MAVEL

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EXPERTISE

Content

- Company introduction
- Turbine technology
- Research & Development
- Production & Services
- Reference projects
- Analysis of the water turbines
- Testing of the water turbines

MAVEL

Mavel is a premier global manufacturing and engineering company specializing in turbines and related technology for hydroelectric power plants from 30 kW to 30+ MW per unit.

Mavel has more than 100 proprietary Kaplan, Francis, Pelton and Micro turbine designs, state of the art European production facilities and worldwide service capability.

History

1990:	Incorporated in Prague, CZ
1993:	Sells First Turbine / Begins Manufacturing
1998:	Buys CKD Turbo Technics, s.r.o.
	Sells 100th Turbine
2002:	Sells 200th Turbine
2005:	Buys Benešov Headquaters Complex
2007:	Sells 300th Turbine
2010:	Purchases 5-Axis Milling Machine
	Establishes USA Subsidiary
2011:	Sells 400th Turbine
2012:	Completes Headquarter´s Expansion Project
2013:	Installs 6-Axis Combination Milling Machine
2015:	Sells 500th Turbine
2016:	Mavel´s Turbine at more than 300 Sites

Installations

LOCATIONS

Armenia, Australia, Austria, Belarus, Bulgaria, Canada, Costa Rica, Czech Republic, Democratic Republic of Congo, Estonia, Finland, France, Germany, Greece, Indonesia, Italy, Japan, Kyrgyzstan, Laos, Latvia, Lithuania, Macedonia, New Zealand, Norway, Pakistan, Panama, Poland, Portugal, Slovakia, Slovenia, South Korea, Spain, Switzerland, Turkey, Uganda, Ukraine, USA and Vietnam

SUMMARY

490+ Turbines Ordered

320+ Installations

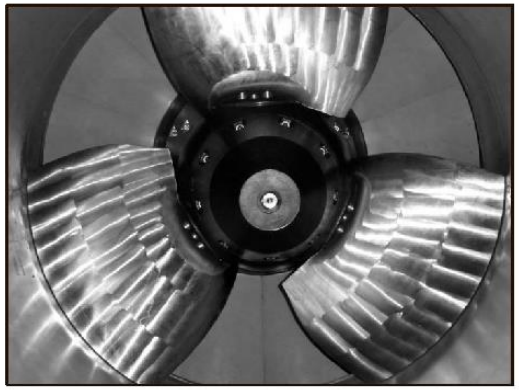
490+ MW Total Power

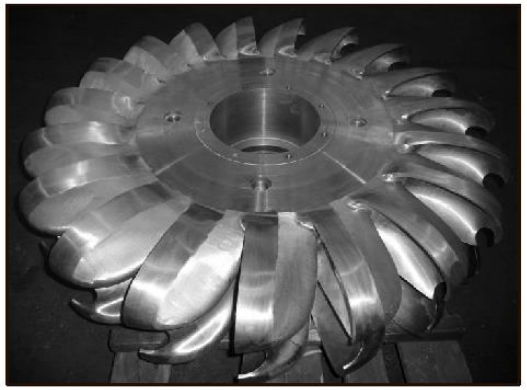
Turbine Technology

Kaplan – Francis – Pelton – Micro

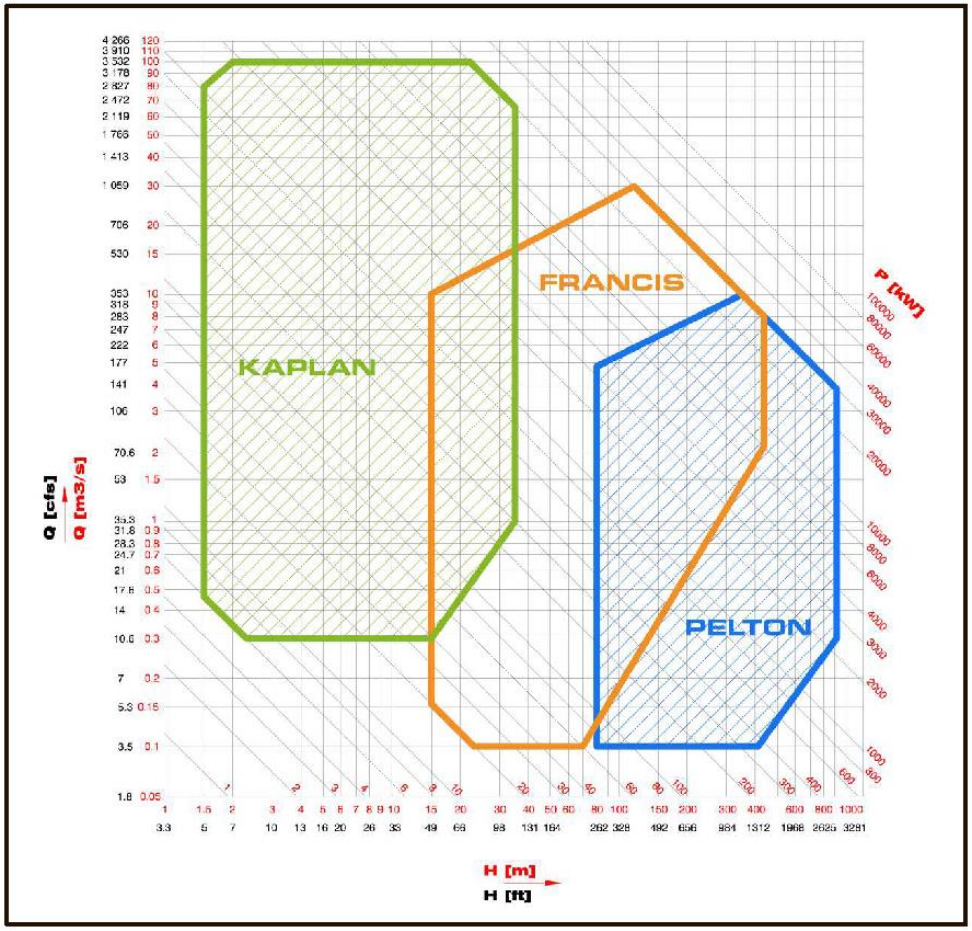
100+ Proprietary Designs

30 kW to 30+ MW





Turbine Application Range



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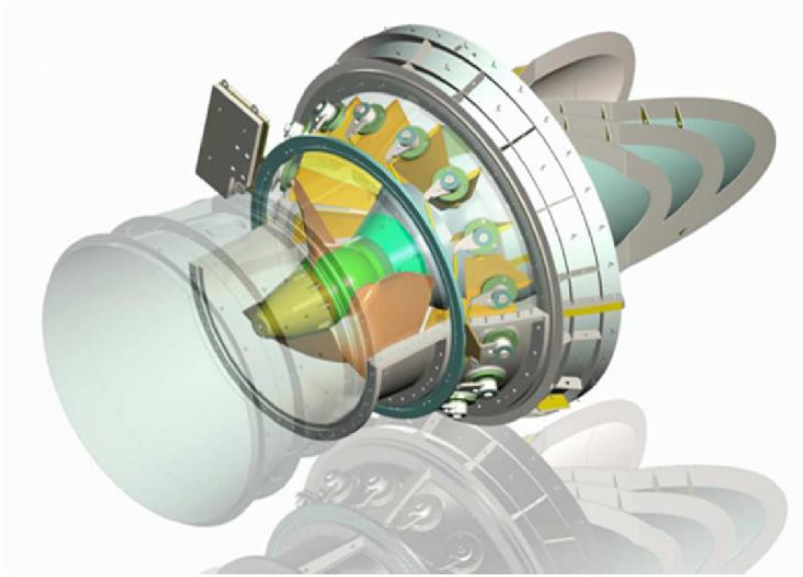
Mavel Kaplan Turbines

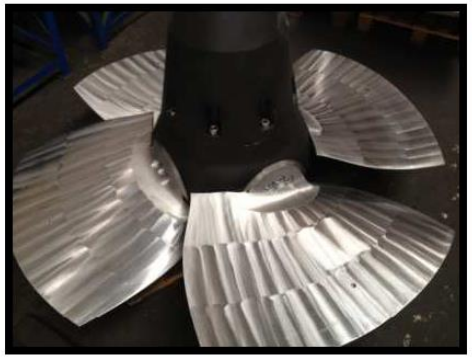
The Kaplan turbine was invented in the Czech Republic in 1912 by Viktor Kaplan. Over the past 100 years the design has improved significantly and a number of Kaplan turbine variations have evolved. Mavel's Kaplan turbines include the PIT, Vertical, Bulb, Z and S with both vertical and horizontal configurations.



Mavel Kaplan PIT Turbine

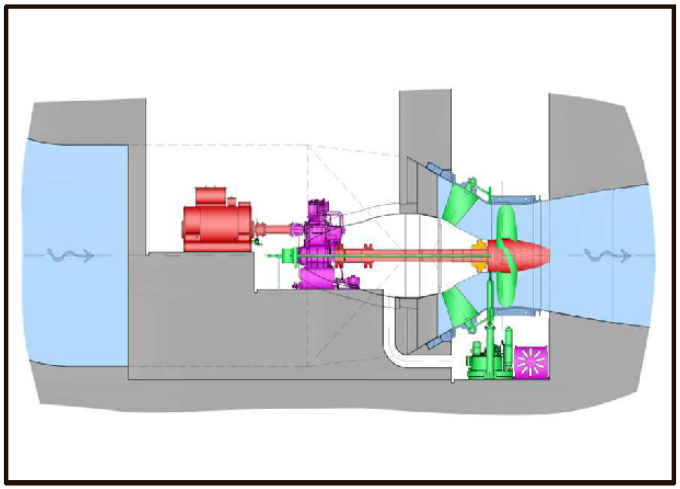
Mavel Kaplan Turbine Range

Mavel's Kaplan turbines are designed for sites up to 20 MW per unit. The turbines are available with runner diameters from 560 mm to 5500 mm, utilize three to six runner blades and can be single or double regulated. They are ideal for run-of-the-river sites with low heads ranging from 1.5 to 35 meters [5 to 115 ft] and optimal flows per turbine between 1.2 and 200 cms [45 to 7060 cfs].



Kaplan PIT Turbine

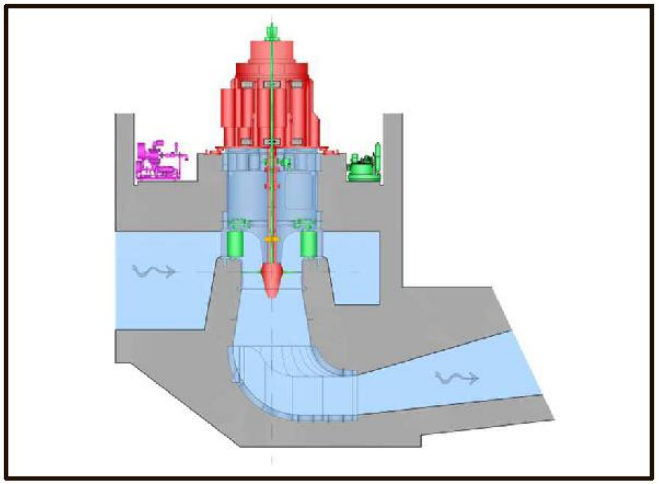
Runner Diameters	1050 mm to 5500 mm
Number of Runner Blades	3 or 4
Head	1.5 to 12 meters [5 to 39.5 ft]
Flow	15 to 150 cms [530 to 5340 cfs]
Power Output	400 kW to 8 MW
Transmission	Belt Drive or Parallel Gearbox



Longitudinal Section of Mavel Kaplan PIT Turbine

Kaplan Vertical Turbine

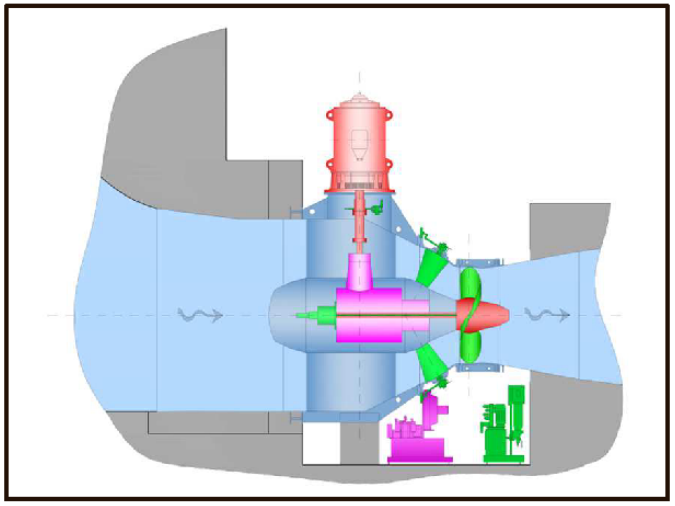
Runner Diameters	850 mm to 5500 mm
Number of Runner Blades	4, 5 or 6
Head	1.5 to 35 meters [5 to 115 ft]
Flow	3.5 to 200 cms [124 to 7060 cfs]
Power Output	70 kW to 20 MW
Transmission	Direct Drive, Belt Drive or Parallel Gearbox



Longitudinal Section of Mavel Kaplan Vertical Turbine

Kaplan Bulb Turbine

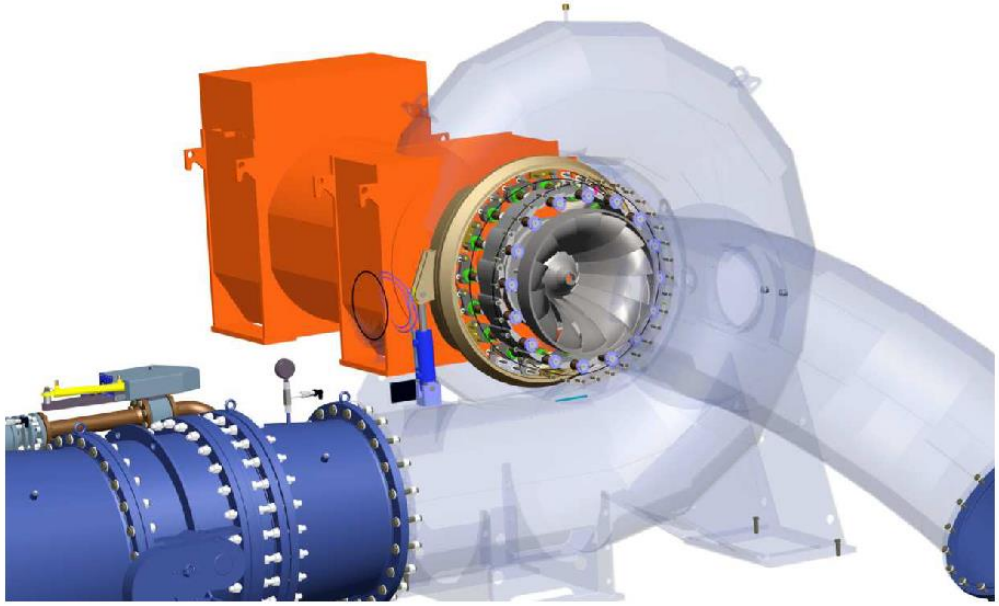
Runner Diameters	1050 mm to 2500 mm
Number of Runner Blades	3 or 4
Head	1.5 to 12 meters [5 to 39.5 ft]
Flow	5 to 45 cms [180 to 1590 cfs]
Power Output	100 kW to 3 MW
Transmission	Direct Drive, Belt Drive or Bevel Gearbox



