



# Hydraulic turbines - Generalities

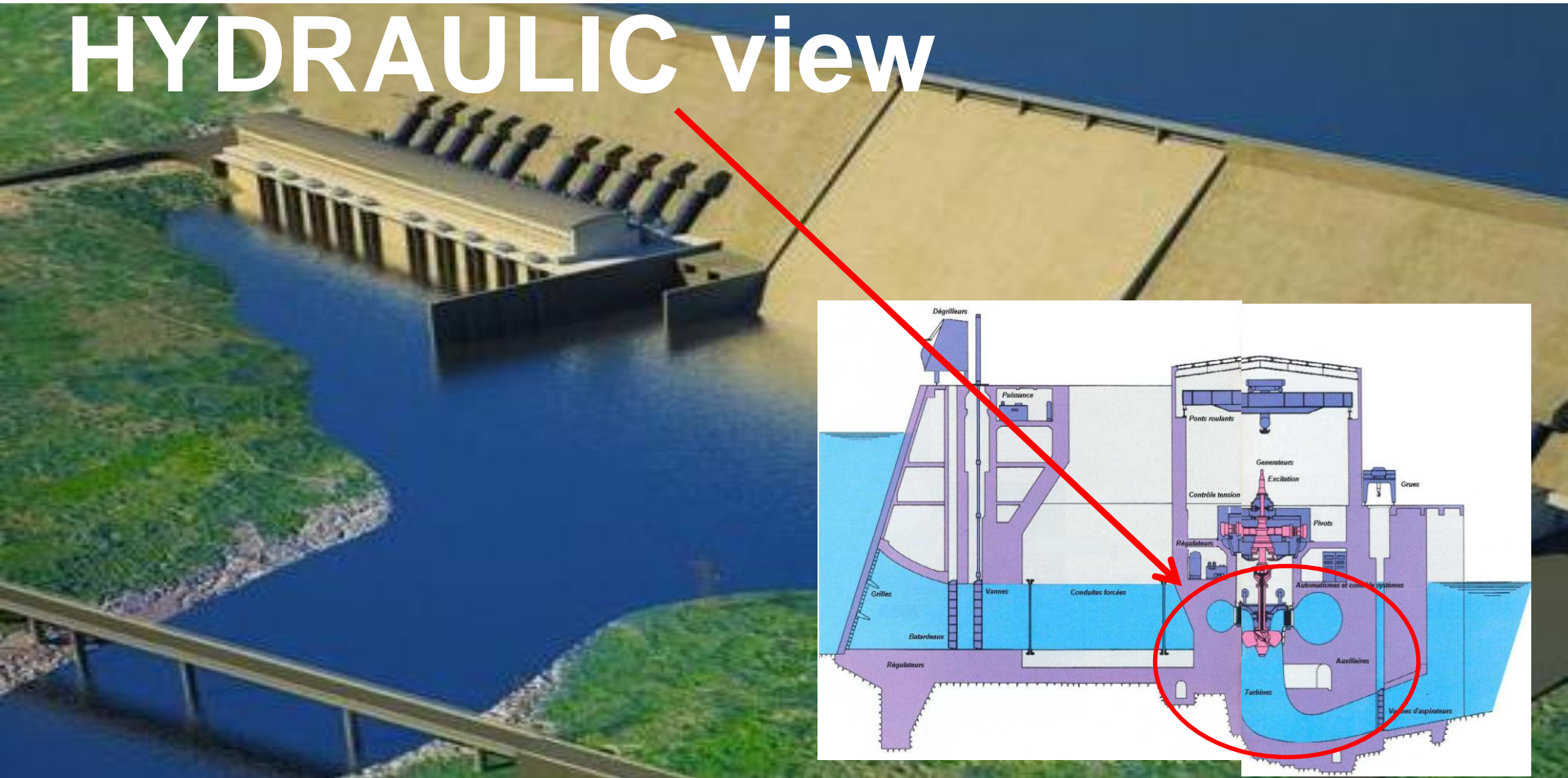
January 20, 2015

**Imagination at work**

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# Hydraulic turbines - Generalities

## HYDRAULIC view



# Hydraulic turbines - Generalities

## Agenda

- Introduction
- Reaction turbines
- Impulse turbines: Pelton



# Introduction

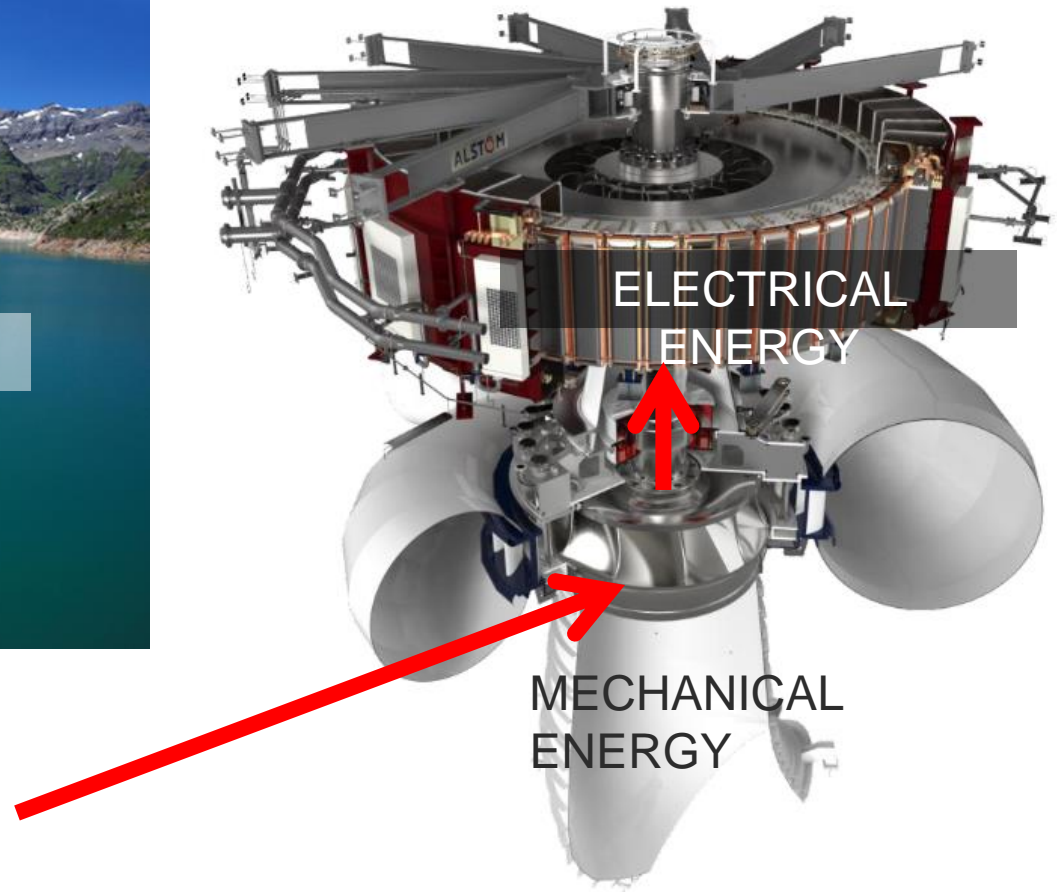


# Introduction

## Why hydraulic turbines?



PRESSURE and KINETIC ENERGY

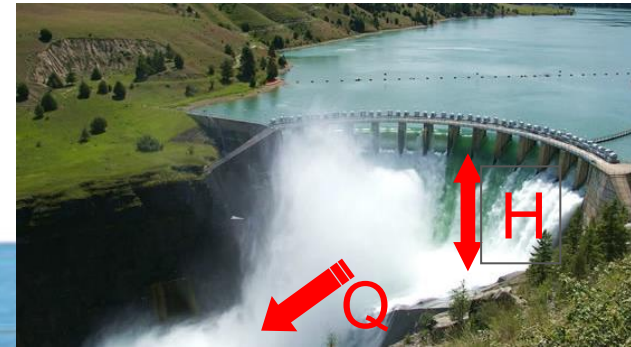
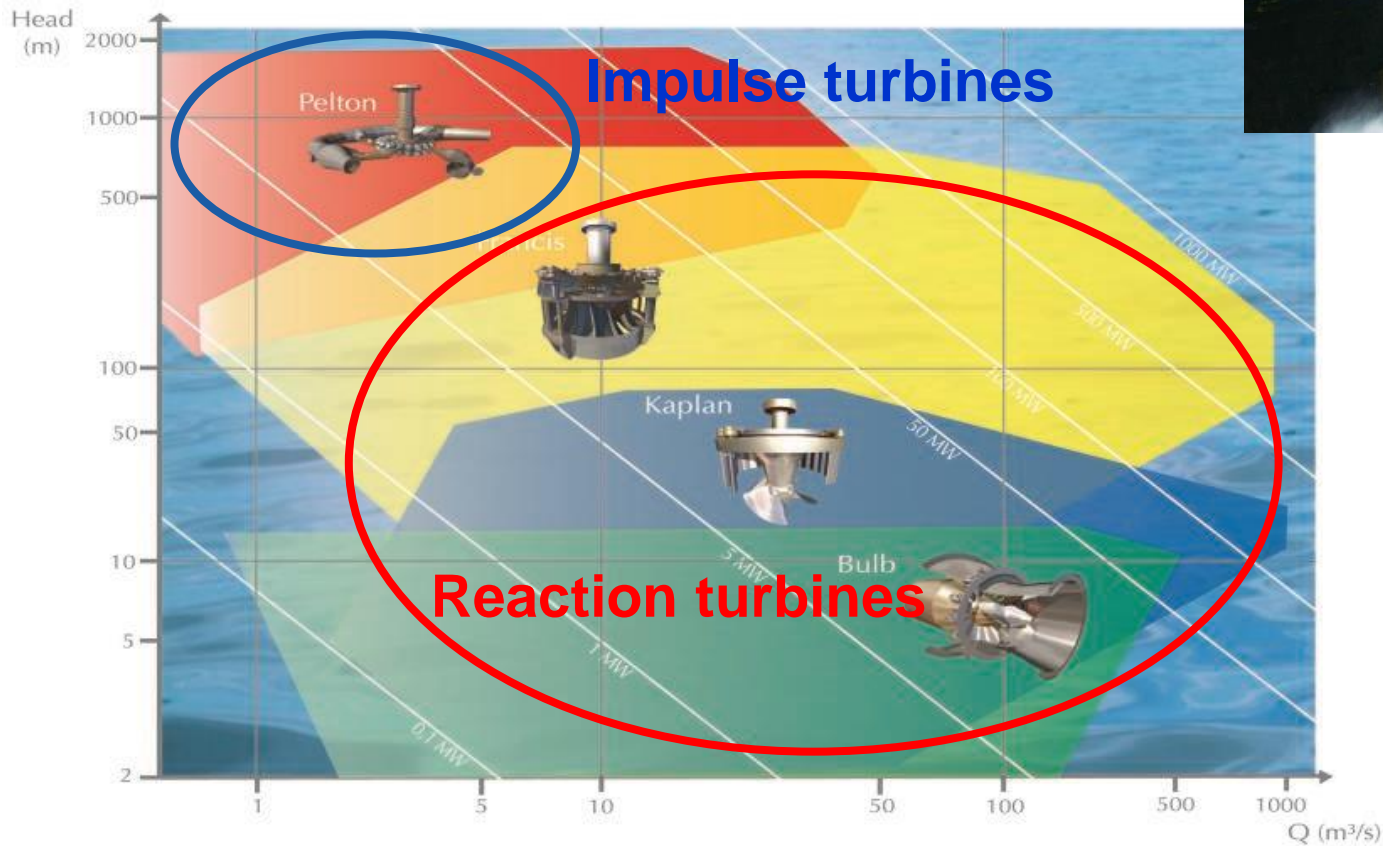




