

Università degli Studi di Padova – Dipartimento di Ingegneria Industriale

Corso di Laurea in Ingegneria Meccanica

Relazione per la prova finale
«Progettazione preliminare di turbine
Pelton e Francis al fine di stimarne
l'installabilità»

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Laureando: *Giovanni Carlo Ruaro*

Padova, 23/09/2024

Fornitori leader a livello globale di apparecchiature elettromeccaniche e servizi per centrali idroelettriche, con oltre 180 anni di esperienza e una capacità mondiale installata di più di 471 GW (oltre 31.900 turbine).

ANDRITZ
Hydro

1. Preparazione

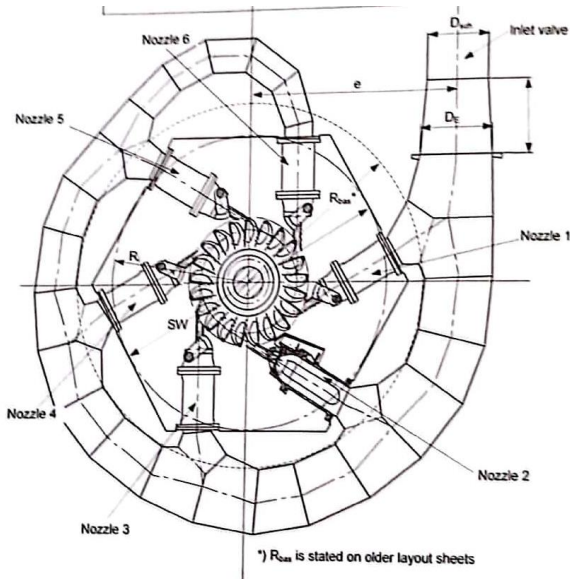
2. Calcolo e dimensionamento preliminare

3. Progettazione meccanica

➤ Approfondimento turbine Pelton



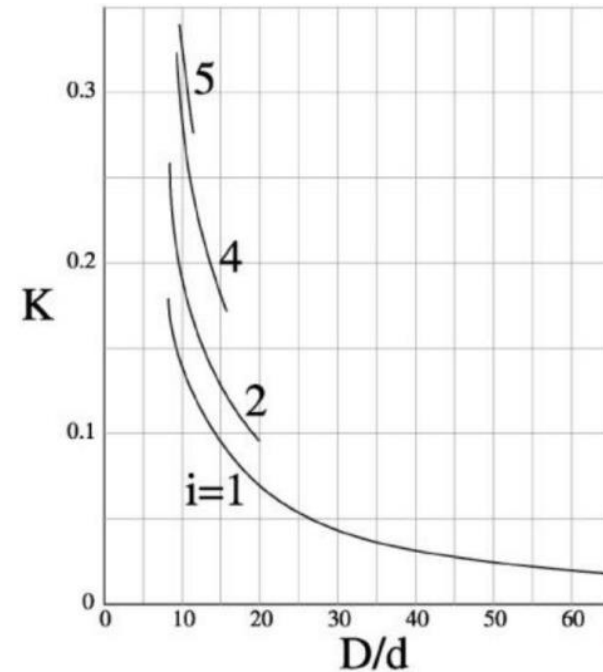
Fascicolo Berili



➤ Dimensionamento preliminare di una turbina Pelton



Libro Macchine 2



Fascicolo Berili

HTLS (Hydraulic Turbine Layout Sheet)