Longitudinal Section of Mavel Kaplan Bulb Turbine

Mavel Francis Turbines

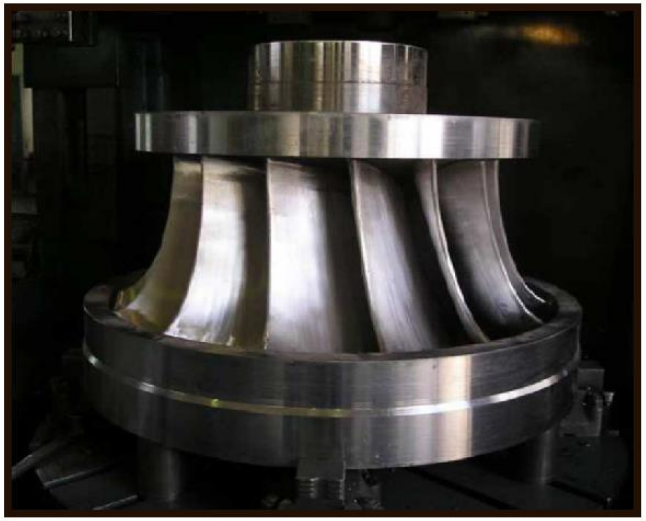
The Francis turbine was invented in Massachusetts in 1848 and is the most common water turbine in use today. Mavel's Francis turbines are available with runner diameters from 400 mm to 2500 mm and may be installed in horizontal or vertical configurations.



Mavel Horizontal Francis Turbine

Mavel Francis Turbine Range

Mavel has installed almost 70 Francis turbines since 1993, including six 5 MW units for a cascade of three plants on the Piedra River in Panama for total installed power of 30 MW. The final plant in this cascade was commissioned in the second quarter of 2013.

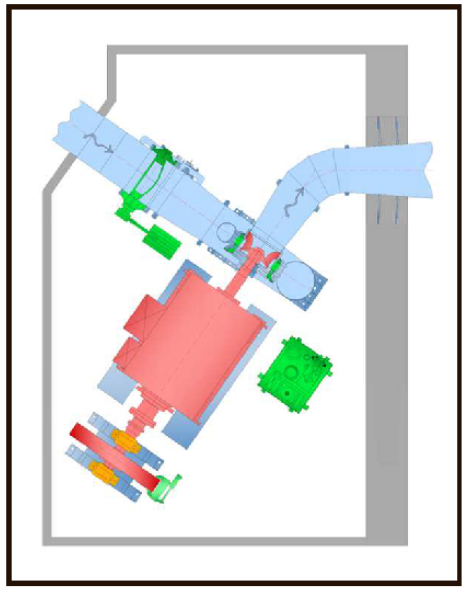


Mavel Francis Turbine Parameters

Runner Diameters	400 mm to 2500 mm
Head	15 to 300 meters [50 to 1000 ft]
Flow	0.5 to 35 cms [18 to 1240 cfs]
Power Output	Up to 30 MW
Transmission	Runner Assembled to Generator or Turbine Shaft

Horizontal Francis Turbine

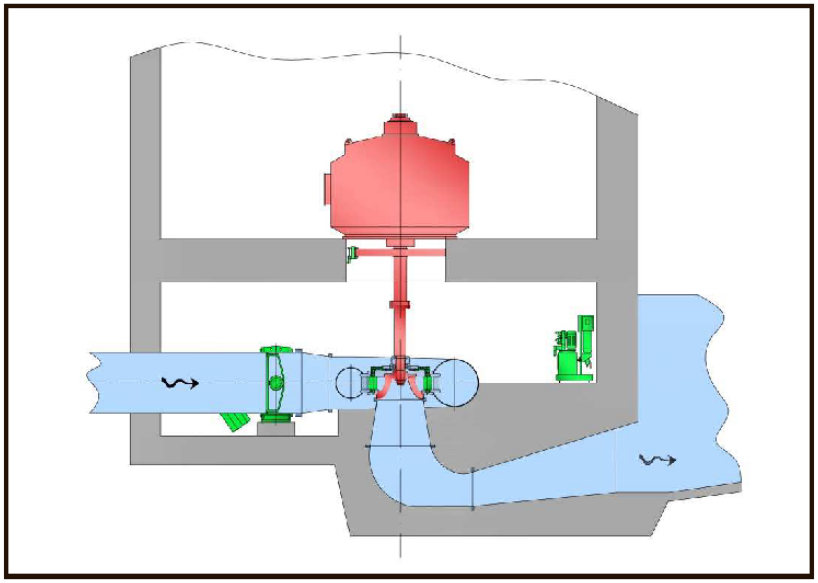
Runner Diameters	400 mm to 1500 mm
Head	15 to 300 meters [50 to 1000 ft]
Flow	0.5 to 20 cms [18 to 706 cfs]
Power Output	100 kW to 12 MW
Transmission	Runner Assembled to Generator or Turbine Shaft



Ground Plan View of Mavel Horizontal Francis Turbine

Vertical Francis Turbine

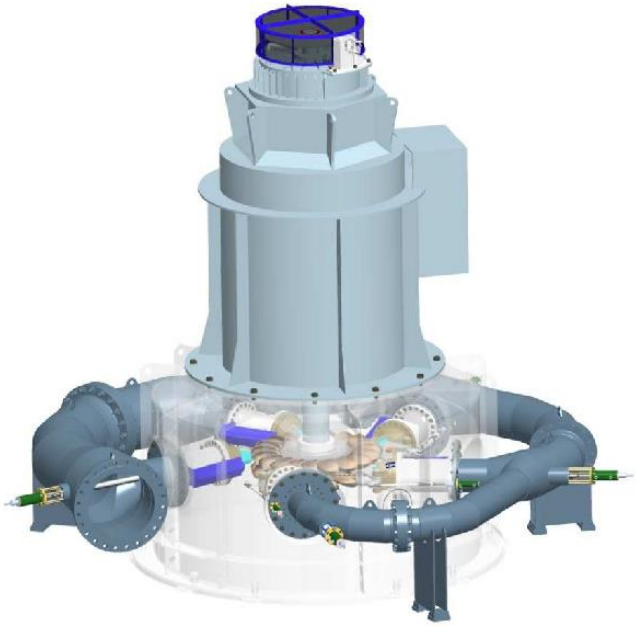
Runner Diameters	1000 mm to 2500 mm
Head	Up to 300 meters [1000 ft]
Flow	Up to 35 cms [1236 cfs]
Power Output	Up to 30 MW
Transmission	Runner Assembled to Generator or Turbine Shaft



Longitudinal Section of Mavel Vertical Francis Turbine

Mavel Pelton Turbines

The Pelton Turbine was invented in the late 1800's during the California gold rush. Mavel's Pelton turbines are available with runner diameters from 500 mm to 2500 mm. These impulse turbines can utilize either a vertical or horizontal configuration and one to six jets. The use of multiple jets can provide two to four times the normal output for a given runner diameter.



Mavel Vertical Pelton Turbine

Mavel Pelton Turbine Range

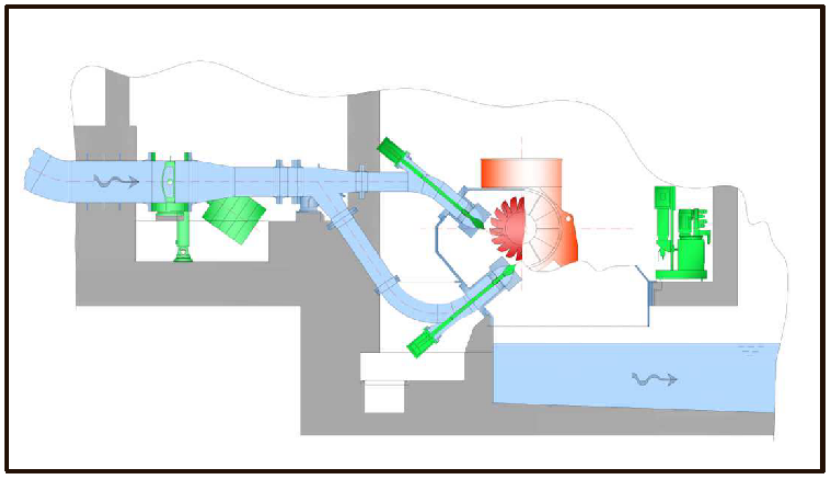
The installations include the 3 MW Vlahi Project in Bulgaria, the two turbine 12.9 MW Yeghesis project in Armenia and the 11.8 MW Upper Clowhom Project in British Columbia.

Mavel Pelton Turbine Range

Runner Diameters	Up to 2500 mm
Number of Jets	1 to 6
Head	50 to 1000 meters [165 to 3300 ft]
Flow	0.1 to 10 cms [4 to 353 cfs]
Power Output	Up to 30+ MW
Transmission	Runner Assembled to Generator or Turbine Shaft

Horizontal Pelton Turbine

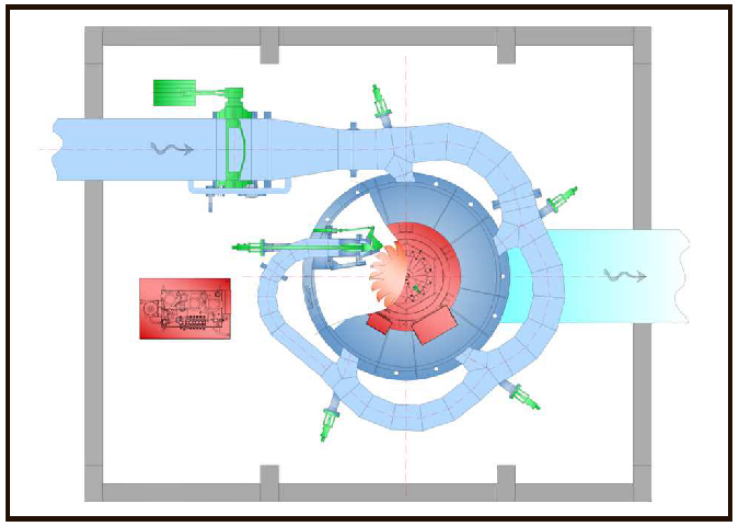
Runner Diameters	500 mm to 1800 mm
Number of Jets	1, 2 or 3
Head	50 to 1000 meters [165 to 3300 ft]
Flow	0.1 to 6 cms [4 to 212 cfs]
Power Output	Up to 30+ MW
Transmission	Runner Assembled to Generator or Turbine Shaft



Longitudinal Section of Mavel Horizontal Pelton Turbine

Vertical Pelton Turbine

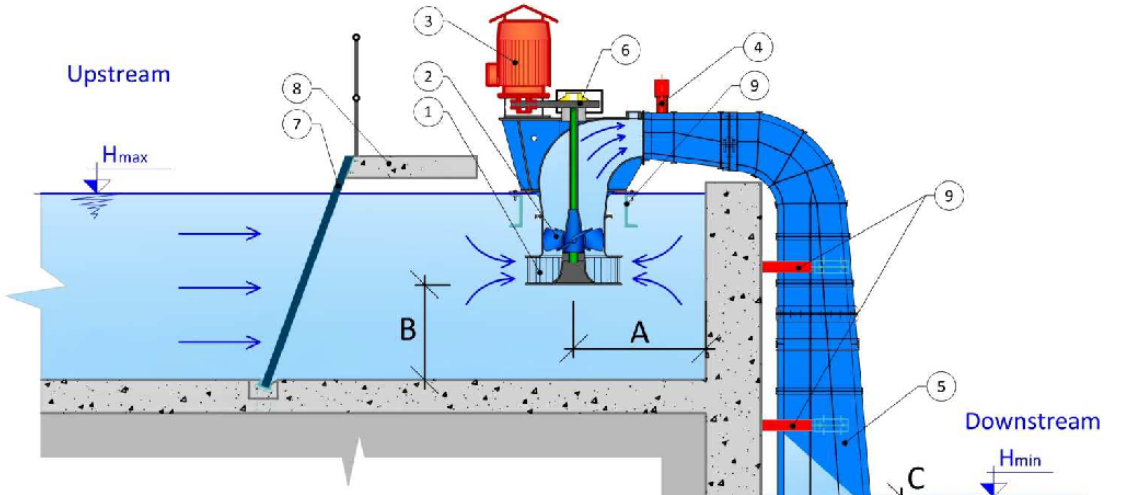
Runner Diameters	500 mm to 2500 mm
Number of Jets	3, 4, 5 or 6
Head	50 to 1000 meters [165 to 3300 ft]
Flow	Up to 10 cms [up to 353 cfs]
Power Output	Up to 30+ MW
Transmission	Runner Assembled to Generator or Turbine Shaft



Ground Plan View of Mavel Vertical Pelton Turbine

Mavel TM Micro Turbines

Mavel TM Micro Turbines are ideal for low head sites from 1.5 to 6 meters [5 to 20 ft] with flow from 0.15 to 5 cms [5 to 177 cfs]. They have power output of up to 160 kW per unit. The TM Micro turbines have no need for a powerhouse and are sold as complete packages comprising of turbine, generator, inlet, draft tube and electric and control systems. The packages are easy to install and cost effective.