# Introduction

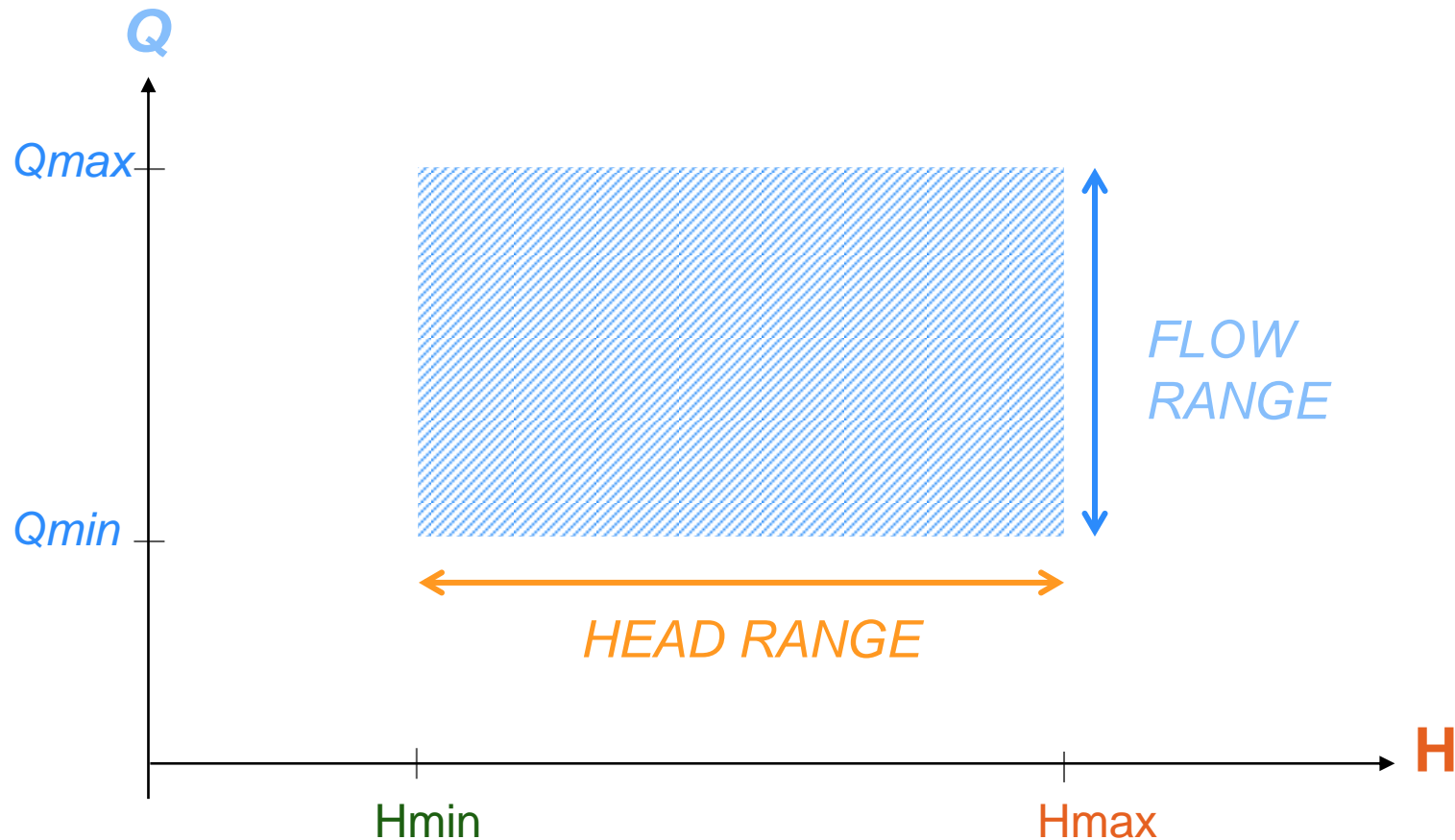
Potential water flow «  $Q$  »

Potential head «  $H$  »



# Introduction

## Operating range



# Introduction

## Efficiency hillchart

Theoretically:

$$P = \rho \cdot g \cdot Q \cdot H$$

Practically:

$$P = \eta \cdot \rho \cdot g \cdot Q \cdot H$$

" $\eta$ ": efficiency of hydraulic turbine

Hydro power  $\rightarrow$  Water falls/flows

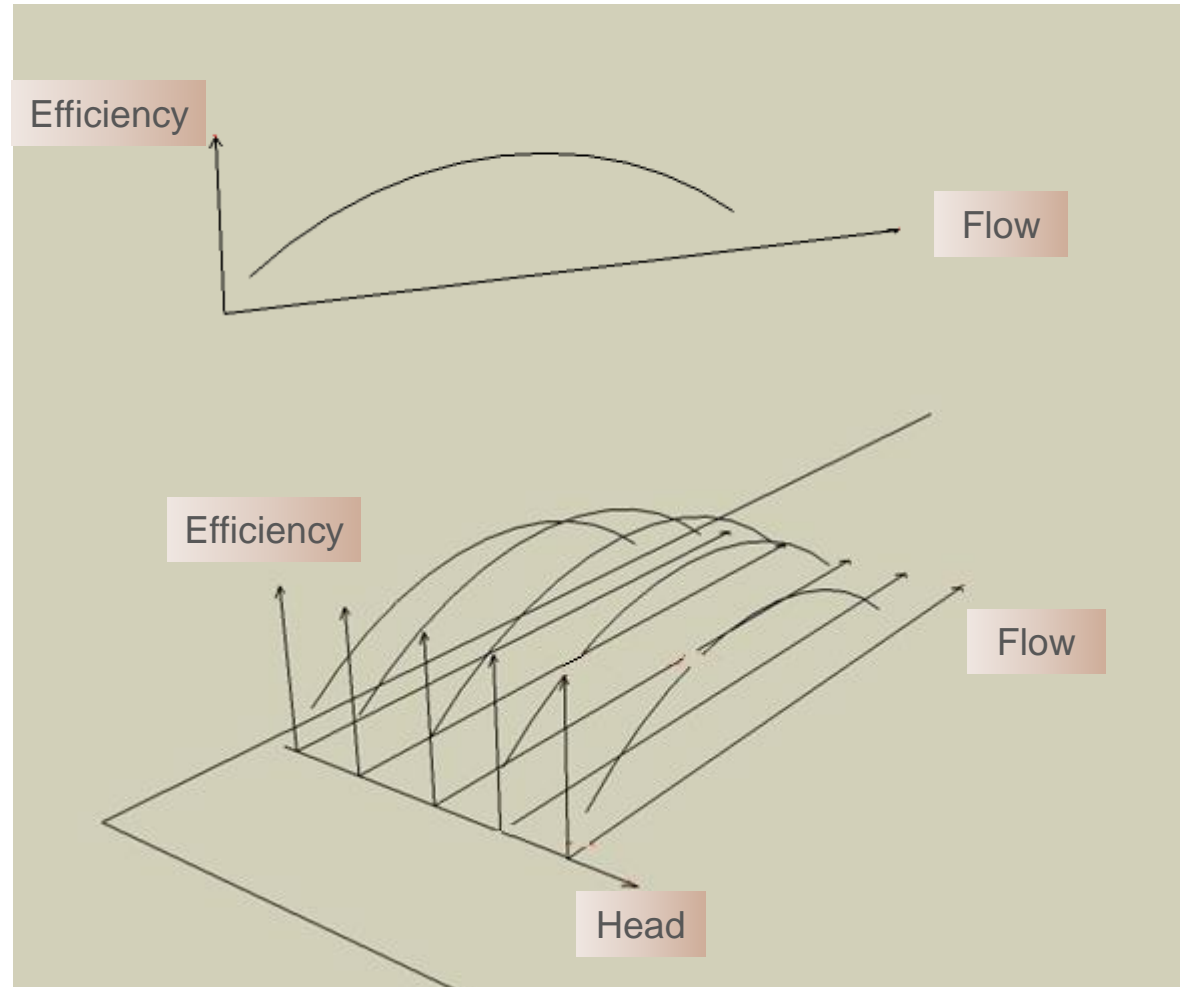
$$P_{hydro} = \rho \cdot g \cdot Q_v \cdot H [W]$$