Runner: concave	Injector: New (ISM)	*) systematic value		Specified? (Yes/No)
D1 2150 mm	Do 235 mm	Distributor: Existing	z0 4 mm	
B2 570 mm	do 195 mm	DE 900 mm	e mm	
	So 138.0 mm	u mm	β mm	
D1/B2 3.77 -	So/Do 0.59	Runner Clearance Height:	ve 9.8 m/s	
z2 21 -	De 610 mm	Amin adm 2210 mm	ve/VE 1.090	
Db 2695.0 mm	DeT 580 mm	Amin eff. 3385 mm	H gross max. 593.55 m	
Dsp 2680.0 mm	dD 322 mm	Betting Level:	μB 60.0 bar	
Da 2715.0 mm	DT 1242 mm	CL Runner 1315.26 masl	μK 66.0 bar	
Ba 604.0 mm	dR 47 mm	TWL max 1310.80 masl	max. Waterhammer 10 %	
uB 7.20 *	α0 84.0 *			
mR 6882 kg	αN 50.0 *			
	Aen/Do2 2			
Man. Type: MicroGuss	ve 10.7 m/s			
Ref Model P1060	Ref Model Jn1069	Ref Model Bth2076V	Ref Model H12055	

	Hmax	Hrated	Hmin
HWL	1908.00	1900.00	1850.00
Refer Level	1314.21	1314.21	1314.21
H gross	593.55	585.55	555.55
H loss	13.17	13.17	13.17
H net	580.38	572.38	542.38
Q	10.12	10.12	10.12
Q OverLoad	11.13	11.13	11.13
P	52.13	51.46	48.85
P OverLoad	56.93	56.18	53.28

BERILI Pelton **ANDRITZ VALTECH HYDRO**

7 Description of the designations on the hydraulic turbine layout sheet (HTLS)
Example of a layout sheet:

HYDRAULIC TURBINE LAYOUT SHEET
PELTON TYPE TURBINE 888-99

Project: Berili Example / 59-07
Country: CH
Client: Kraftwerke Vorderhein AG (KVR)
Consultant: NOK AG
Alternative: spot

Acquisition: 2007
Layout: 2007
Manufacturing: 2007
Delivery date: 11.12.2006

Scope: 3 Pelton Turbines
Type: 521414A
Frequency: 50 Hz
Speed: 428.8 rpm

Generator: synchronous
Start device: direct driven
Remarks: item

EFFICIENCY CALCULATION
Ref Model: TANAHASA/ST-95
Layout Rev: 01

ACCEPTANCE TEST
Model test: thermodynamic
Site test: thermodynamic
Remarks: Laboratory: HSY

Uncertainty % = ±0.85 (10 Yrs Eff)
Uncertainty % = ±0.15 (50 Yrs Eff)

Specified? (Yes/No)
STEP UP
In % = 0.09
In % = 15.17
IEC 193

Runner: concave
D1 2150 mm
B2 570 mm
D1/B2 3.77 -
z2 21 -
Db 2695.0 mm
Dsp 2680.0 mm
Da 2715.0 mm
Ba 604.0 mm
uB 7.20 *
mR 6882 kg

Injector: New (ISM)
Do 235 mm
do 195 mm
So 138.0 mm
So/Do 0.59
De 610 mm
DeT 580 mm
dD 322 mm
DT 1242 mm
dR 47 mm
α0 84.0 *
αN 50.0 *
Aen/Do2 2
ve 10.7 m/s

*) systematic value
Distributor: Existing
z0 4 mm
DE 900 mm
e mm
u mm
β mm
Rbas mm
ve 9.8 m/s
ve/VE 1.090
H gross max. 593.55 m
μB 60.0 bar
μK 66.0 bar
max. Waterhammer 10 %

Casing: Modified
BG1 2600 mm
BG2 1000 mm

Runner Clearance Height:
Amin adm 2210 mm
Amin eff. 3385 mm

Betting Level:
CL Runner 1315.26 masl
TWL max 1310.80 masl

Man Type: MicroGuss

Ref Model: P1060, Jn1069, Bth2076V, H12055

	Hmax	Hrated	Hmin
HWL	1908.00	1900.00	1850.00
Refer Level	1314.21	1314.21	1314.21
H gross	593.55	585.55	555.55
H loss	13.17	13.17	13.17
H net	580.38	572.38	542.38
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Q OverLoad	11.13	11.13	11.13
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THURST (Values per Runner)
F Jet 339.9 kN
FA hyd 3.2 kN
FR hyd 520.8 kN
LR hyd 10.00 *