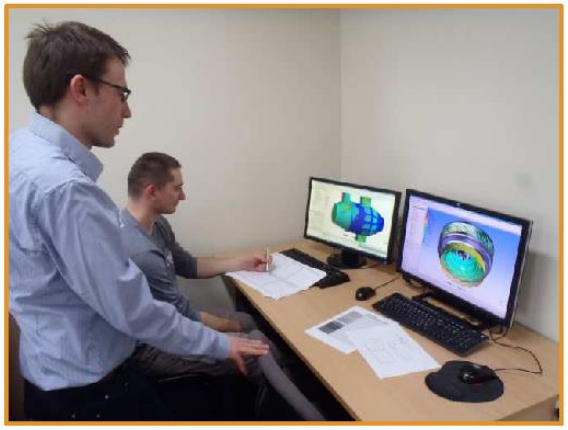
	A [mm]	B [mm]	C [mm]
TM3	800	300	100
TM5	1200	300	150
TM8	1900	500	170
TM10	2400	600	200

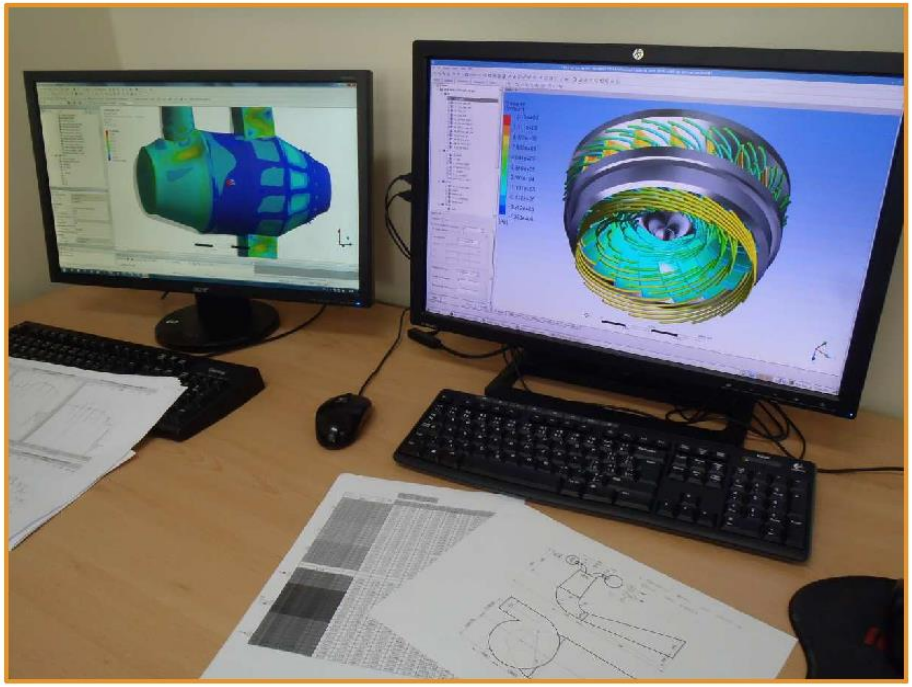
MAVEL´S DELIVERY	
1	DISTRIBUTOR
2	TURBINE TM
3	GENERATOR
4	ELECTROMAGNETIC VALVE
5	DRAFT TUBE
6	BELT DRIVE

SUPPLIED BY OTHERS	
7	TRASH RACKS
8	SERVICE BRIDGE
9	SUPPORTING STRUCTURE

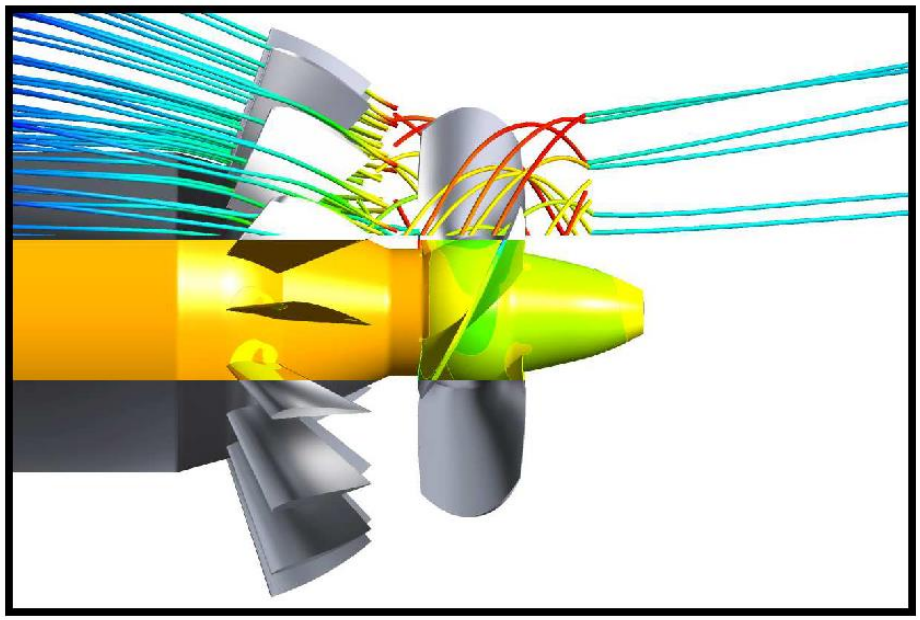
Research & Development Engineering

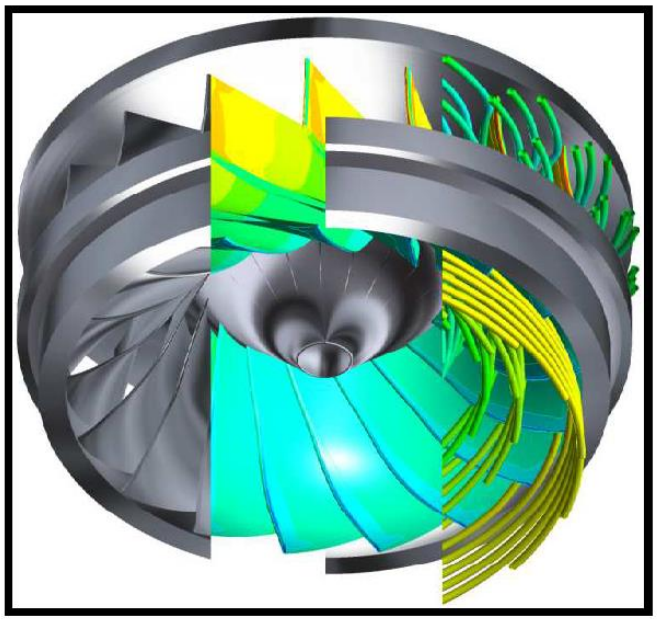
R&D Department





Research & Development





Examples of the Visualizations from Flow Calculations

Production & Services

Production Capability

Production Facilities	Two Production Halls
Combined Properties	Land: 27,000 SM Production/Storage: 10,300 SM Administration: 2,600 SM
Production Capabilities	Milling, Boring, Drilling, Pressing, Grinding, Sawing, Metal Rolling, Cutting, Turning, Painting, Welding, Coating, Assembly and Testing
Engineers	60
Production Machines	40
Total Crane Capacity	85 ton
Quality Control	ISO Certified / Specialized Team
Specialized Machinery	6-axis milling (2013) 5-axis milling (2010)

Runners Milled From Forgings

Precision 5-Axis Milling

Precision 6-Axis Milling

Services

Mavel provides the following services to support its customers:

* proposal of an optimal solution from a technical and economic viewpoint
* evaluation and quality control of sub-suppliers
* engineering, visualization, manufacturing
* installation, testing and commissioning supervision
* field services – warranty, repair and testing
* diagnostic – field and in-house
* refurbishments and repairs – field and in-house

These services are available to customers around the world.

Company ISO and OHSAS Certification

Quality Control.....ISO 9001:2008

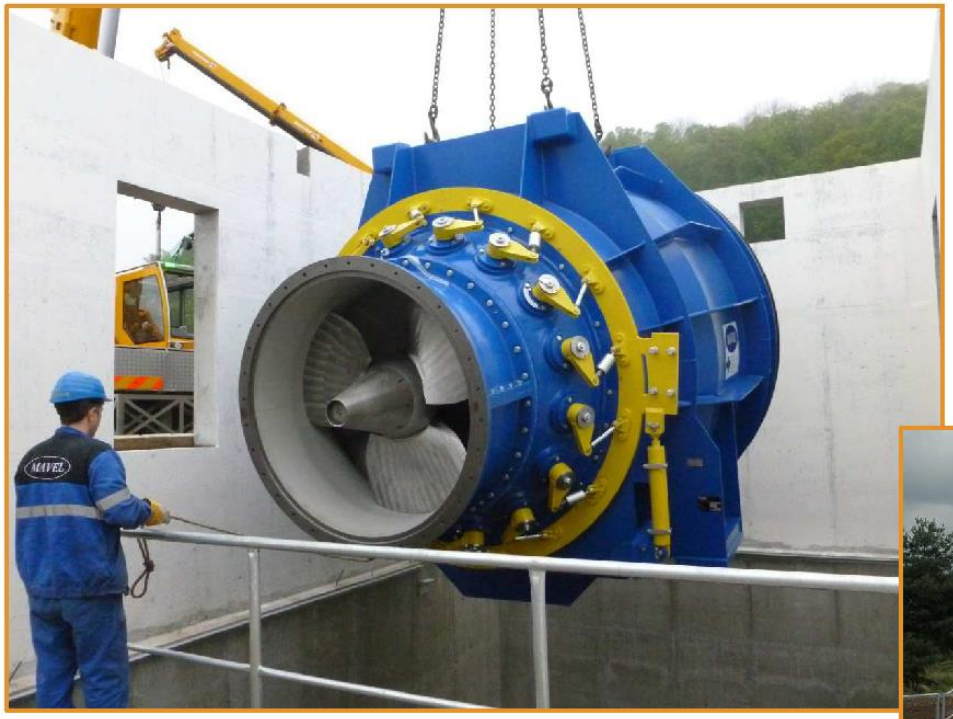
Environmental Qualification.....ISO 14001:2004

Health and Safety Qualification.....OHSAS 18001:2007

Welding Qualification.....ISO 3834-2:2005

Reference Projects

Hluboká n. V. HPP, Czech Republic



1x Kaplan Turbine

[272 kW]

Liběchov HPP, Czech Republic

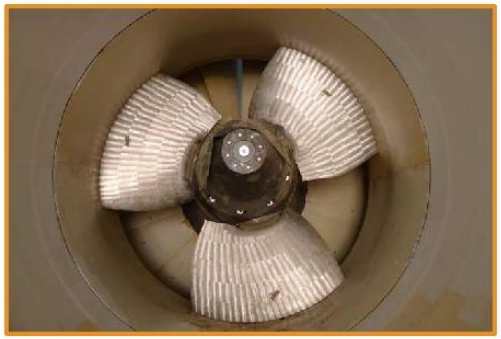
1x Kaplan Turbine

[2 450 kW]

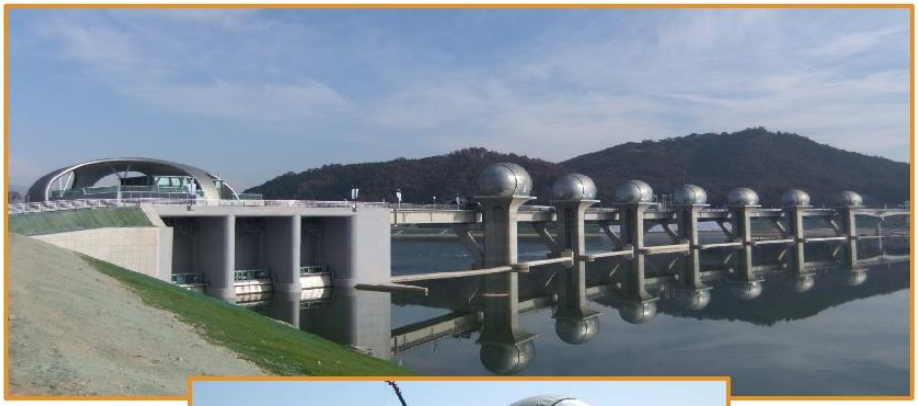
Roudnice HPP, Czech Republic

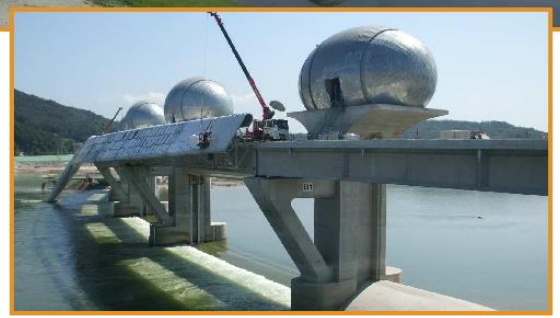
4x Kaplan Turbines

[4 000 kW]



Yipo HPP, South Korea





3x Kaplan Turbines

[3 330 kW]