Mechanical energy  $\rightarrow$  Turbine

$$P_{meca} = T \cdot \omega [W]$$

Electrical energy  $\rightarrow$  Generator

$$P_{elec} = U \cdot I \cdot \sqrt{3} \cdot \cos \varphi [W]$$



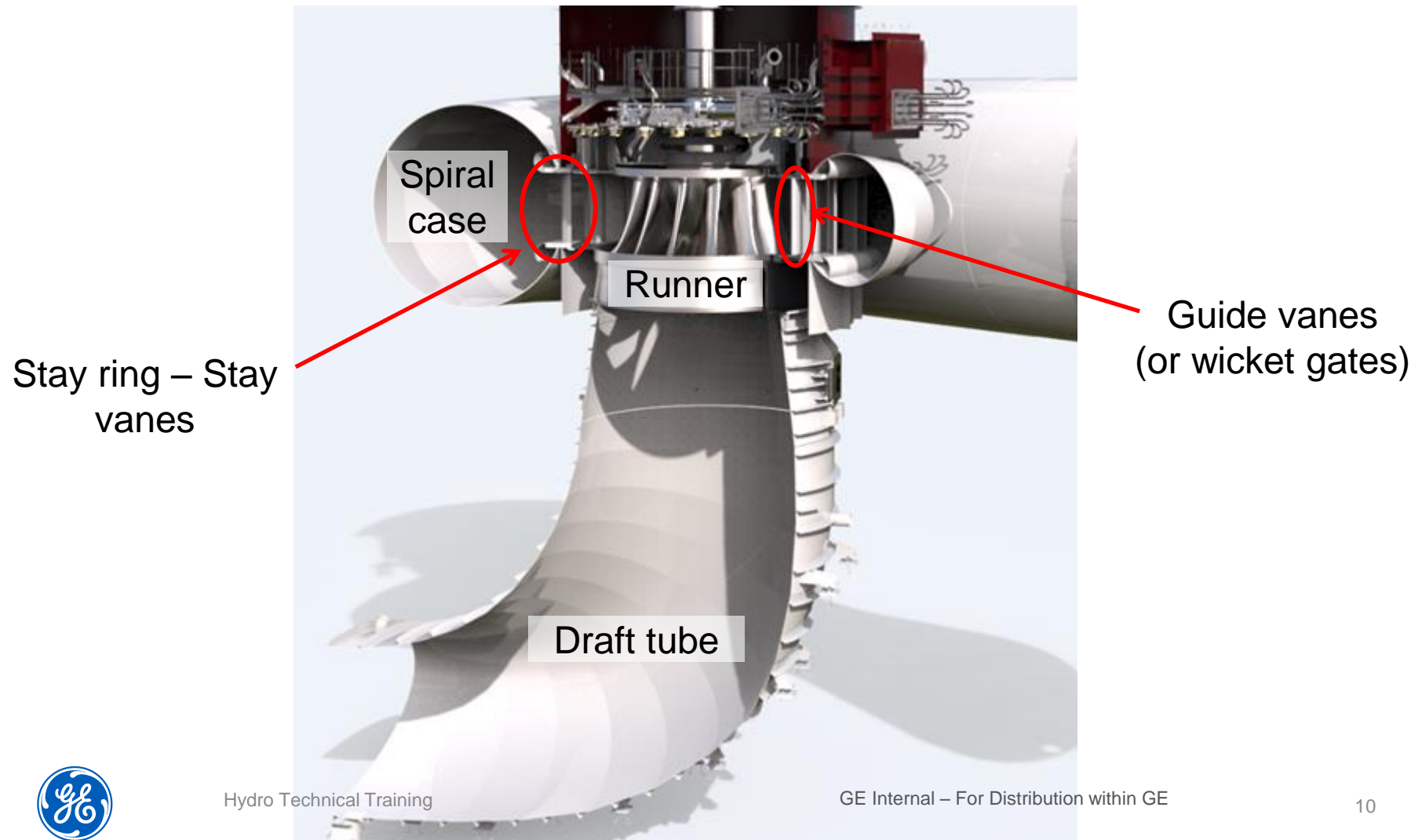


# Reaction Turbines



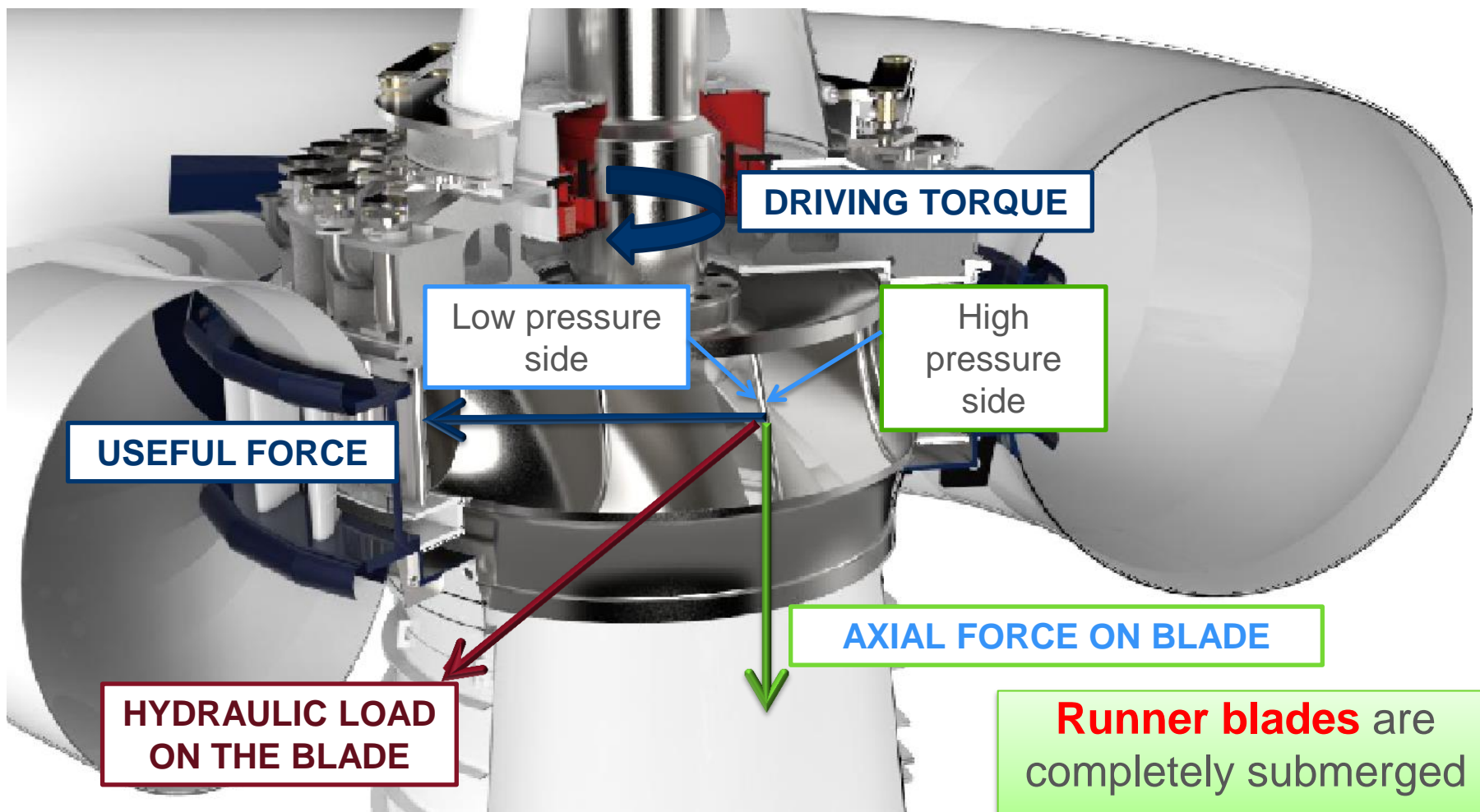
# Reaction Turbines

## Main hydraulic components



# Reaction Turbines

## Working principle



# Reaction Turbines

## Additional functionalities

### Problem to be solved

### *Possible solution*

Flow or head variation



*Variable blades or  
variable speed*

Need of storage



*Pumping*

Distribution network  
special needs



*Synchronous  
condenser mode*

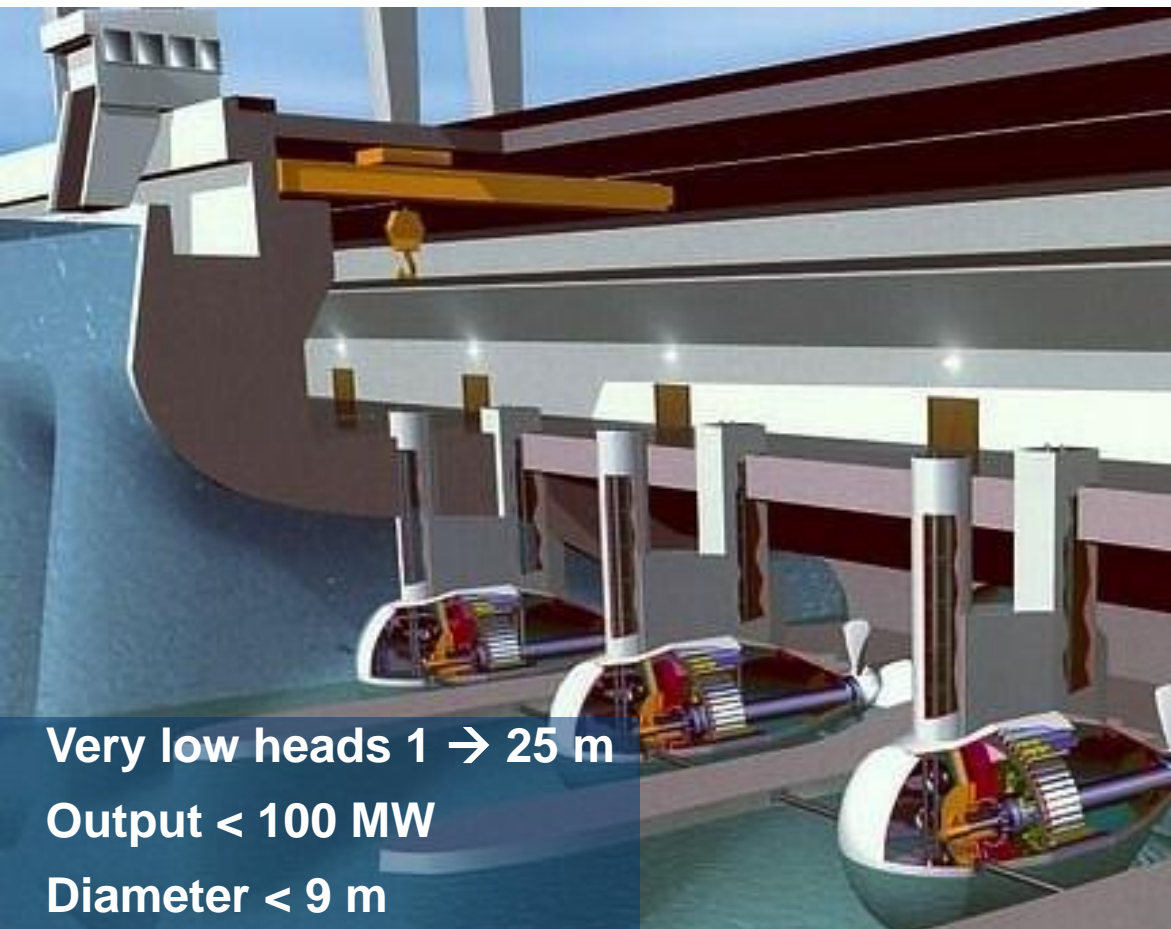
Preserving the  
