helps decelerate the water and recover kinetic energy.

Kaplan turbine efficiencies are typically over 90%
Mechanisms

Kaplan bulb turbines are used in the occasion of a high flow and low head.

Due to the ability to adjust the angle of the wicket gates and the angle of the runners, kaplan bulbs have a high efficiency across a large range of percent full loads.
Kaplan turbines follow the Euler’s Turbine Equation.

Where torque equals

\[ T = (-r_1 V_1 \cos \alpha_1) \rho (\text{\(-Q\)}) + (-r_2 V_2 \cos \alpha_2) \rho (\text{\(+Q\)}) \]

and Power equals

\[ P = \rho Q \omega (r_1 V_1 \cos \alpha_1 - r_2 V_2 \cos \alpha_2) \]
Specific Uses

- Primarily used in the low head range with large volumes of water
- Used in varying water flows
- Mainly used to produce electrical power
- Dams
- Tidal power stations
Examples

- Budarhals Hydroelectric Plant
  - Construction began in November 2010, start-up took place in March 2014
  - Located in the lower highlands of southern Iceland on the rivers Tungnaa and Kaldakvisl
  - Power output is 95 MW in two Kaplan turbines with a vertical axis
  - Electricity generation is up to 585 GWh per year
Examples

- Hydroelectric Power Station Jasyretâ-Apipé
  - Built over the waterfalls of Jasyretâ-Apipé in the Paraná River
  - Dam is 808 metres (2,651 ft) long
  - Maximum power output of 3,100 megawatts (4,200,000 hp)
  - Record maximum annual power output of 20.091 TWh (72.33 PJ) achieved in year 2012
  - Maximum water flow rate of 55,000 cubic meters per second
Examples

- Peixe Angical
  - Located on the Tocantins River, and connected to the North-South Interconnexion for power supply within Brazil
  - Three Kaplan turbine generators
  - Largest of their kind
  - Total installed power of 452 MW
  - Flows of 880 cubic meters per second
  - Generates enough electricity to provide for four million people
Pros

- Automatically adjusting propeller blades and wicket gates to achieve efficiency over a wide range of flows and water levels
- Allows efficient power production in low-head applications that is not possible with Francis turbines
- Efficiency may reach up to 95%
- Long life cycle
- Varies in size
Cons

- Material erosion and vibration from cavitation is highly likely due to low pressure
- Large flow rate required
- Expensive to design, manufacture, and install
References

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Bulb Units: The Complete Solution for Low Heads

Bulb/pit/S-turbines and generators

Budarhals Hydroelectric Plant
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Peixe Angical, Brazil

Yacyretá Dam
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