Grodnenskaya HPP, Belarus

5x Kaplan Turbines

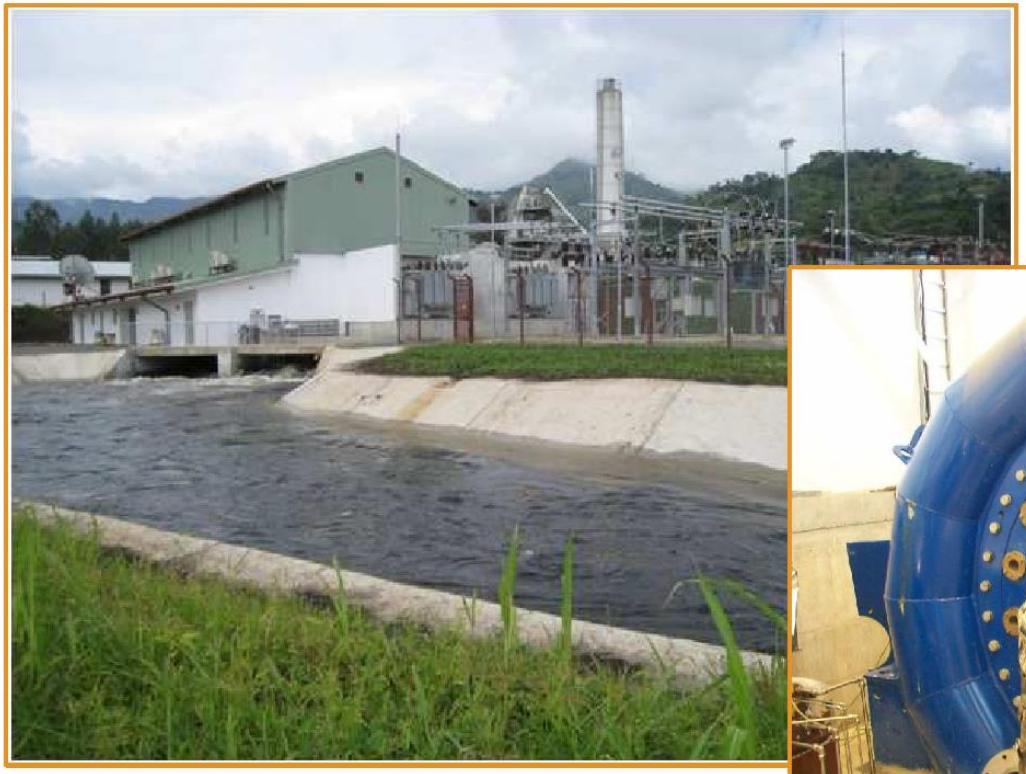
[18 870 kW]

Rio HPP, USA

1x Francis Turbine

[887 kW]

Bugoye HPP, Uganda



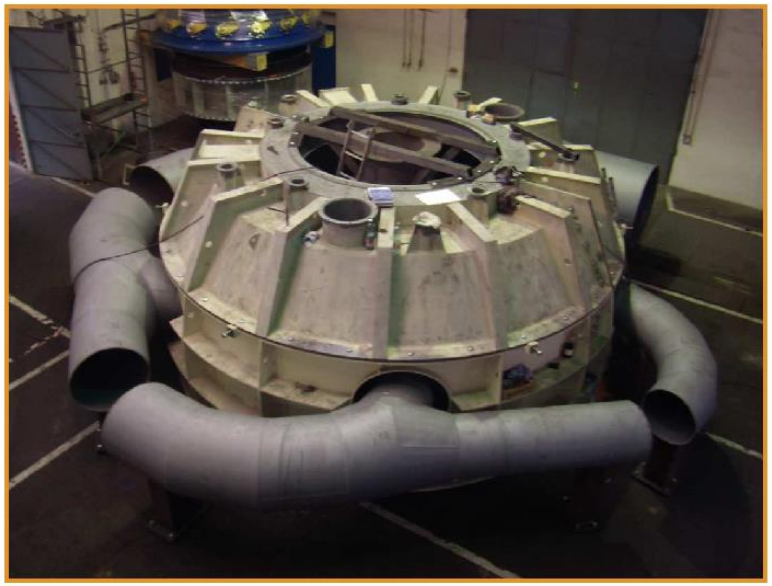
2x Francis Turbines

[14 332 kW]

Upper Clowhom HPP, Canada

1x Pelton Turbine

[11 300 kW]



Kyoto HPP, Japan

1x TM5 Micro Turbine

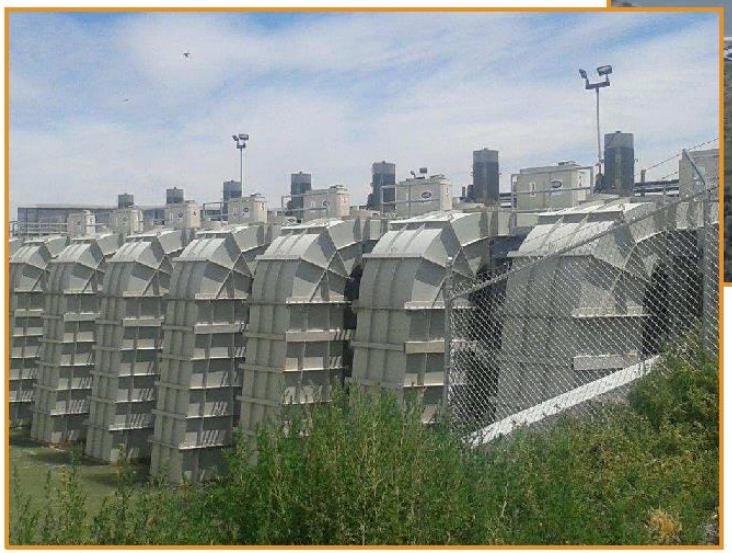
[4 kW]

Český Krumlov HPP, Czech Republic

2x TM5 Micro Turbines

[60 kW]

Head of the U Canal HPP, USA



8x TM10 Micro Turbines

[1 240 kW]

Polotskaya HPP, Belarus

5x Kaplan Turbines
[24 250 Kw]

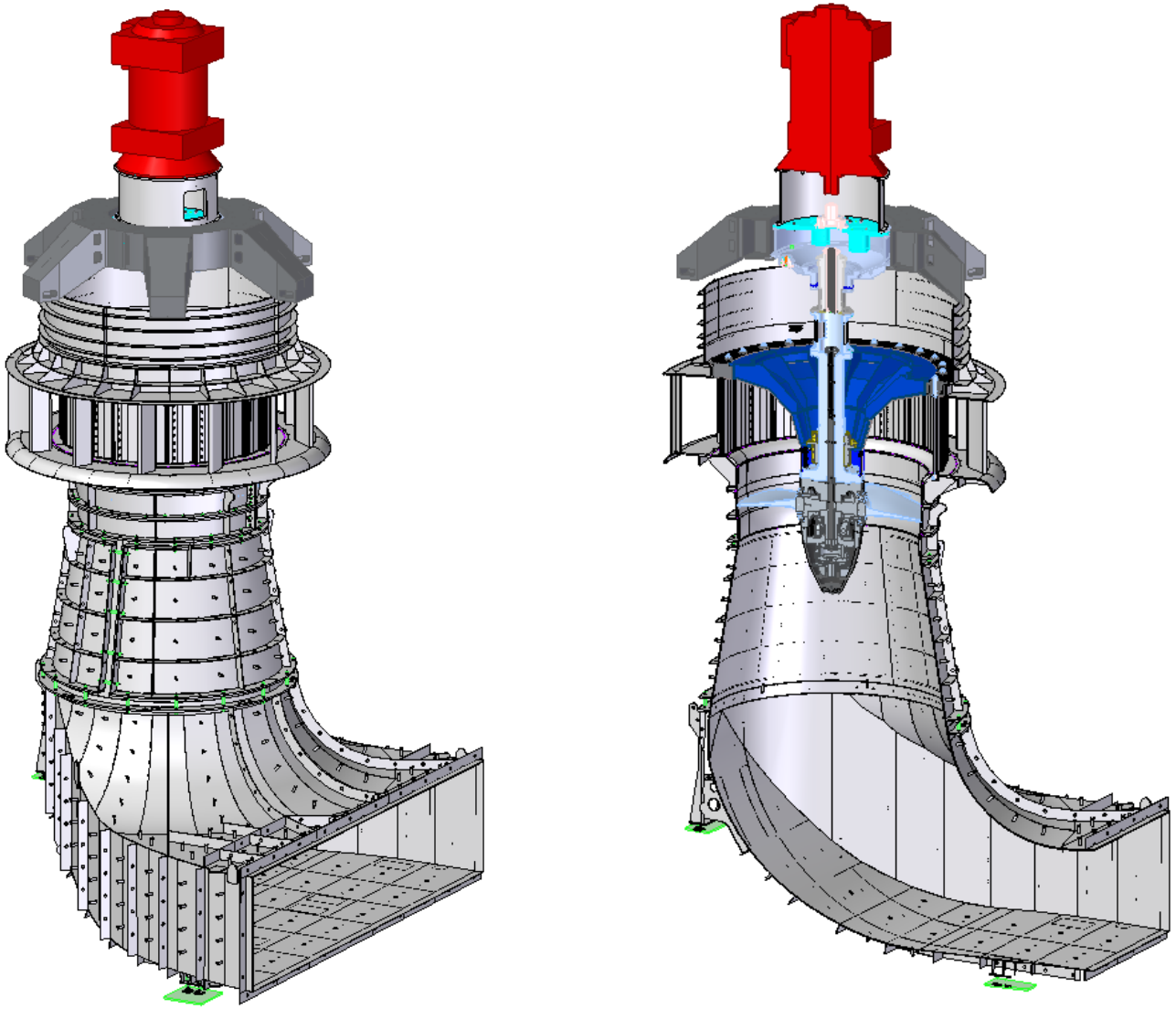
Analysis of the water turbines

FEM Analysis

Vertical turbine

Nominal runner diameter:	4250 mm
Rated output:	5036 kW
Rated speed:	83 rpm
Rated head:	6 m
Rated flow:	96 m^3/s
Number of runner blades:	4
Number of wicket gates	24