VENTILATION LOSSES (per Runner)
P Vent air 85 kW
P Vent water 85 kW
Aeration m³/s

PHYSICAL PROPERTIES
Average water temp: 10 °C
Maximum water temp: 18 °C
Average air temp: 115.4 °C
Geographical latitude: 47 °

REMARKS:
Hydraulic Turbine Layout Sheet as example for BERILI

Layout: Karakolov
Checked: Humann
1st Issue: 16-Aug-07
Revision 03: 8-Apr-08

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Obiettivi:

- Ricavare dimensioni principali delle turbine (diametro della girante, diametro del getto,...) → **TURBINE PELTON**
- Verifica fattibilità strutturale e valutazione efficienza dei cono di scarico → **TURBINE FRANCIS**

$$K = \frac{\pi n}{30} \frac{Q^{0,5}}{(gh)^{0,75}}$$

$$ku = \frac{\eta_{id}}{2\varphi_u}$$

$$\varphi_u \approx 0,96 \div 0,98$$

$$\eta_{id} \approx 0,88 \div 0,9$$

$$\frac{D}{d_0} = \frac{2,1ku\sqrt{2i}\sqrt{\varphi_u}}{K}$$

$$c_1 = \varphi_u\sqrt{2gh}$$

$$d = \sqrt{\frac{4Q}{\pi ic_1}}$$

$$u = ku\sqrt{2gh}$$

$$D = \frac{60u}{\pi n}$$

Analitico

Metodi

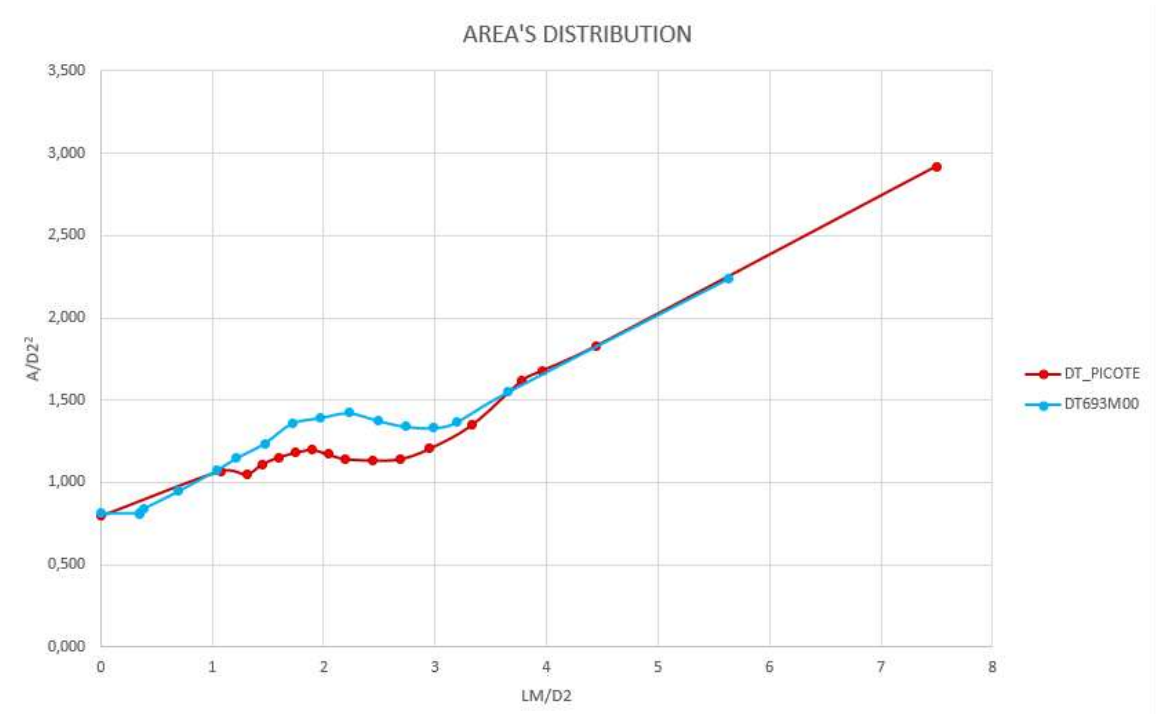
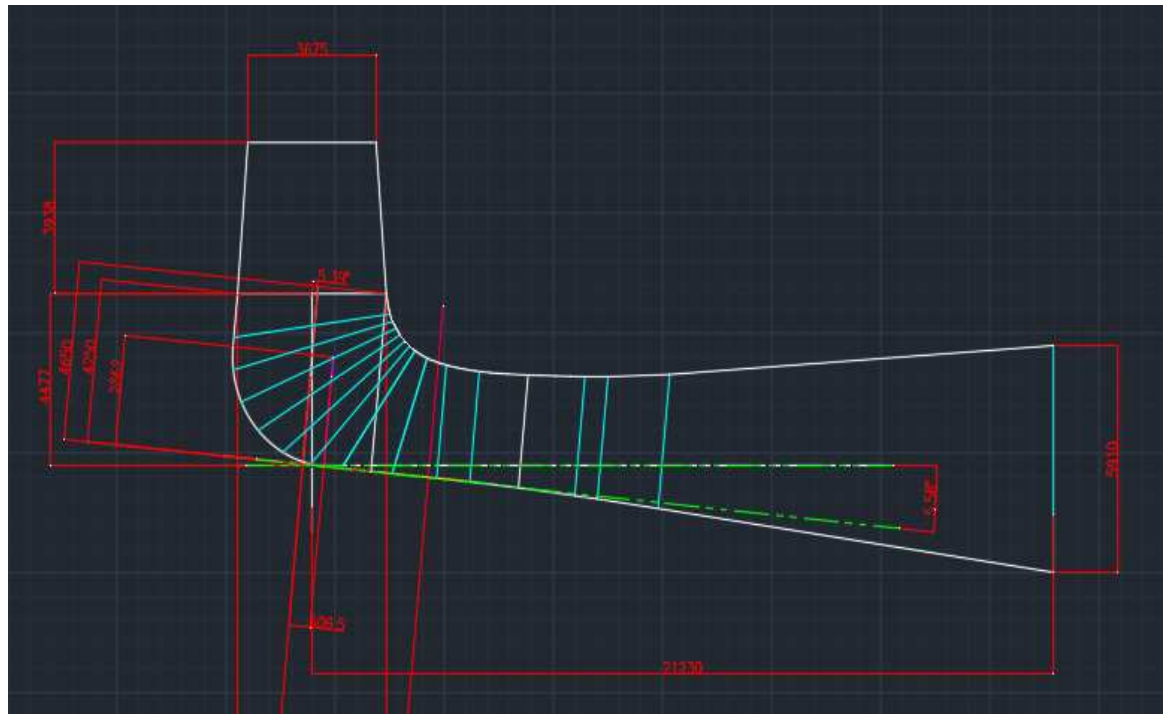
**Software di calcolo
Pelton_ETA**