environment



*« Fish-friendly » turbines*



# Reaction Turbines: BULB



**Very low heads 1 → 25 m**

**Output < 100 MW**

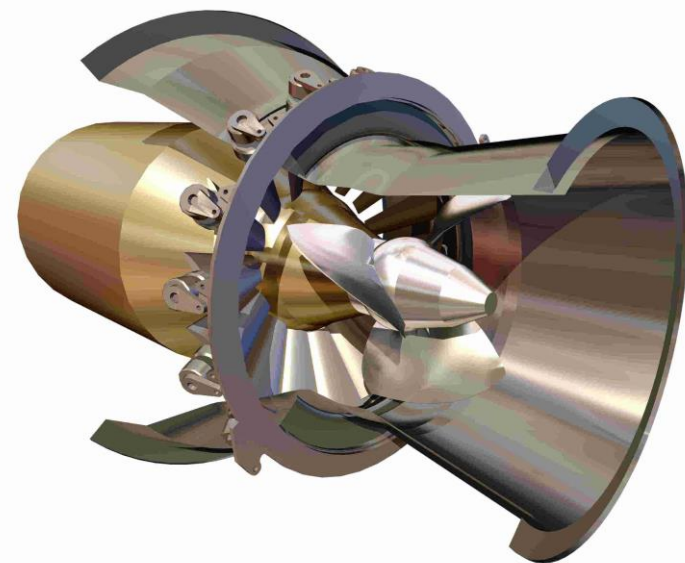
**Diameter < 9 m**

**Inside the dam**

**Horizontal axis**

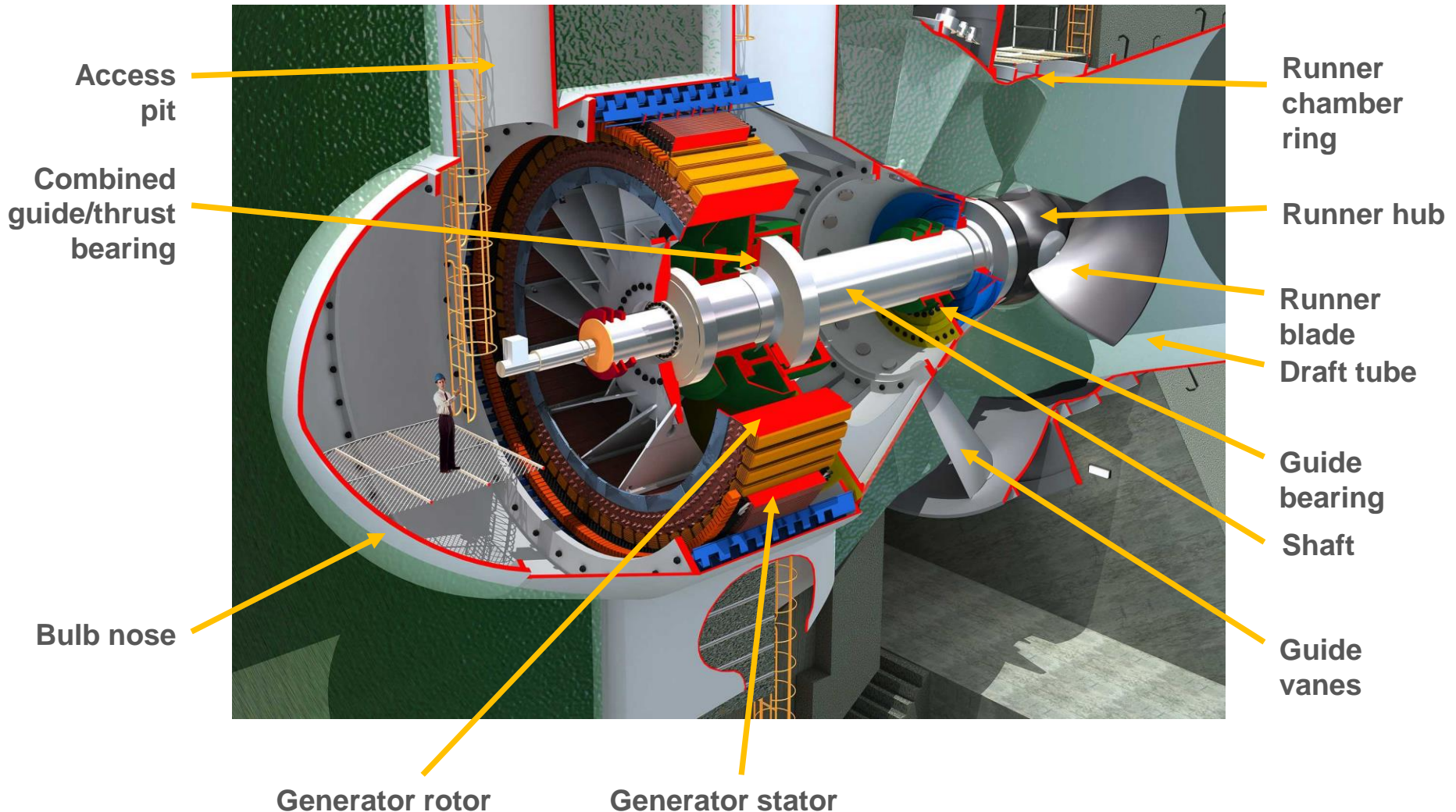
**Generator in watertight enclosure**

**Mostly Double regulated (guide vanes and blades)**



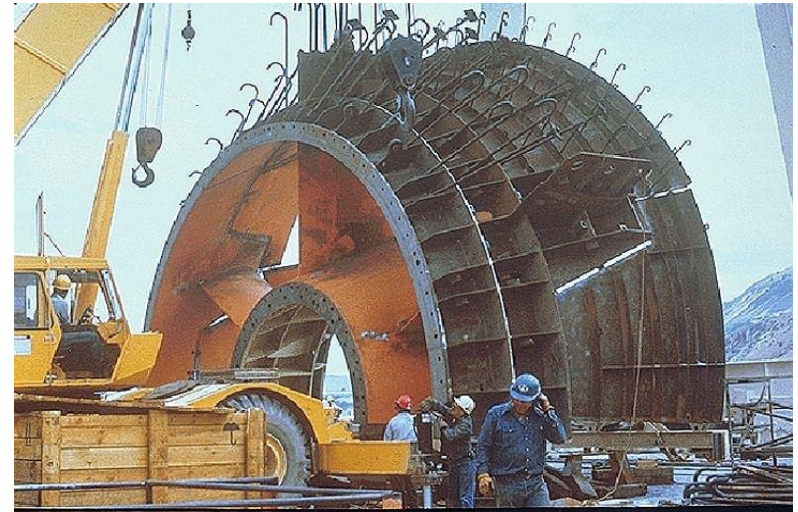


# Reaction Turbines: BULB





# Reaction Turbines: BULB



# Reaction Turbines: KAPLAN

**Vertical axis**

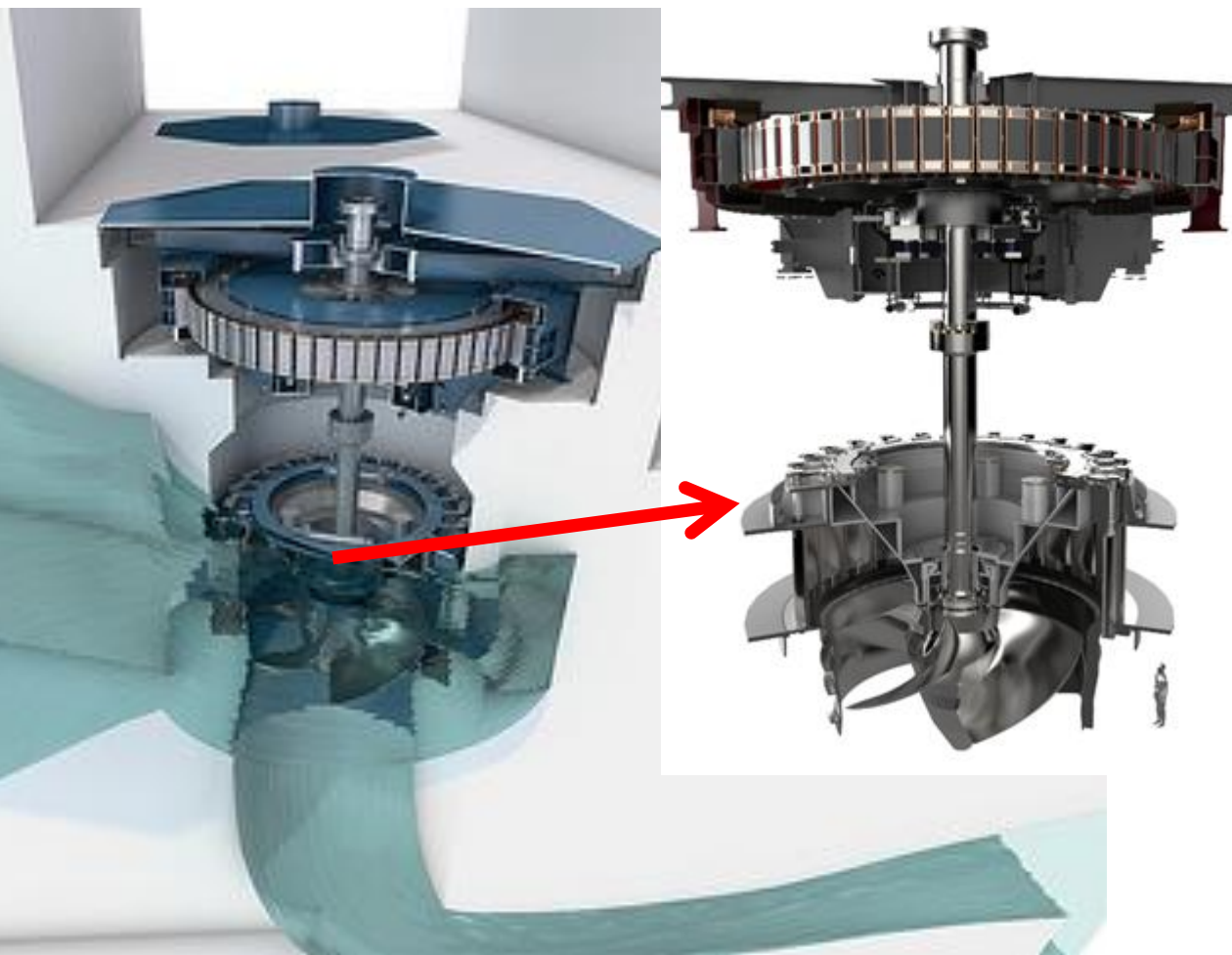
**Inside the dam**

**Double regulated  
(guide vanes and  
blades)**

**Low heads 5 → 55 m**

**Output < 220 MW**

**Diameter < 10 m**



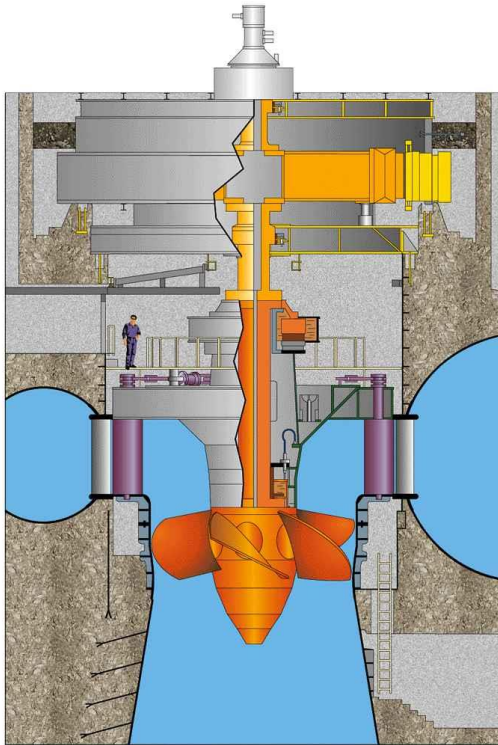