FEM Analysis



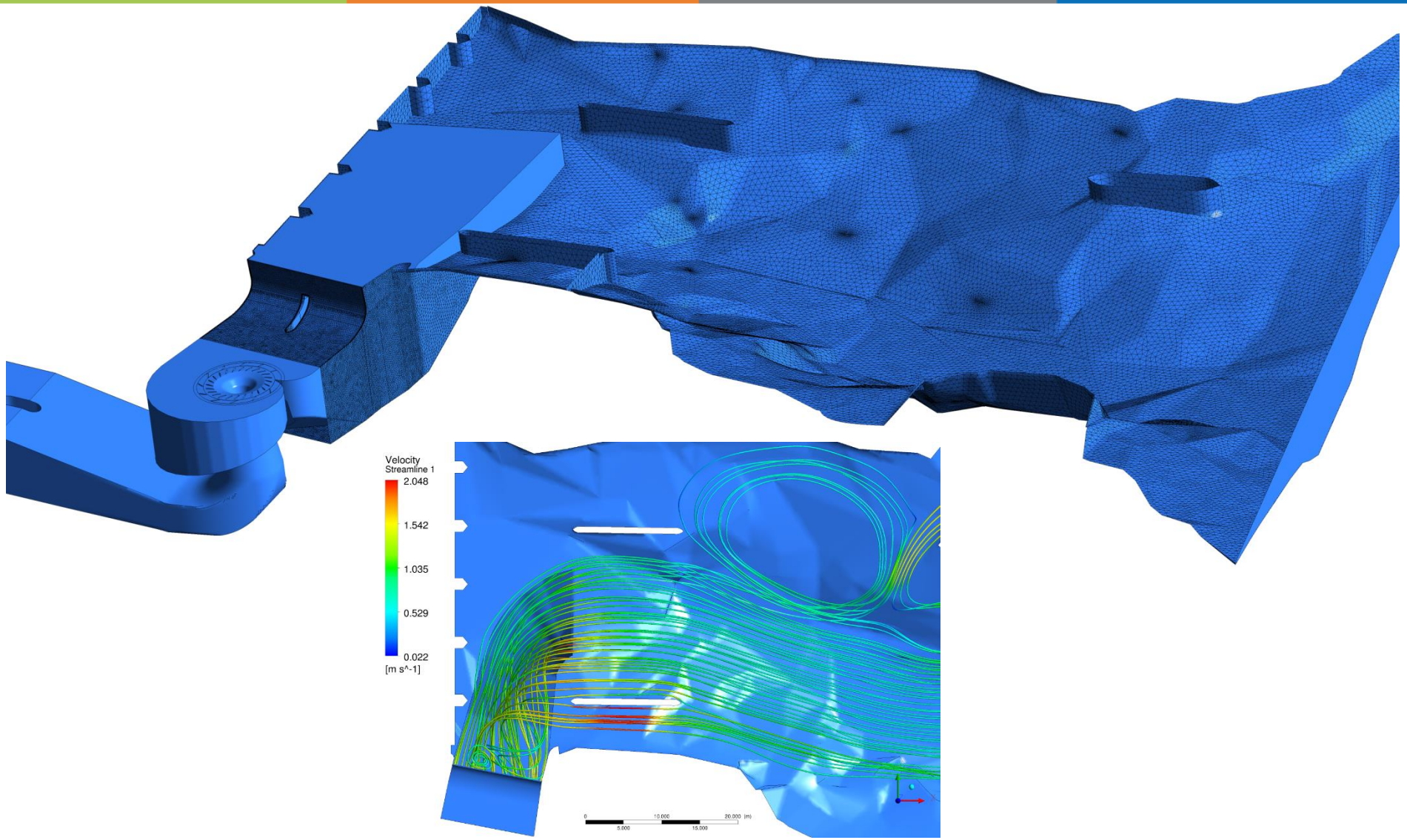
FEM Analysis

R&D

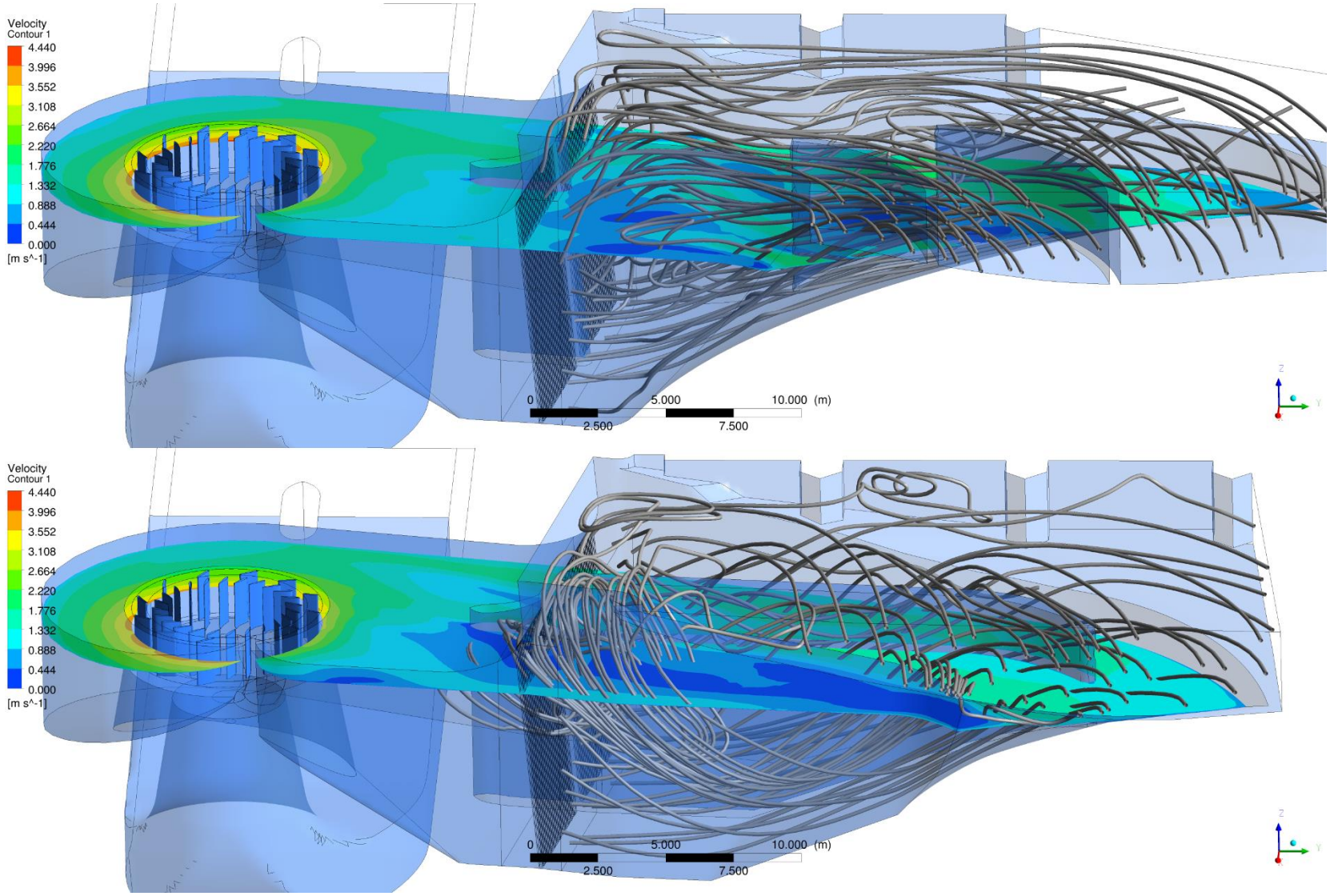
ANSYS CFD Premium

- CFD simulation of the intake object.
- CFD simulation of interaction between the intake object and turbine.
- Detailed CFD simulation of the turbine.

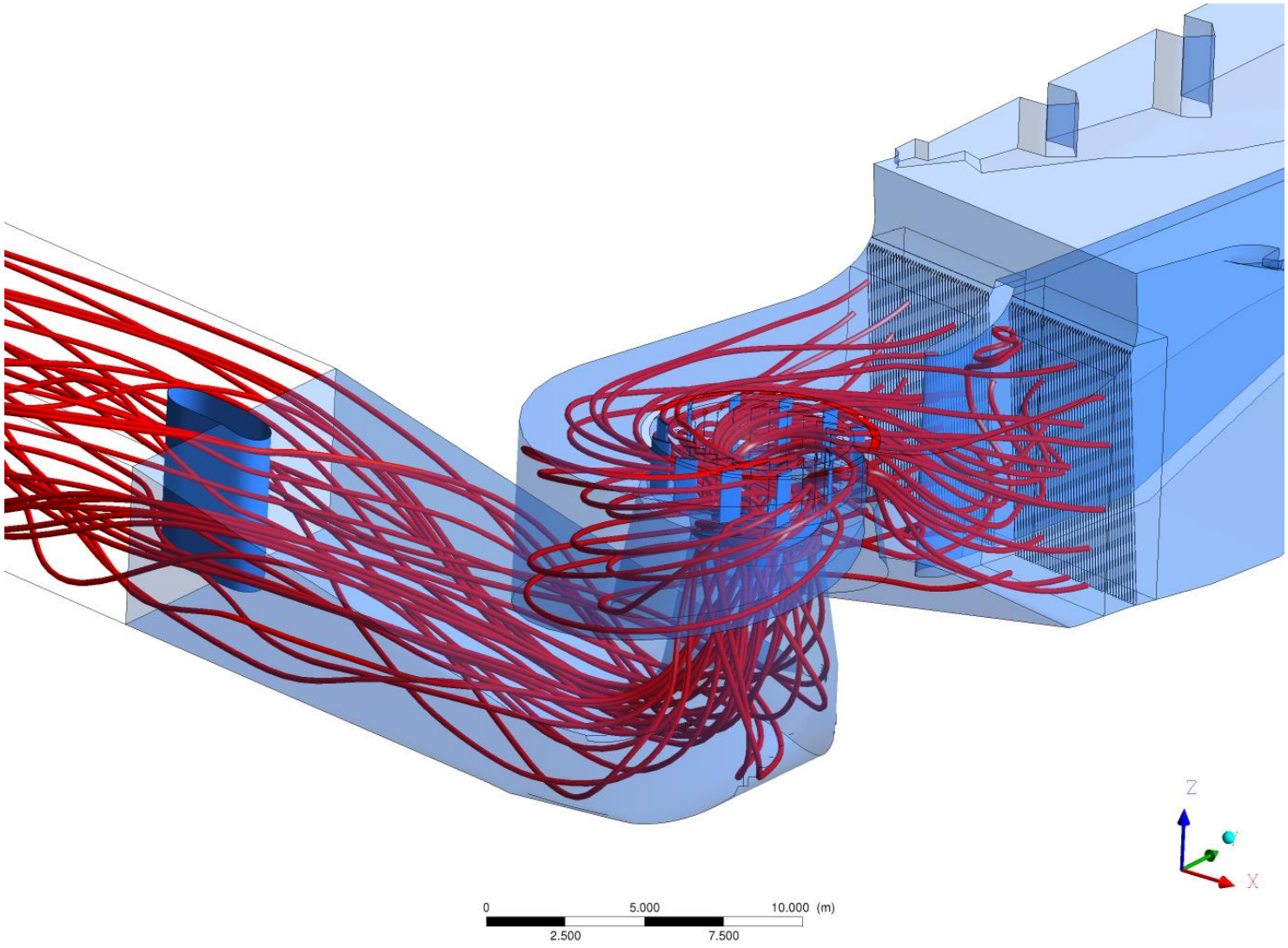
FEM Analysis



FEM Analysis



FEM Analysis



FEM Analysis

Design department

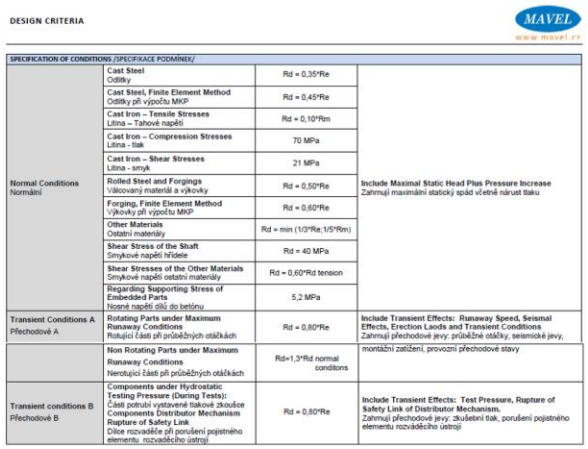
ANSYS Professional NLS

- Static structural analysis
- Modal analysis
- Harmonic response analysis
- Topology optimization
- Parametric optimization

FEM Analysis

Design of the structure

- Mavel design criteria
- Specification of materials
- Non- destructive tests
- ASME Code



DESIGN CRITERIA

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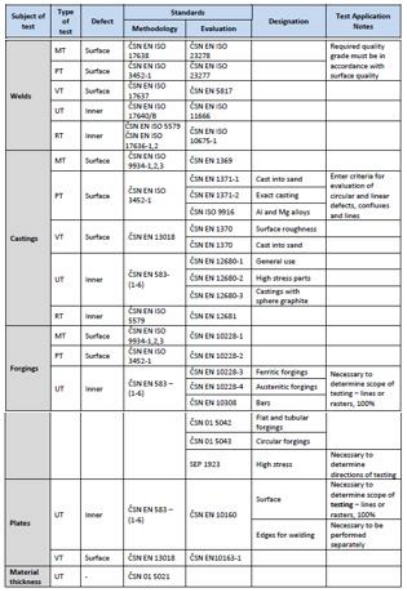
SPECIFICATION OF CONDITIONS /SPECIFIKACE PODMÍNEK/			
Normal Conditions Normální	Cast Steel Odlitky	Rd = 0,35*Re	Include Maximal Static Head Plus Pressure Increase Zahrnují maximální statický spád včetně nárust tlaku
	Cast Steel, Finite Element Method Odlitky při výpočtu MKP	Rd = 0,45*Re	
	Cast Iron – Tensile Stresses Litina – Tahové napětí	Rd = 0,10*Rm	
	Cast Iron – Compression Stresses Litina - tlak	70 MPa	
	Cast Iron – Shear Stresses Litina - smyk	21 MPa	
	Rolled Steel and Forgings Válcovaný materiál a výkovky	Rd = 0,50*Re	
	Forging, Finite Element Method Výkovky při výpočtu MKP	Rd = 0,60*Re	
	Other Materials Ostatní materiály	Rd = min (1/3*Re;1/5*Rm)	
	Shear Stress of the Shaft Smykové napětí hřídele	Rd = 40 MPa	
	Shear Stresses of the Other Materials Smykové napětí ostatní materiály	Rd = 0,60*Rd tension	
	Regarding Supporting Stress of Embedded Parts Nosné napětí dílů do betónu	5,2 MPa	
Transient Conditions A Přechodové A	Rotating Parts under Maximum Runaway Conditions Rotující části při průběžných otáčkách	Rd = 0,80*Re	Include Transient Effects: Runaway Speed, Seismal Effects, Erection Laods and Transient Conditions Zahrnují přechodové jevy: průběžné otáčky, seismické jevy,
	Non Rotating Parts under Maximum Runaway Conditions Nerotující části při průběžných otáčkách	Rd=1,3*Rd normal conditons	montážní zatížení, provozní přechodové stavy
Transient conditions B Přechodové B	Components under Hydrostatic Testing Pressure (During Tests): Části potrubí vystavené tlakové zkoušce Components Distributor Mechanism Rupture of Safety Link Dílce rozvaděče při porušení pojistného elementu rozvaděcího ústrojí	Rd = 0,80*Re	Include Transient Effects: Test Pressure, Rupture of Safety Link of Distributor Mechanism, Zahrnují přechodové jevy: zkušební tlak, porušení pojistného elementu rozvaděcího ústrojí

ABBREVIATION

MT ..... Magnetic Particle Test / Zkouška magnetická práškovací
UT ..... Ultrasonic test / Zkouška ultrazvukem
RT ..... X-ray Test / Zkouška prozářením
VT ..... Visual Test / Zkouška vizuální
PT ..... Liquid Penetrant Test / Zkouška kapilární



Subject of test	Type of test	Defect	Standards: Methodology	Standards: Evaluation	Designation	Test Application Notes
Welds	MT	Surface	ČSN EN ISO 17638	ČSN EN ISO 23278		Required quality grade must be in accordance with surface quality
	PT	Surface	ČSN EN ISO 3452-1	ČSN EN ISO 23277		
	VT	Surface	ČSN EN ISO 17637	ČSN EN 5817		
	UT	Inner	ČSN EN ISO 17640/B	ČSN EN ISO 11666		
	RT	Inner	ČSN EN ISO 5579 ČSN EN ISO 17636-1,2	ČSN EN ISO 10675-1		
Castings	MT	Surface	ČSN EN ISO 9934-1,2,3	ČSN EN 1369		
	PT	Surface	ČSN EN ISO 3452-1	ČSN EN 1371-1	Cast into sand	Enter criteria for evaluation of circular and linear defects, confluxes and lines
				ČSN EN 1371-2	Exact casting	
				ČSN ISO 9916	Al and Mg alloys	
	VT	Surface	ČSN EN 13018	ČSN EN 1370	Surface roughness	
				ČSN EN 1370	Cast into sand	
	UT	Inner	ČSN EN 583-(1-6)	ČSN EN 12680-1	General use	
				ČSN EN 12680-2	High stress parts	
				ČSN EN 12680-3	Castings with sphere graphite	
	RT	Inner	ČSN EN ISO 5579	ČSN EN 12681		
Forgings	MT	Surface	ČSN EN ISO 9934-1,2,3	ČSN EN 10228-1		
	PT	Surface	ČSN EN ISO 3452-1	ČSN EN 10228-2		
	UT	Inner	ČSN EN 583 – (1-6)	ČSN EN 10228-3	Ferritic forgings	Necessary to determine scope of testing – lines or rasters, 100%
				ČSN EN 10228-4	Austenitic forgings	
				ČSN EN 10308	Bars	
Plates				ČSN 01 5042	Flat and tubular forgings	
				ČSN 01 5043	Circular forgings	
				SEP 1923	High stress	Necessary to determine directions of testing
	UT	Inner	ČSN EN 583 – (1-6)	ČSN EN 10160	Surface	Necessary to determine scope of testing – lines or rasters, 100%
					Edges for welding	Necessary to be performed separately
	VT	Surface	ČSN EN 13018	ČSN EN10163-1		
Material thickness	UT	-	ČSN 01 5021			

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NÁVRHOVÉ KRITÉRIA

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SPECIFICATION OF MATERIAL
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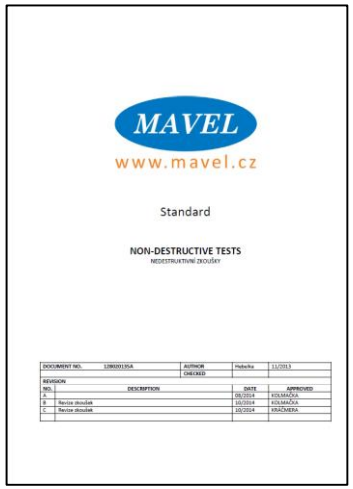