# Reaction Turbines: KAPLAN



# Reaction Turbines: KAPLAN

Typical cross section

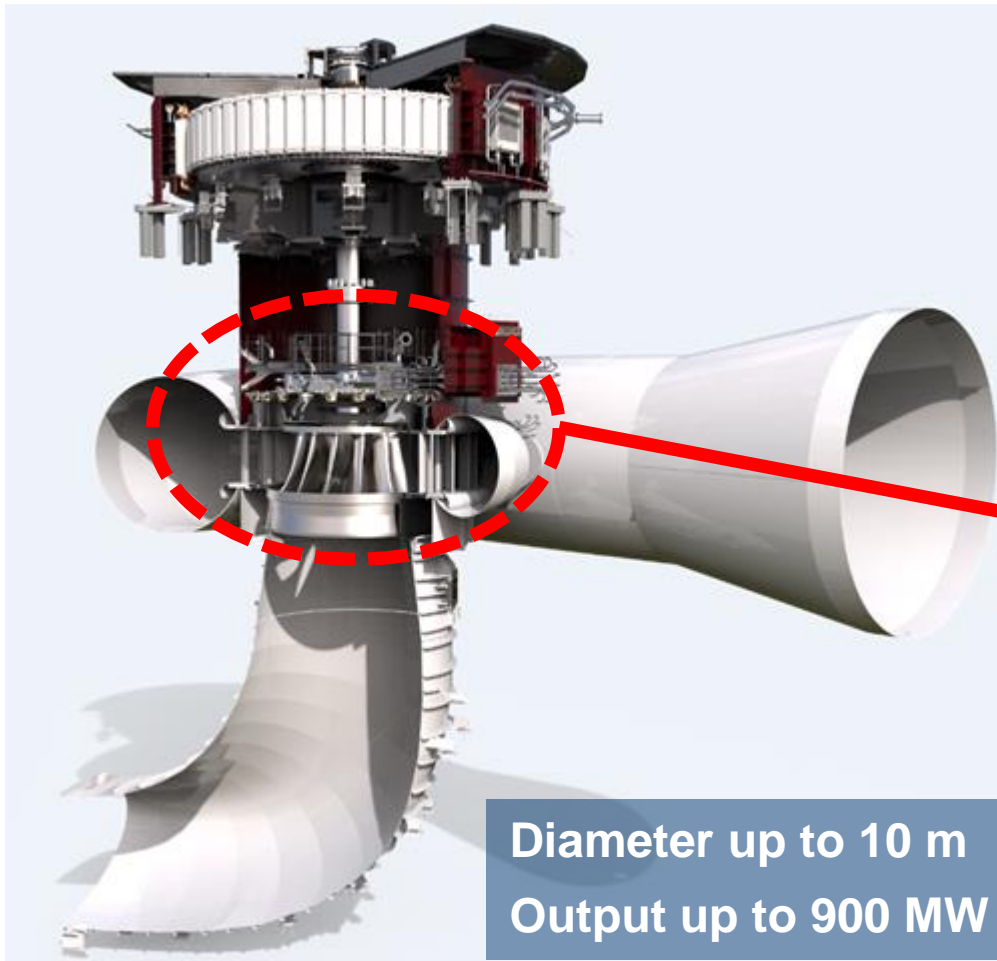


Pre-assembled rotor



Blade inspection

# Reaction Turbines: FRANCIS

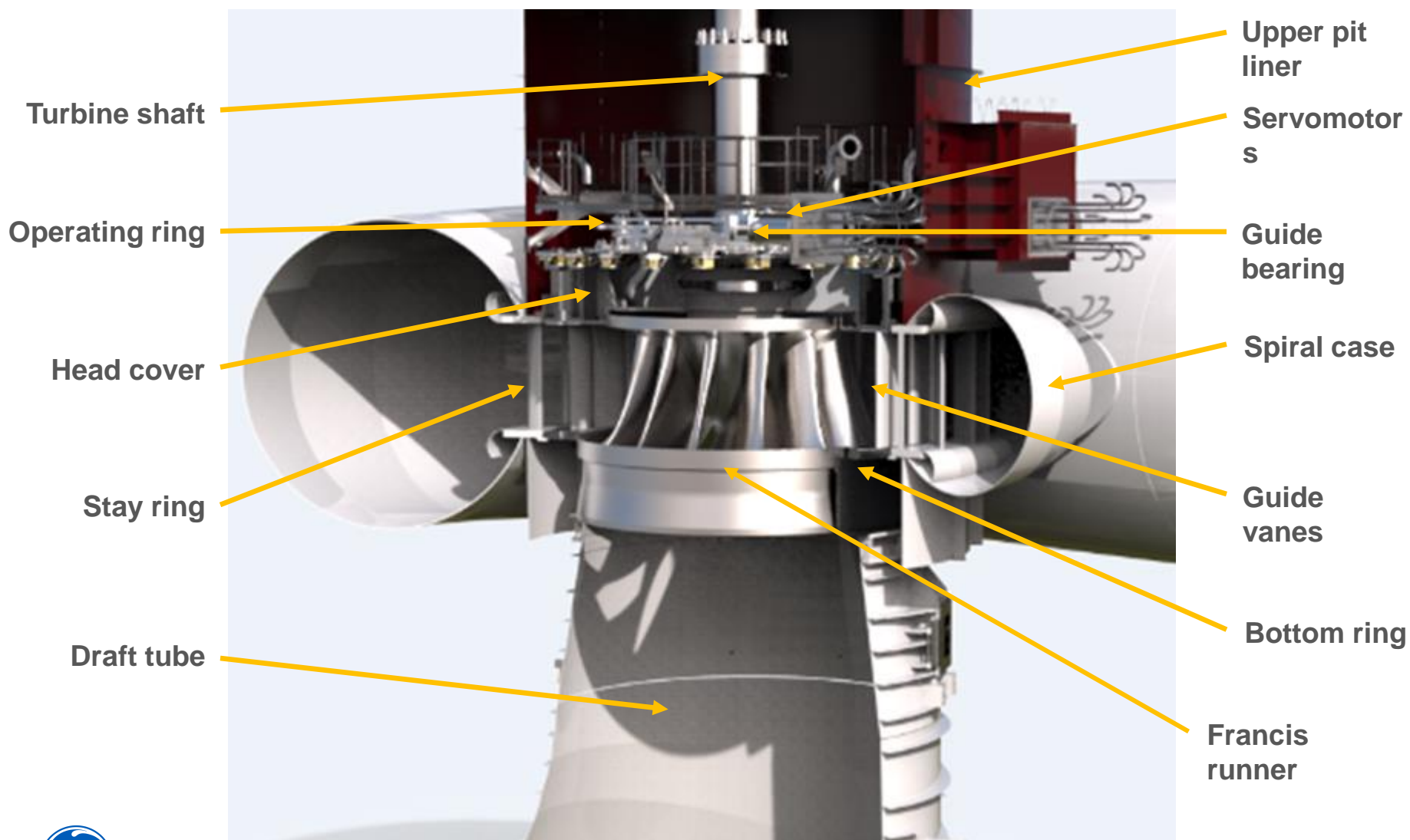


**Medium and high heads**  
**Horizontal or vertical axis**





# Reaction Turbines: FRANCIS





# Reaction Turbines: FRANCIS

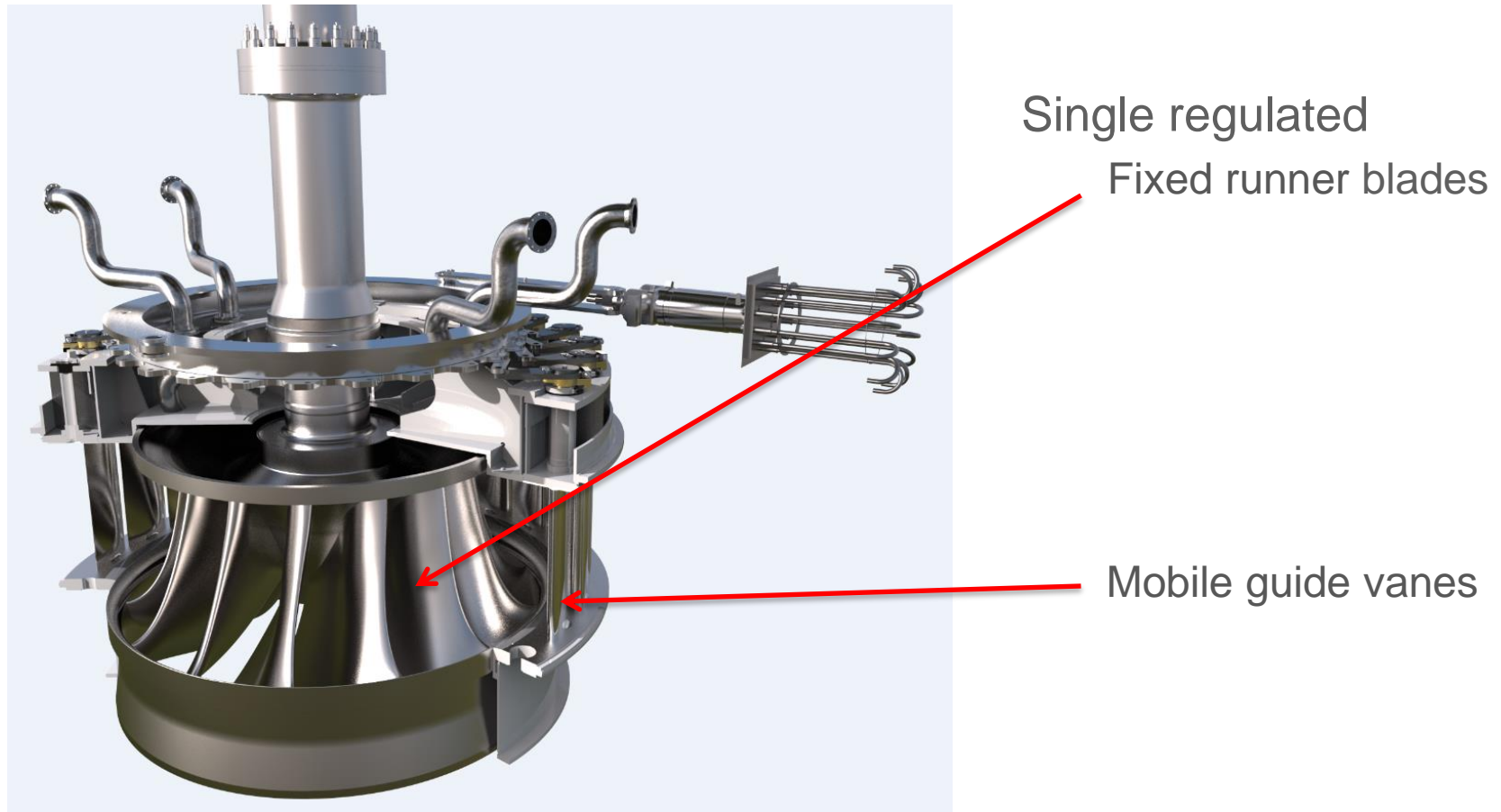
## Main characteristics

Most widely spread turbine, large variety of runner profiles



# Reaction Turbines: FRANCIS

## Main characteristics



# Reaction Turbines: PUMP TURBINES (PSP)



Medium to very high heads

Vertical axis

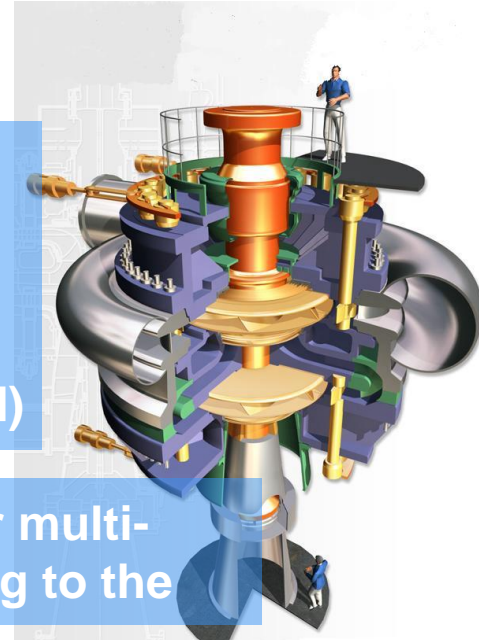
Fixed speed or variable (Varspeed)

Single stage or multi-stage according to the

Head from 100m to more than 1000m

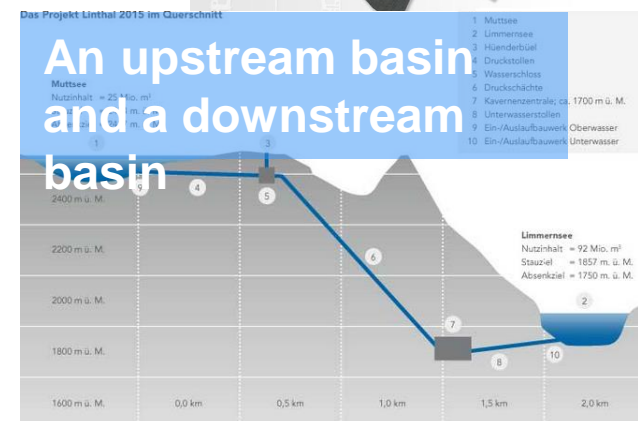
Output → 600 MW

Diameter < 1 to 7m according to the head



Das Projekt Linthal 2015 im Querschnitt

An upstream basin and a downstream basin



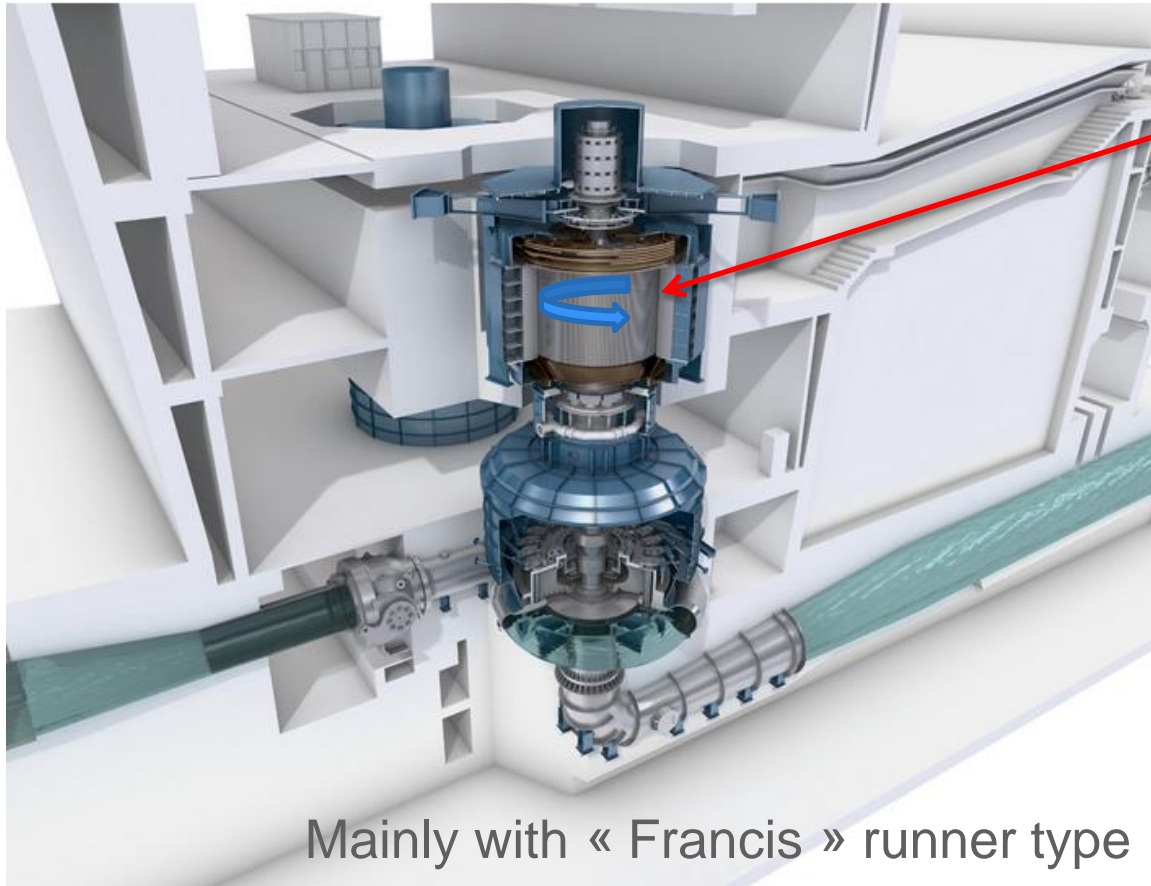
## Working principle



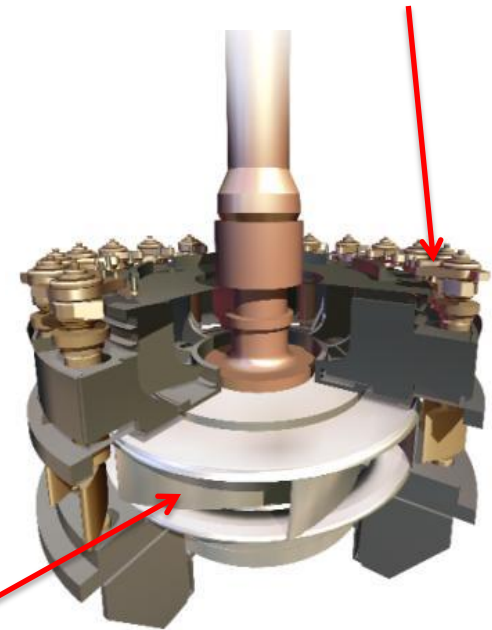


# Reaction Turbines: PUMP TURBINES (PSP)

## Main characteristics



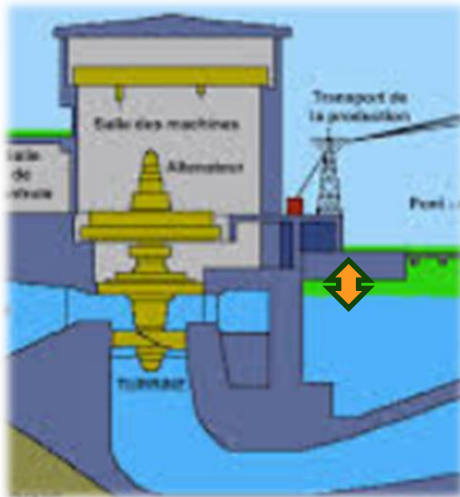
Single or double regulated  
Variable speed  
Mobile distributor



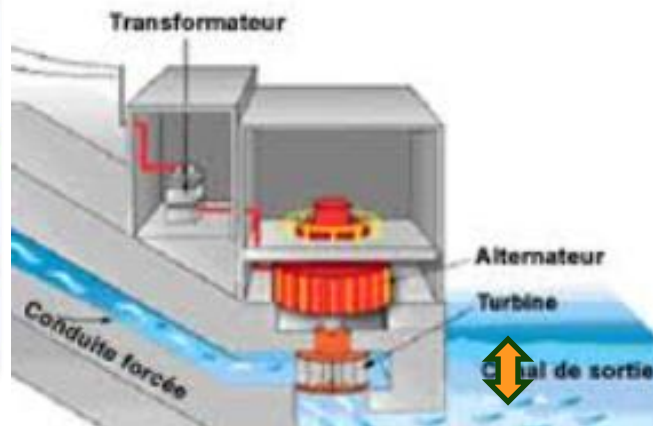
# Reaction Turbines: PUMP TURBINES (PSP)

## Main hydraulic characteristics

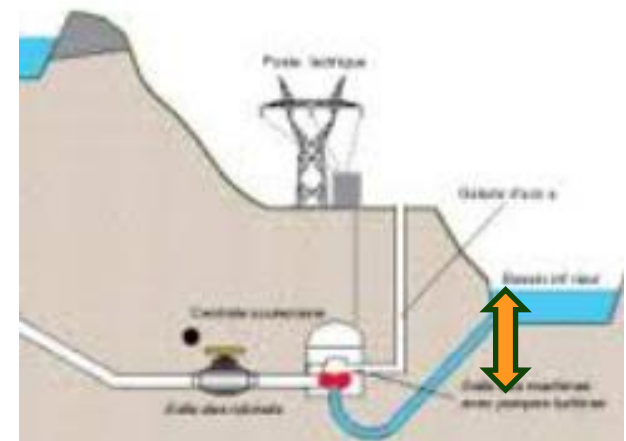
High difference between downstream level and runner axis level (Also called submergence) needed for the pump mode



KAPLAN



FRANCIS



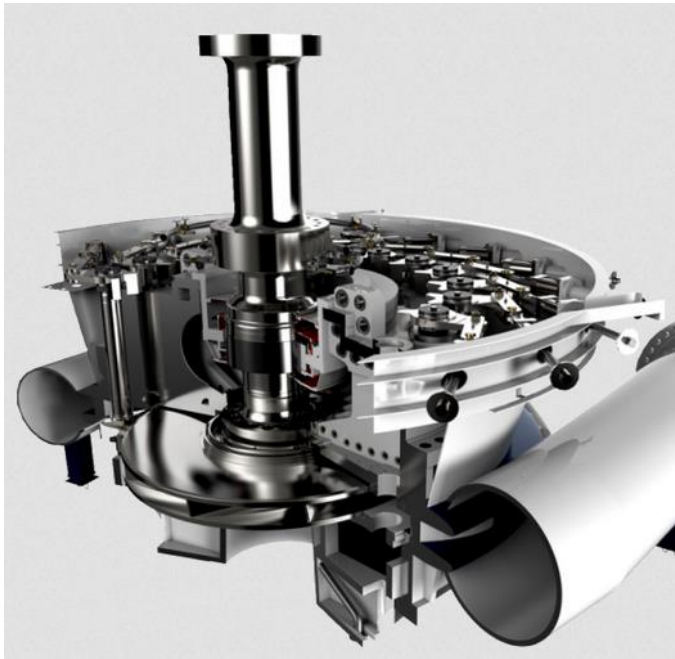
PSP



# Reaction Turbines: PUMP TURBINES (PSP)

## Main hydraulic characteristics

Single stage or multi-stage according to the head (from 1 to 5 runners)



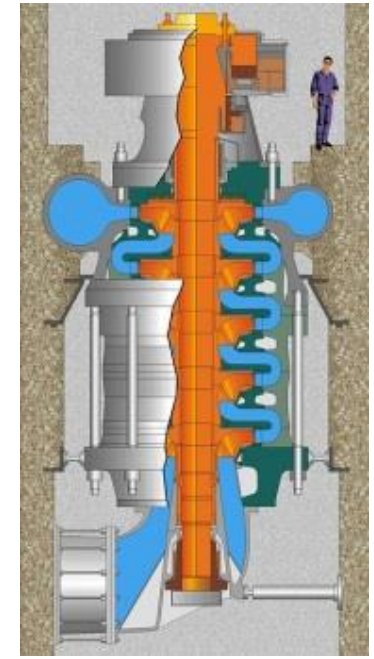
**1 STAGE / 1 RUNNER**

**$H \leq 600$  m**



**2 STAGES / 2  
RUNNERS**

**$600 < H \leq 900$  m**



**5 STAGES**

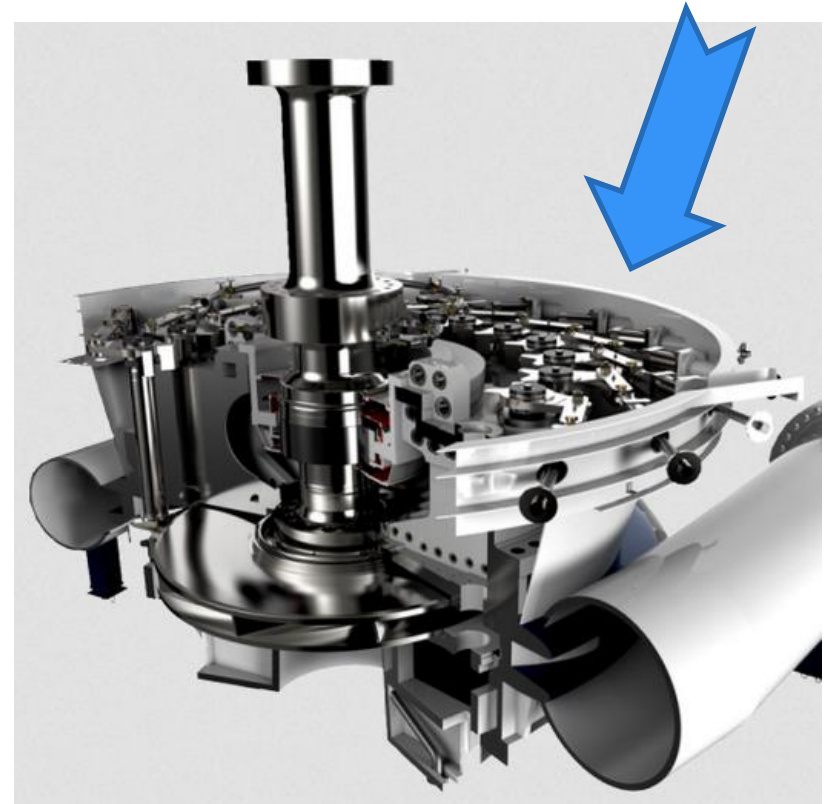
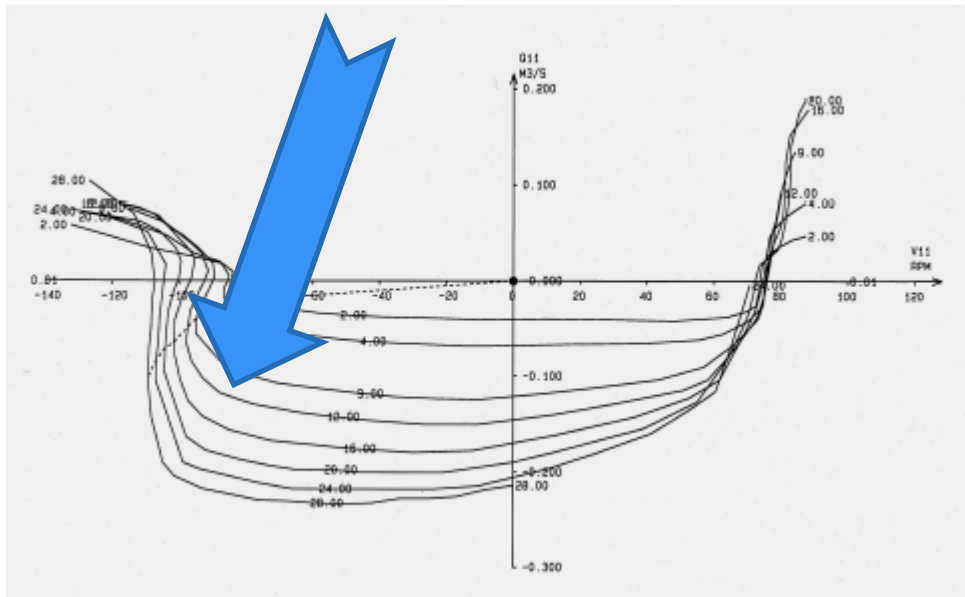
**1 RUNNER for ~200  
m**