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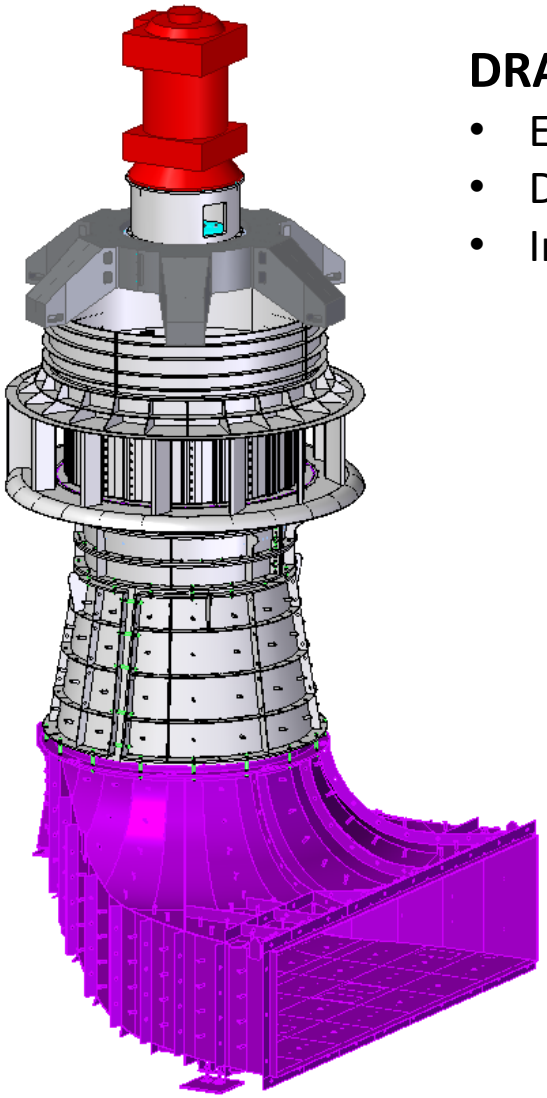
FEM Analysis

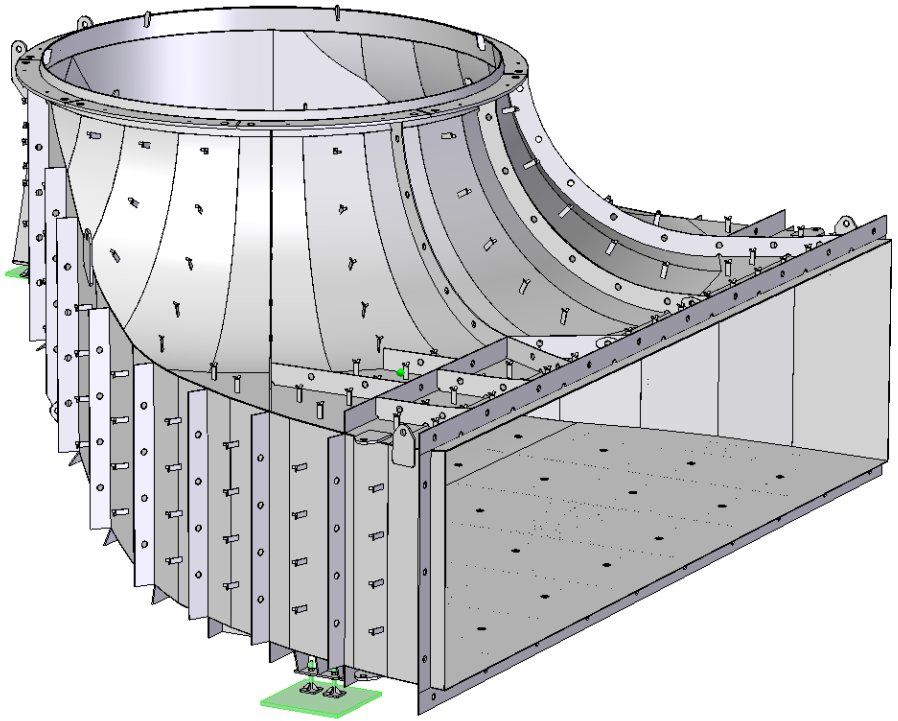


DRAFT TUBE ELBOW

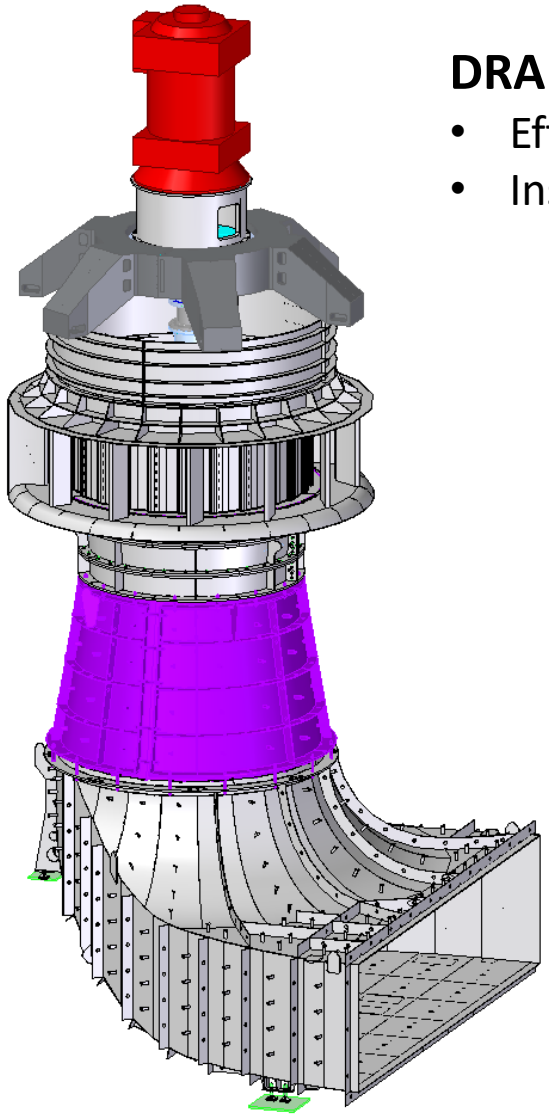
- Effect of concrete pressure
- Deformation from gravity
- Installation of supports

Analysis:

- Deformation
- Stress



FEM Analysis

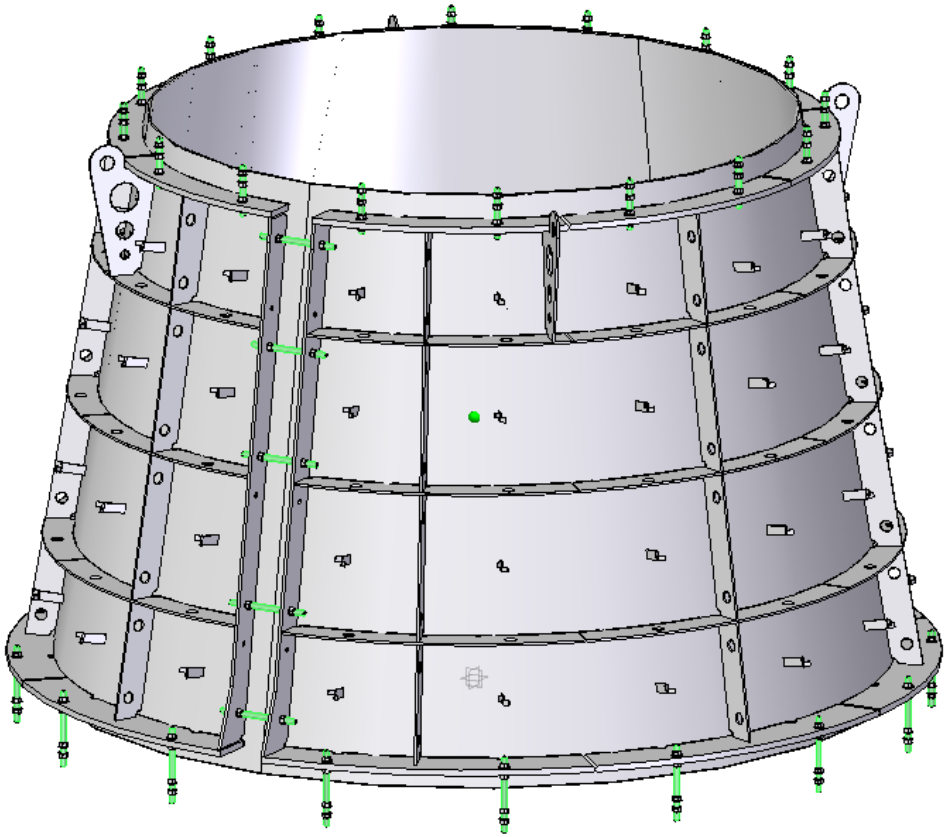


DRAFT TUBE CONE

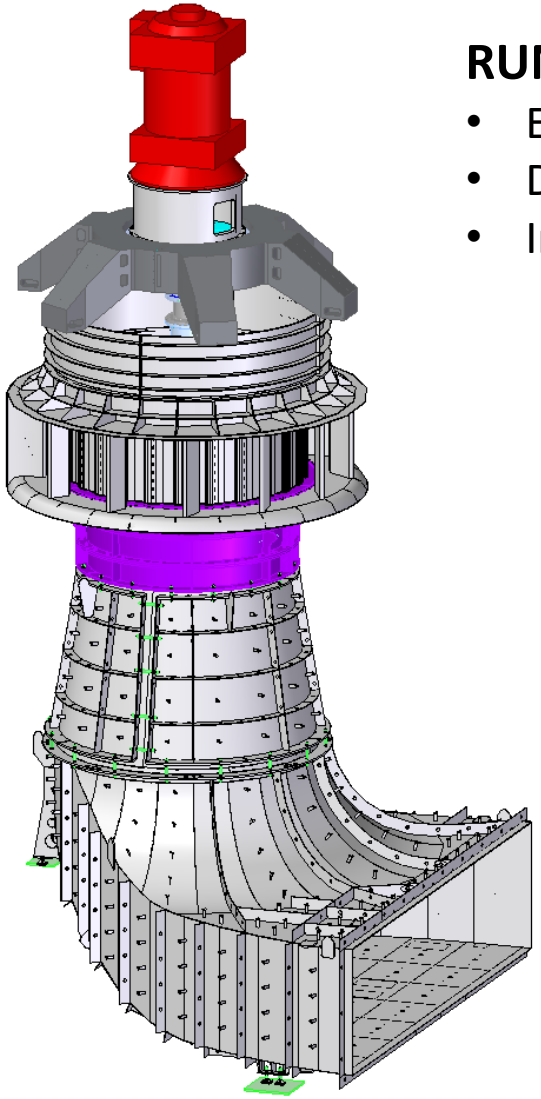
- Effect of concrete pressure
- Installation of supports

Analysis:

- Deformation
- Stress



FEM Analysis

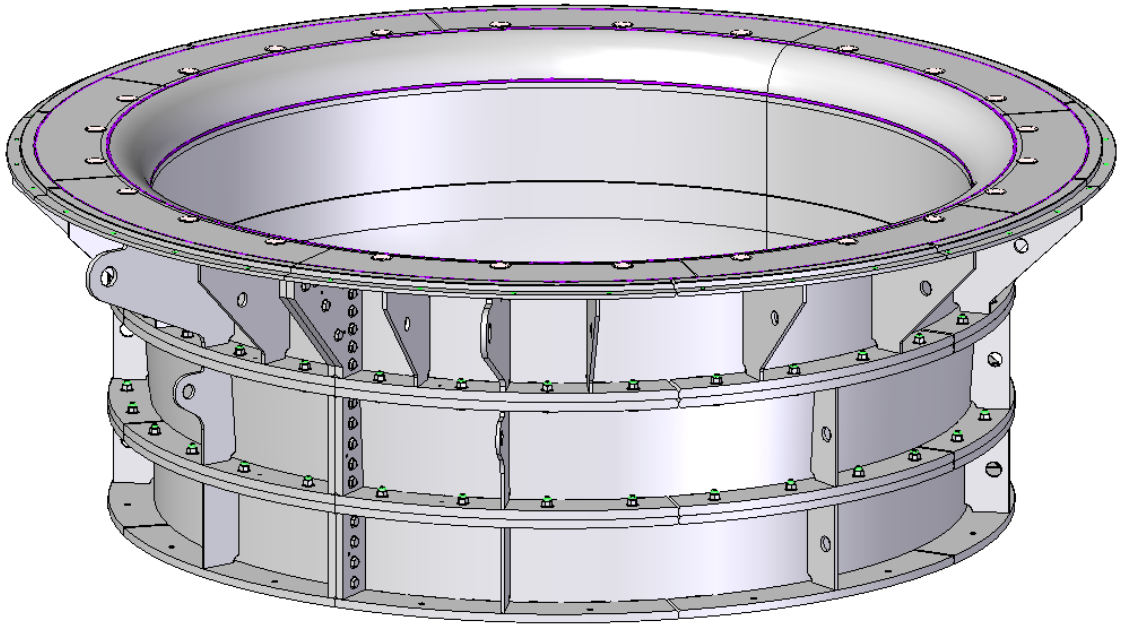


RUNNER CHAMBER

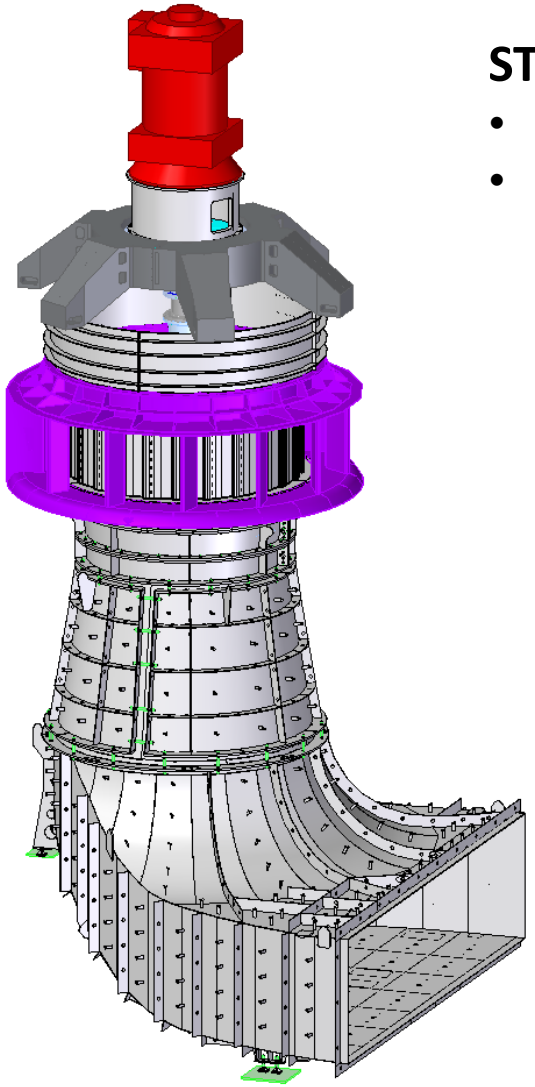
- Effect of concrete pressure
- Deformation from gravity
- Installation of supports