# Reaction Turbines: PUMP TURBINES (PSP)

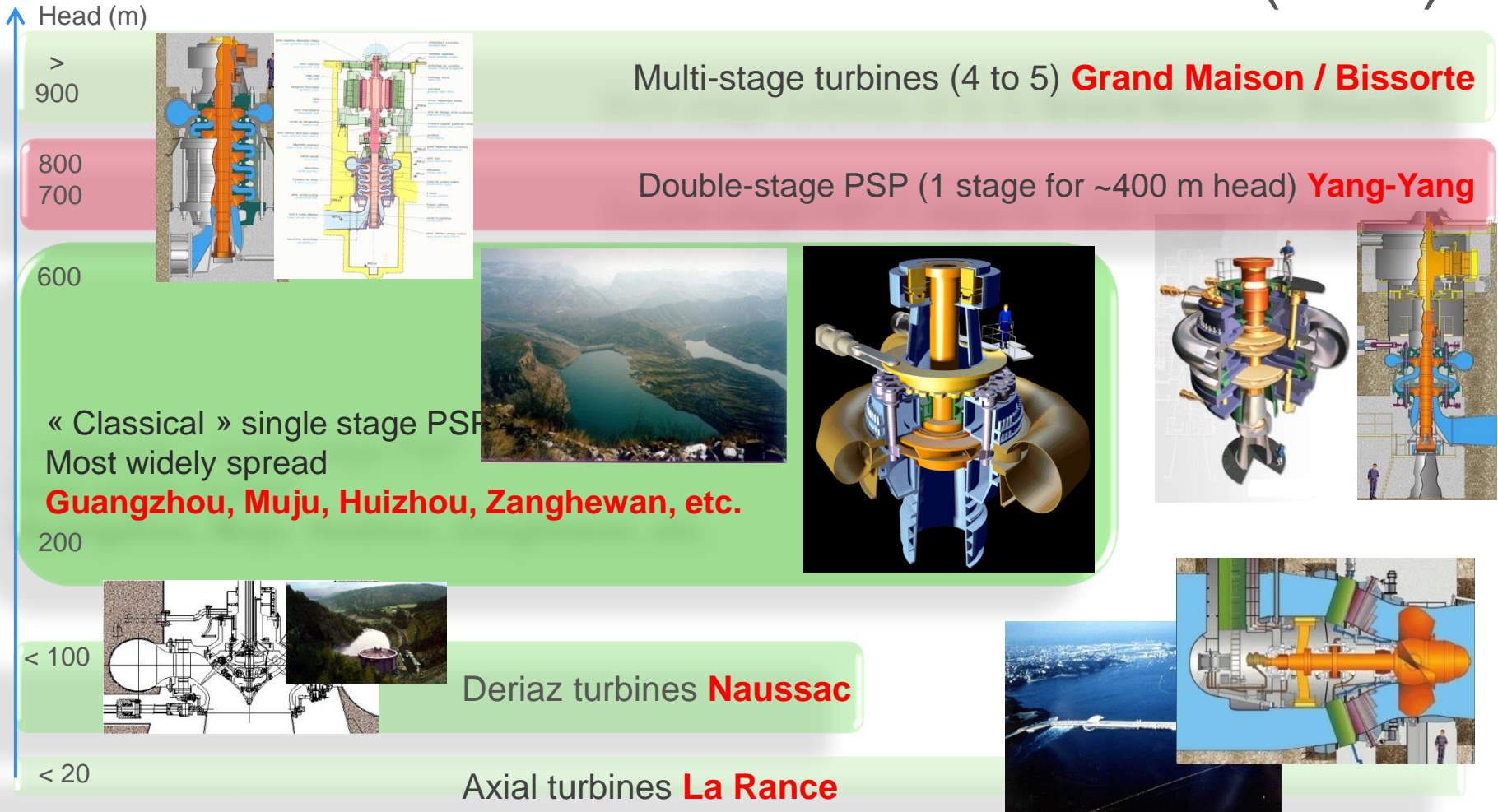
## Main hydraulic characteristics

Instability zone in turbine mode



Guide vanes with independent servomotors

# Reaction Turbines: PUMP TURBINES (PSP)



In summary: Range of use according to the head

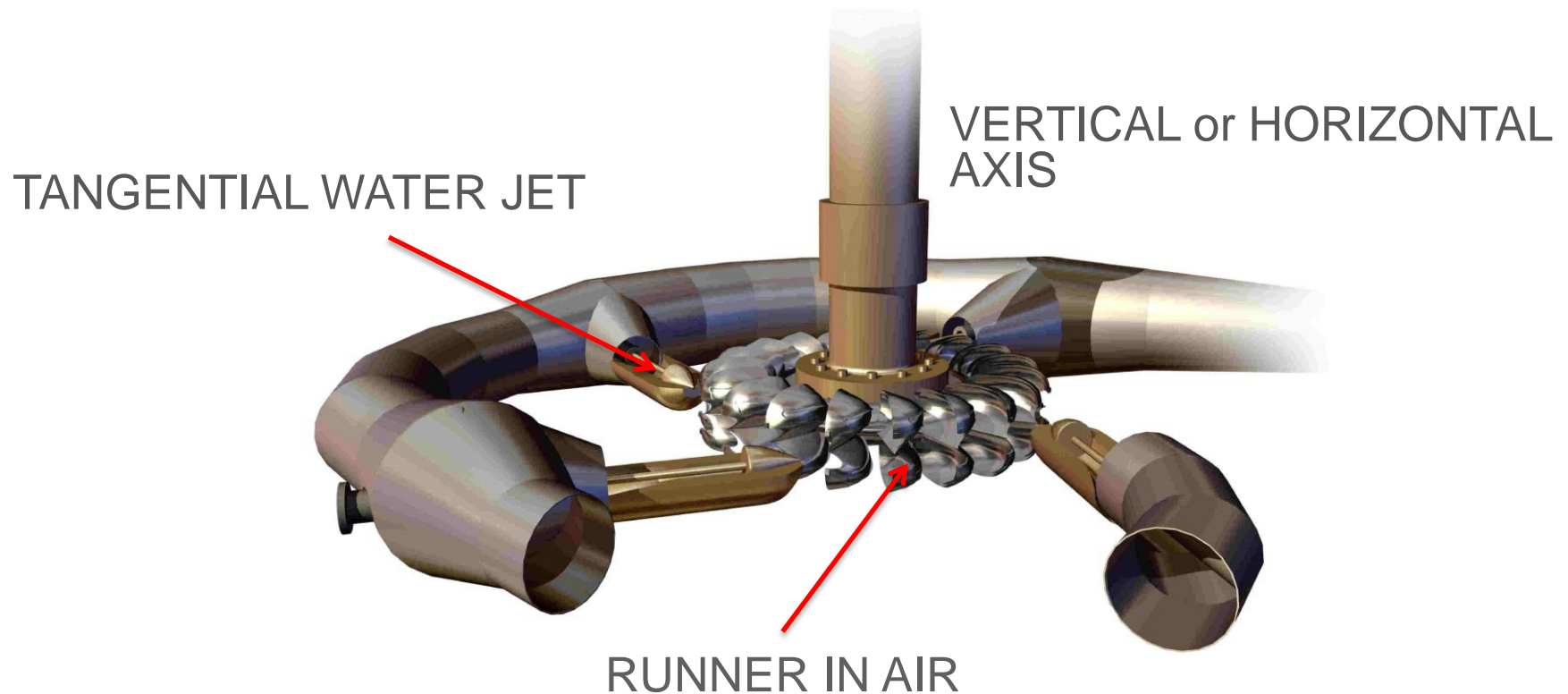
# Impulse Turbines



# Impulse Turbines: PELTON

Maxi HEAD: 1900 m

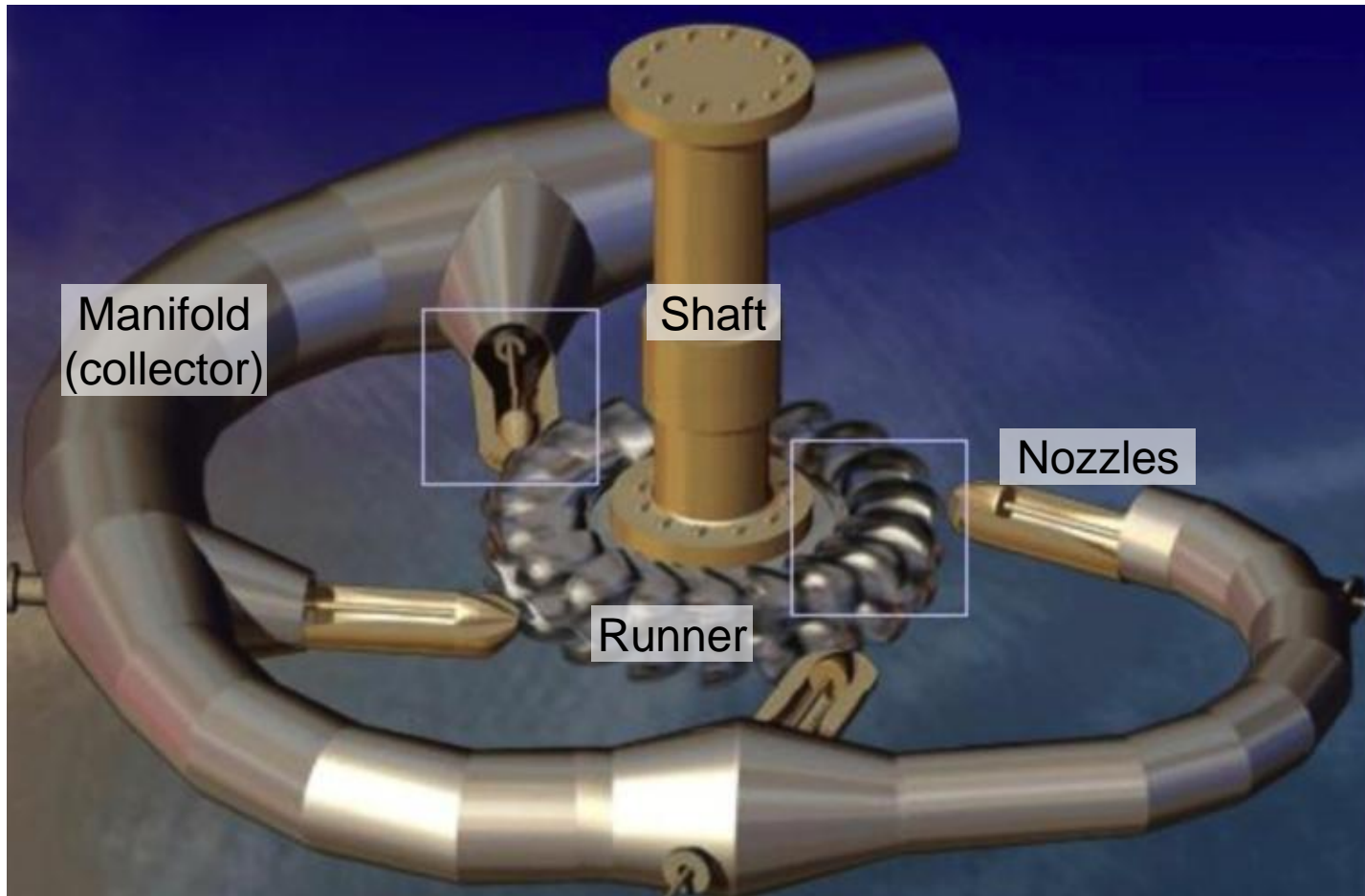
Maxi OUTPUT: 430 MW





# Impulse Turbines: PELTON

## Main hydraulic components





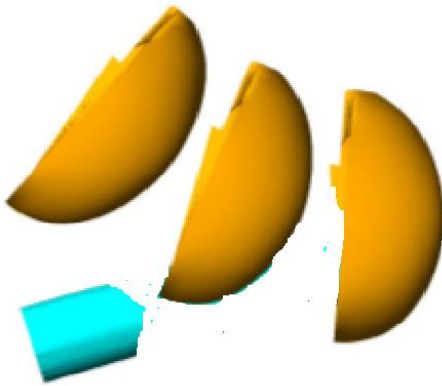
# Impulse Turbines: PELTON

## Working principle

- Step 1

*Before the impact*

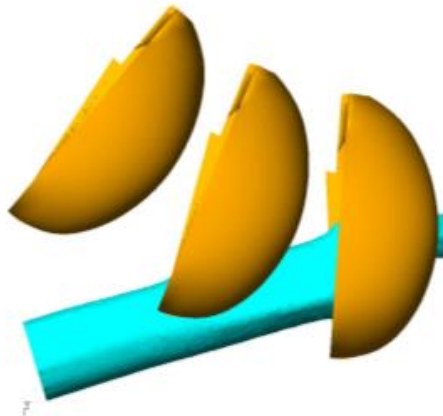
→ Water jet with kinetic energy



- Step 2

*During the impact*

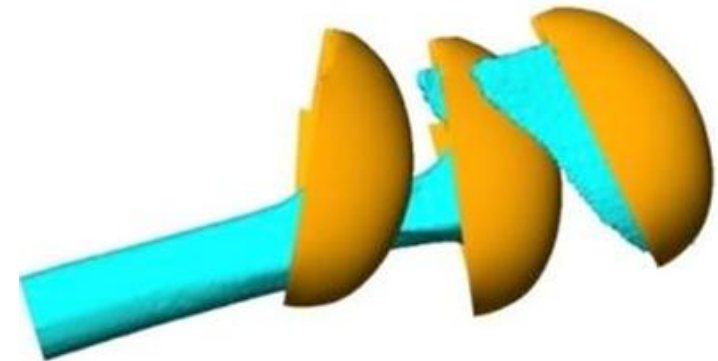