Analysis:

- Deformation
- Stress



FEM Analysis

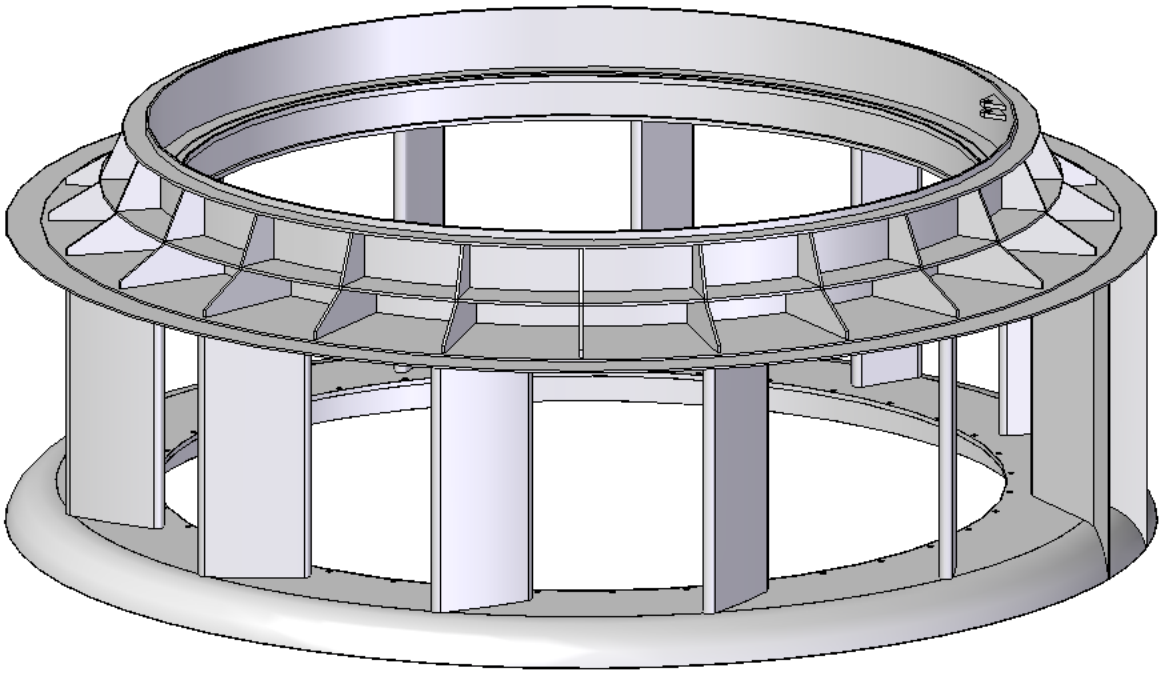


STAY RING

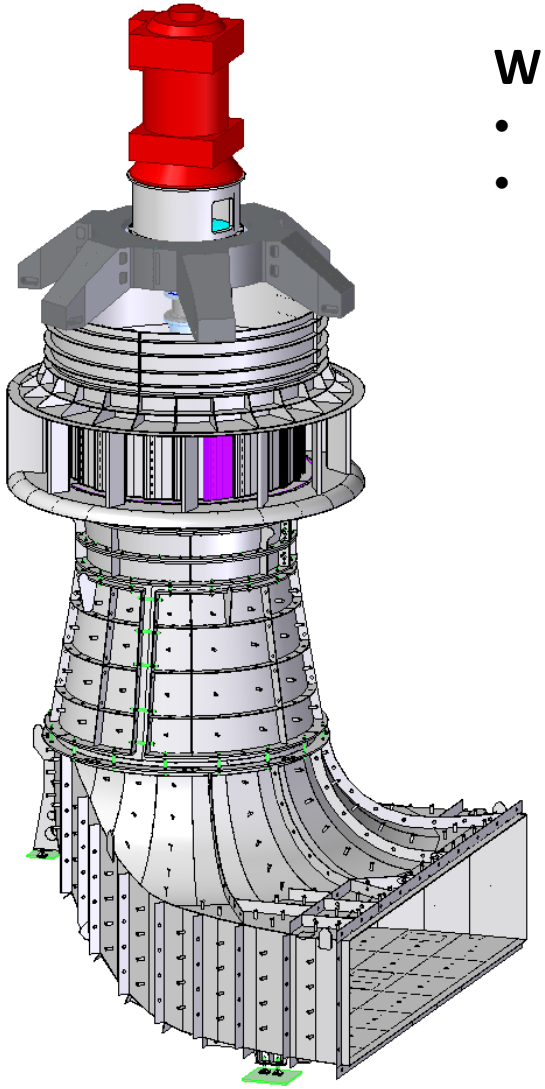
- Effect of concrete pressure
- Loading from steel structures
  - Reaction force of distributor

Analysis:

- Deformation
- Stress



FEM Analysis



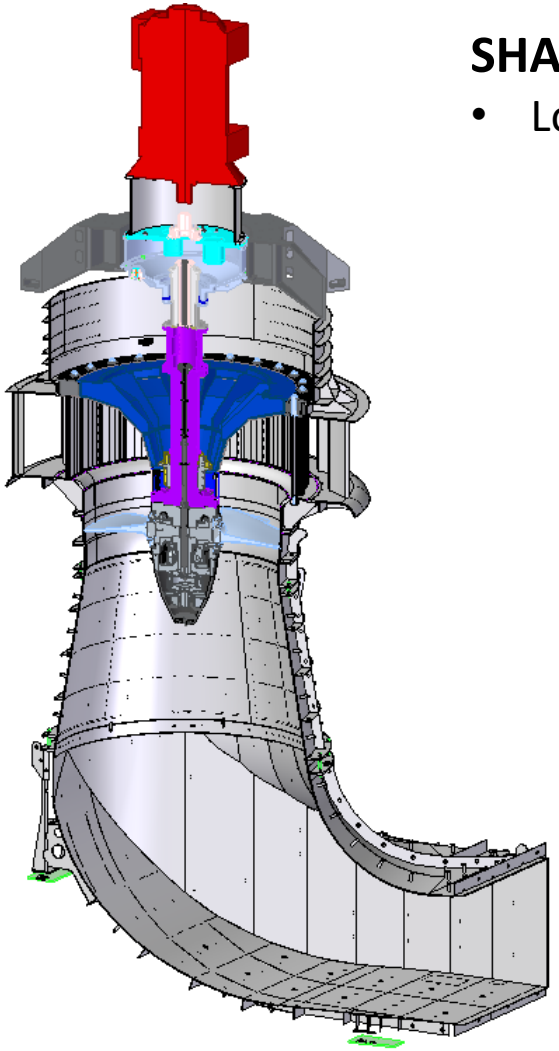
WICKET GATE

- Load from the flow of water
- Load from a foreign body

Analysis:

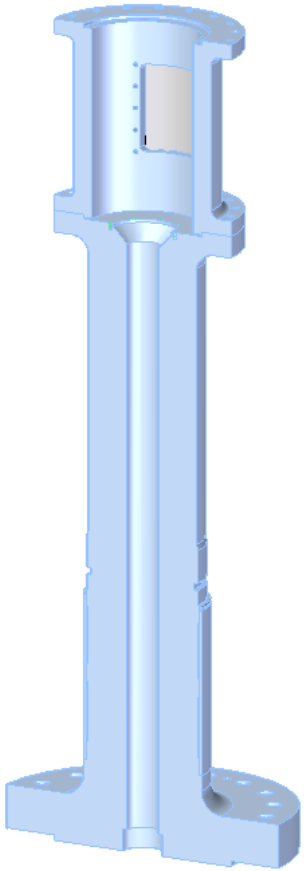
- Topology optimization
- Parametric optimization
- Deformation
- Stress

FEM Analysis



SHAFT AND COUPLING

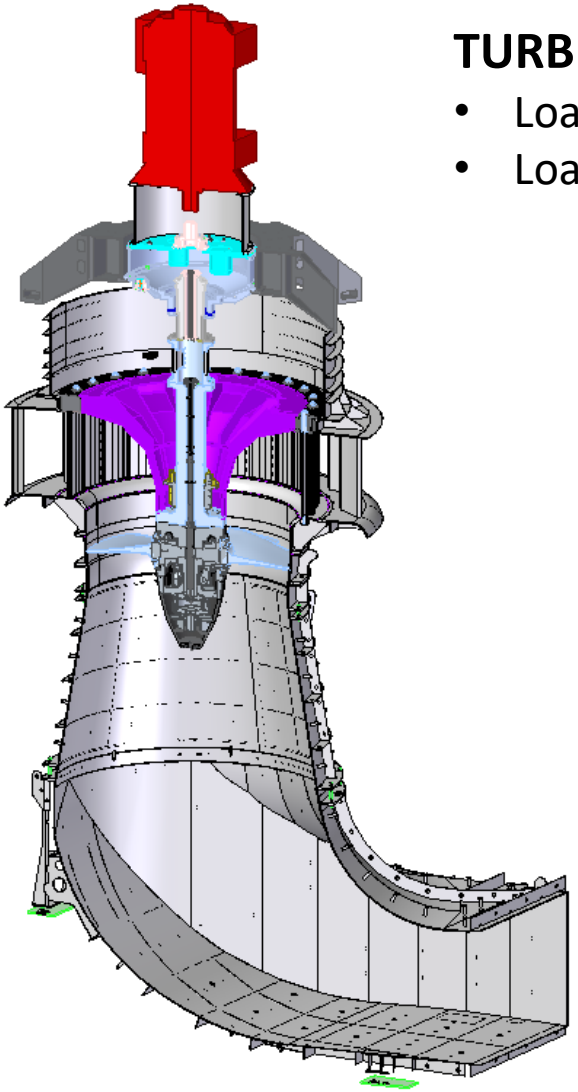
- Load from the runner
  - Moment
  - Axial force



Analysis:

- Deformation
- Stress
- Modal Analysis
- Harmonic response analysis

FEM Analysis

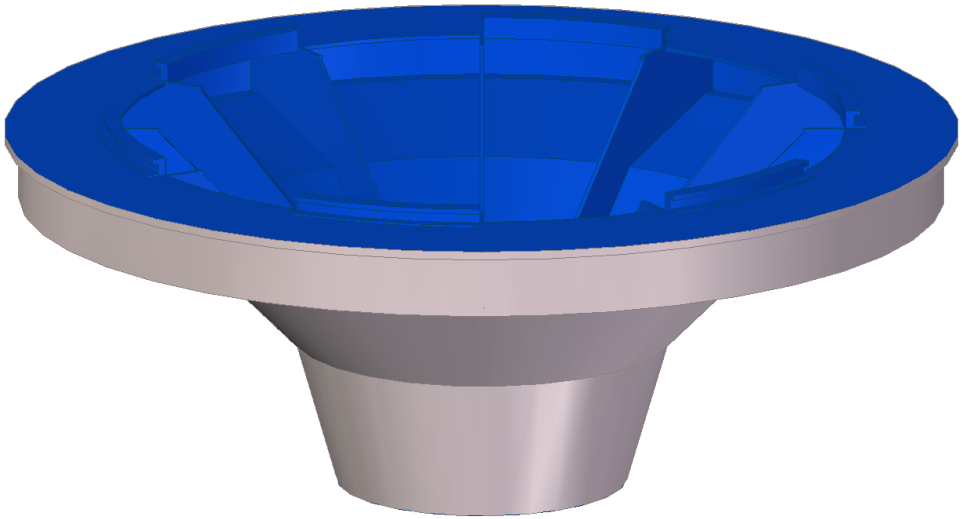


TURBINE COVERS

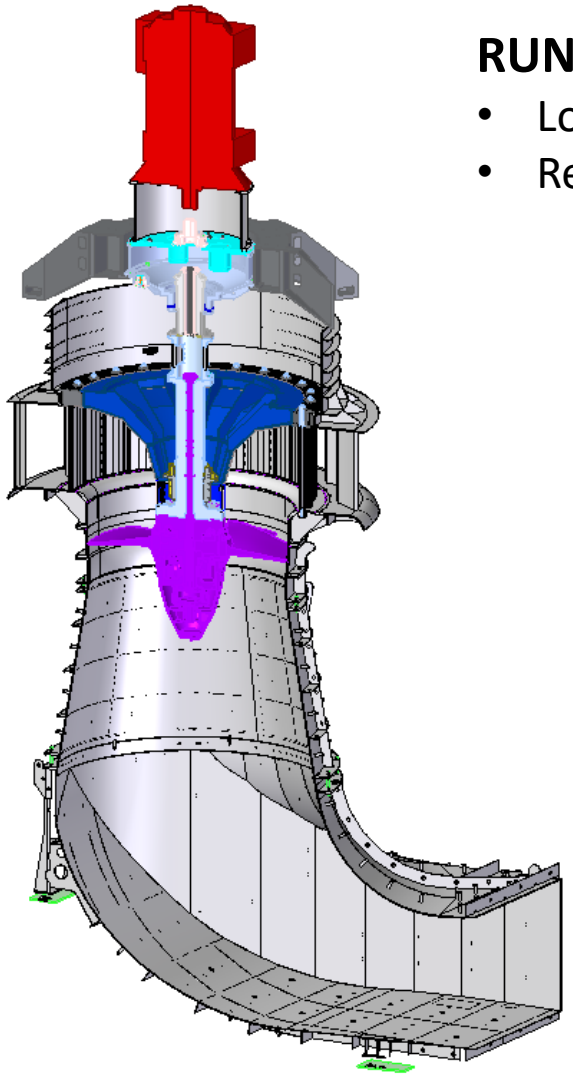
- Load from shaft (shaft, runner)
- Load from the water

Analysis:

- Deformation
- Stress



FEM Analysis

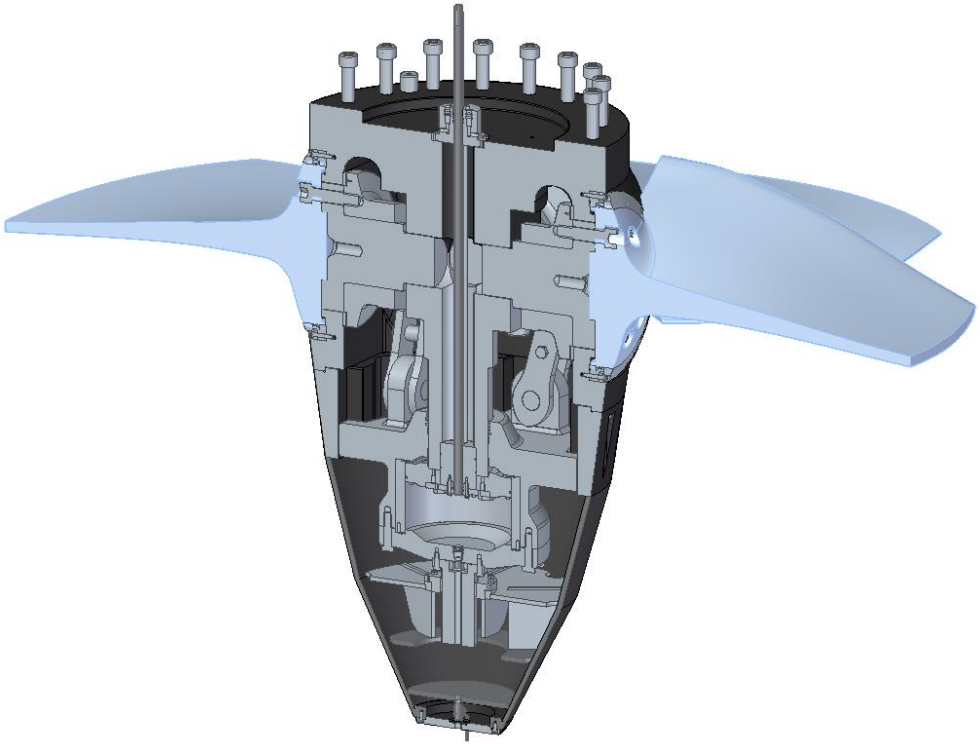


RUNNER

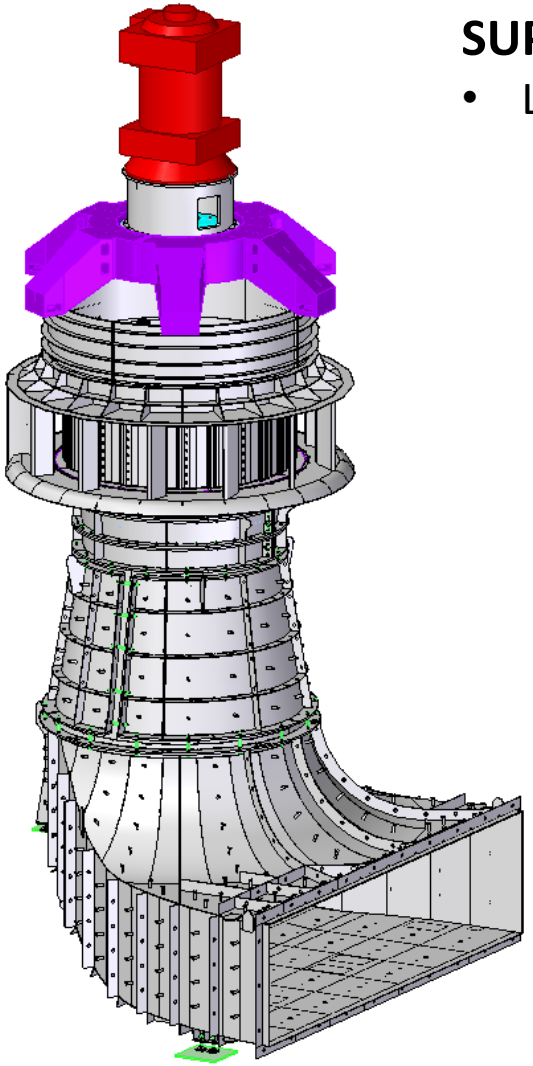
- Load from flow of the water
- Reaction forces in the mechanism

Analysis:

- Deformation
- Stress



FEM Analysis

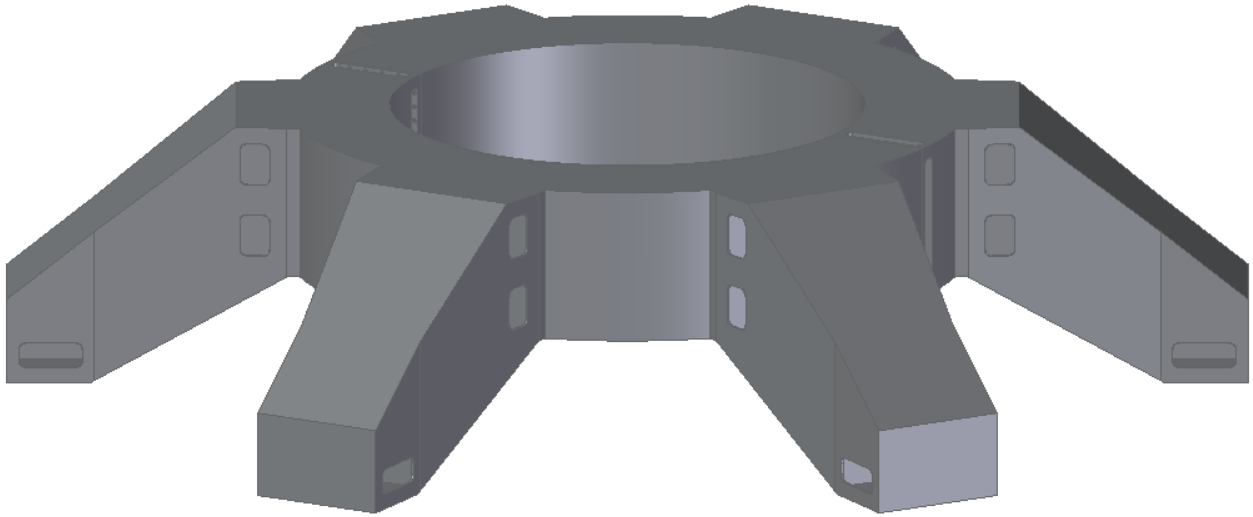


SUPPORT BRACKET

- Load from generator response
  - Axial force
  - Moment of generator

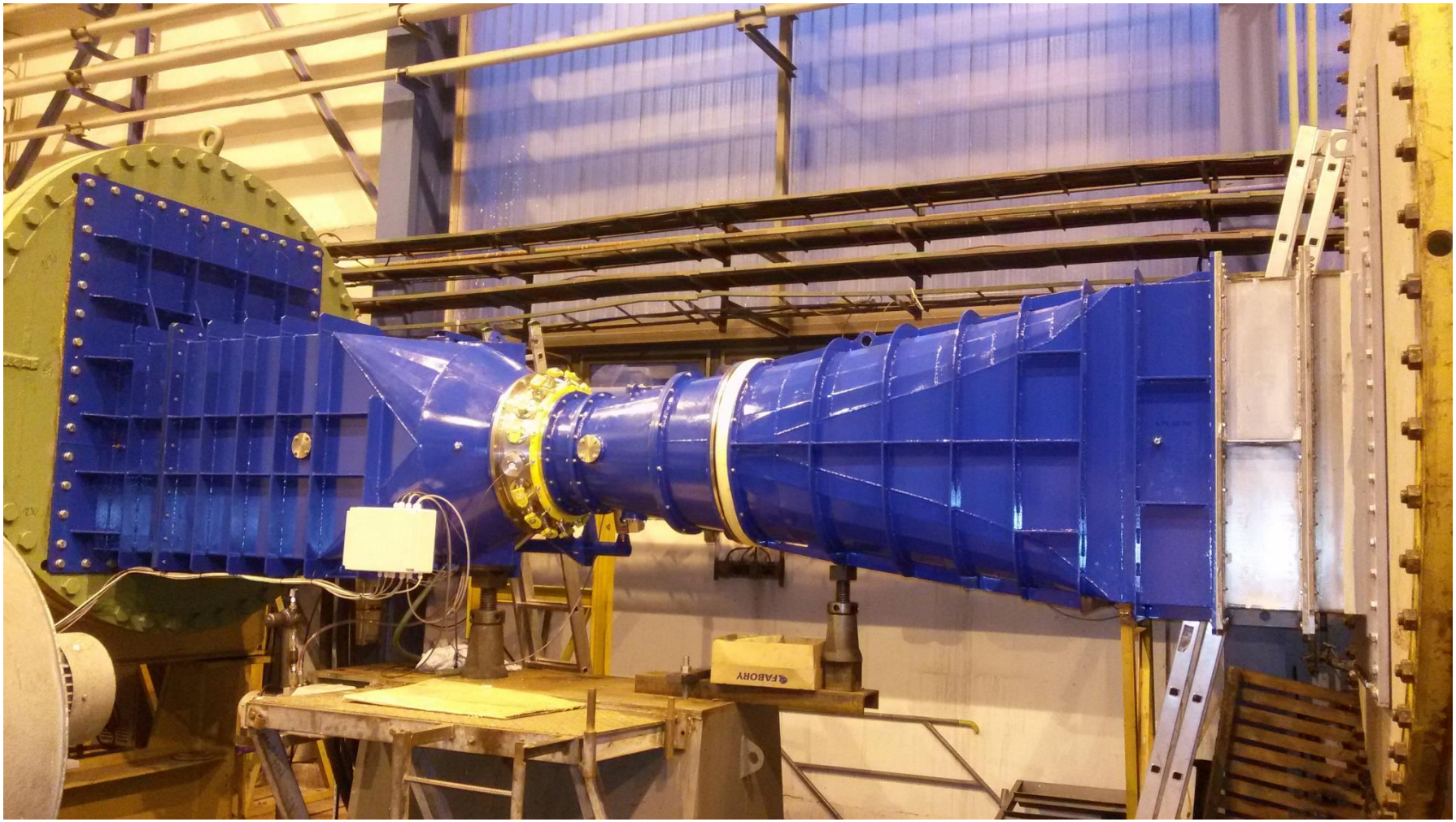
Analysis:

- Deformation
- Stress
- Modal Analysis
- Harmonic response analysis



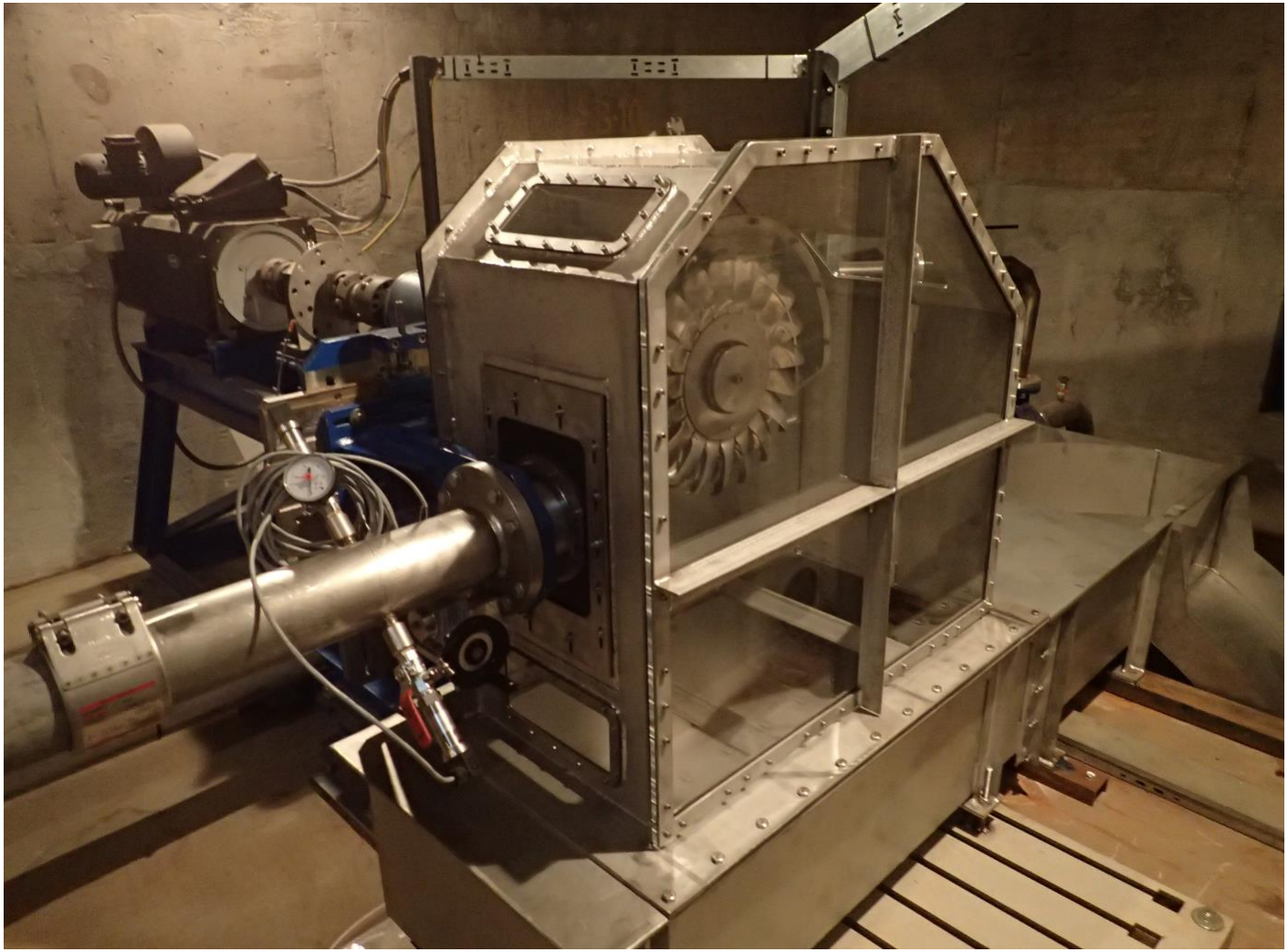
Testing of the water turbines

Testing



Testing

Testing



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Thank you for your attention