→ Energy transfer between water jet and the bucket



- Step 3

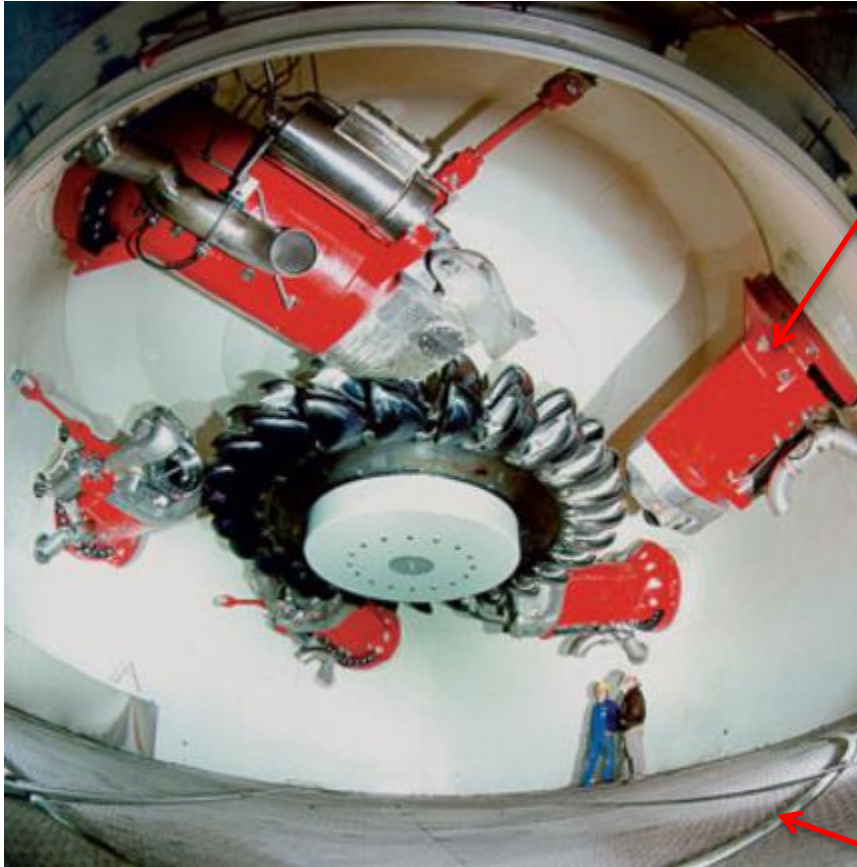
*After the impact*

→ Kinetic energy turned into mechanical energy (torque)



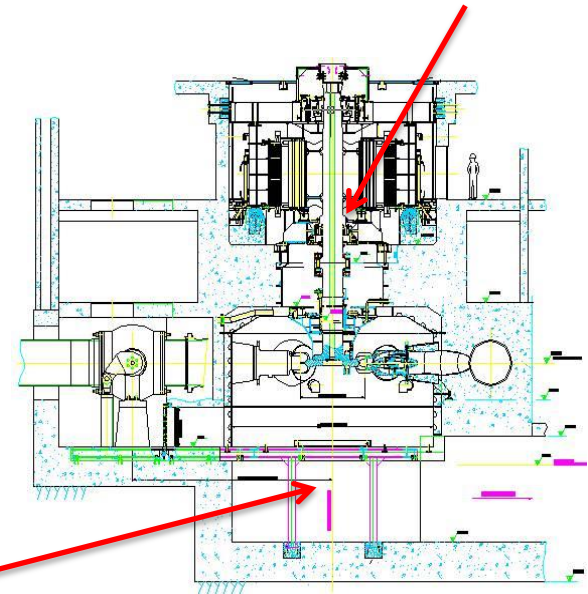
# Impulse Turbines: PELTON

## Main characteristics



From 1 to 6 jets

High output → Vertical axis

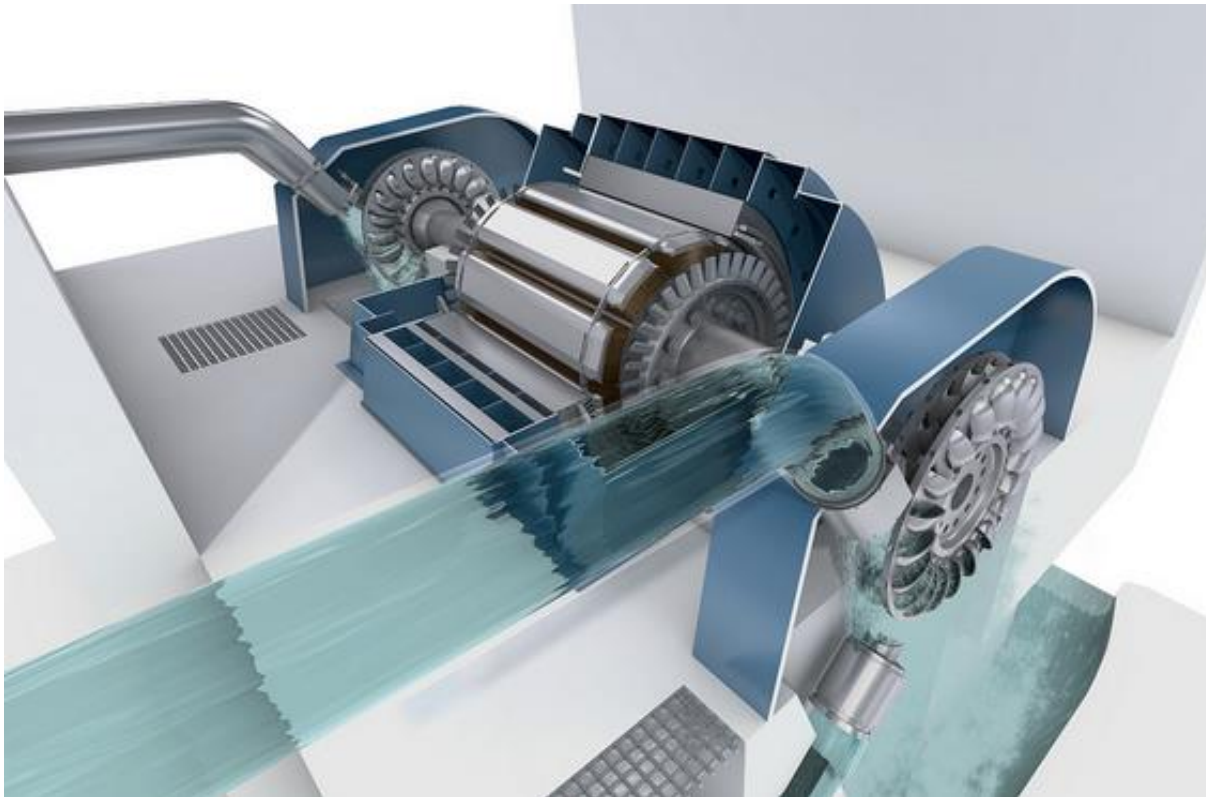


Runner position above the downstream water level

# Impulse Turbines: PELTON

## Main characteristics

Low output → Horizontal axis



# Impulse Turbines: PELTON

## Hooped Pelton (GE Hydro patent)



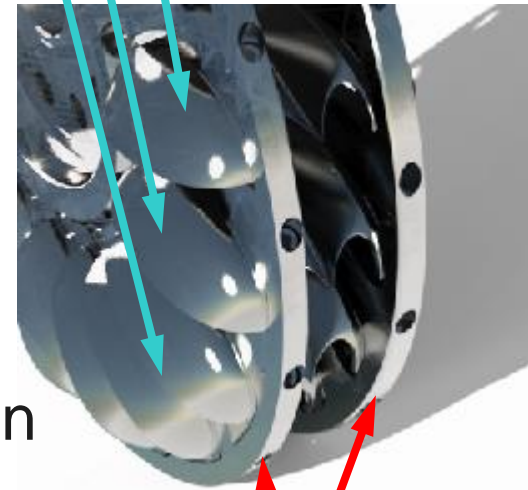
Separate the functions

➤ hydraulic

➤ Mechanical

Higher manufacturing quality (Precision, proven extended NDT, serial production of buckets...)

INDIVIDUAL BUCKETS



RIMS