Confronto tra opzioni fattibili

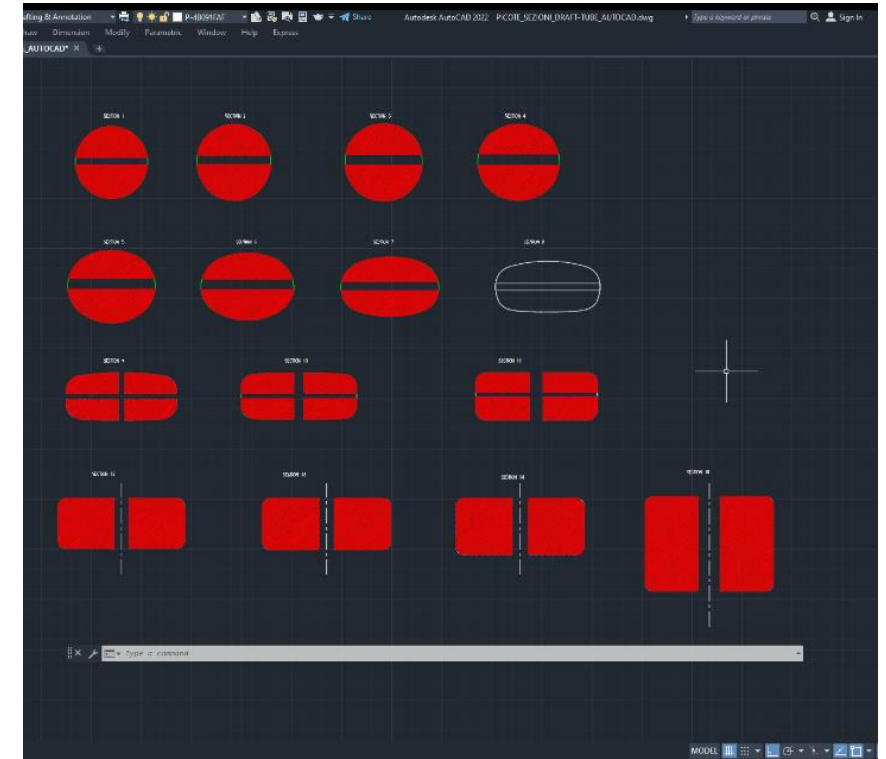
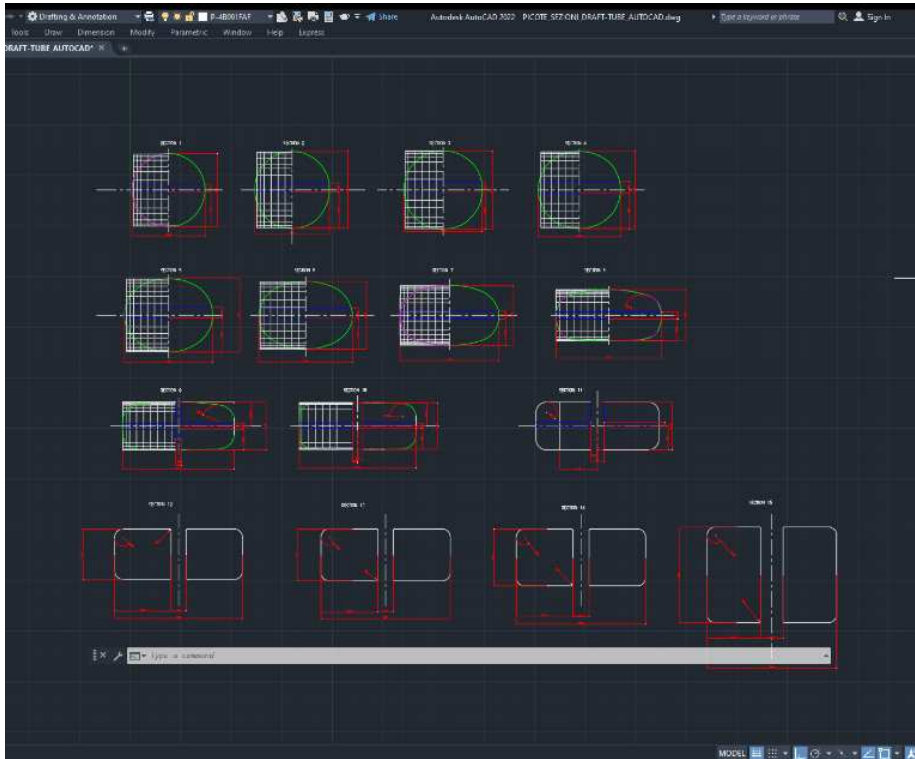
SCELTA

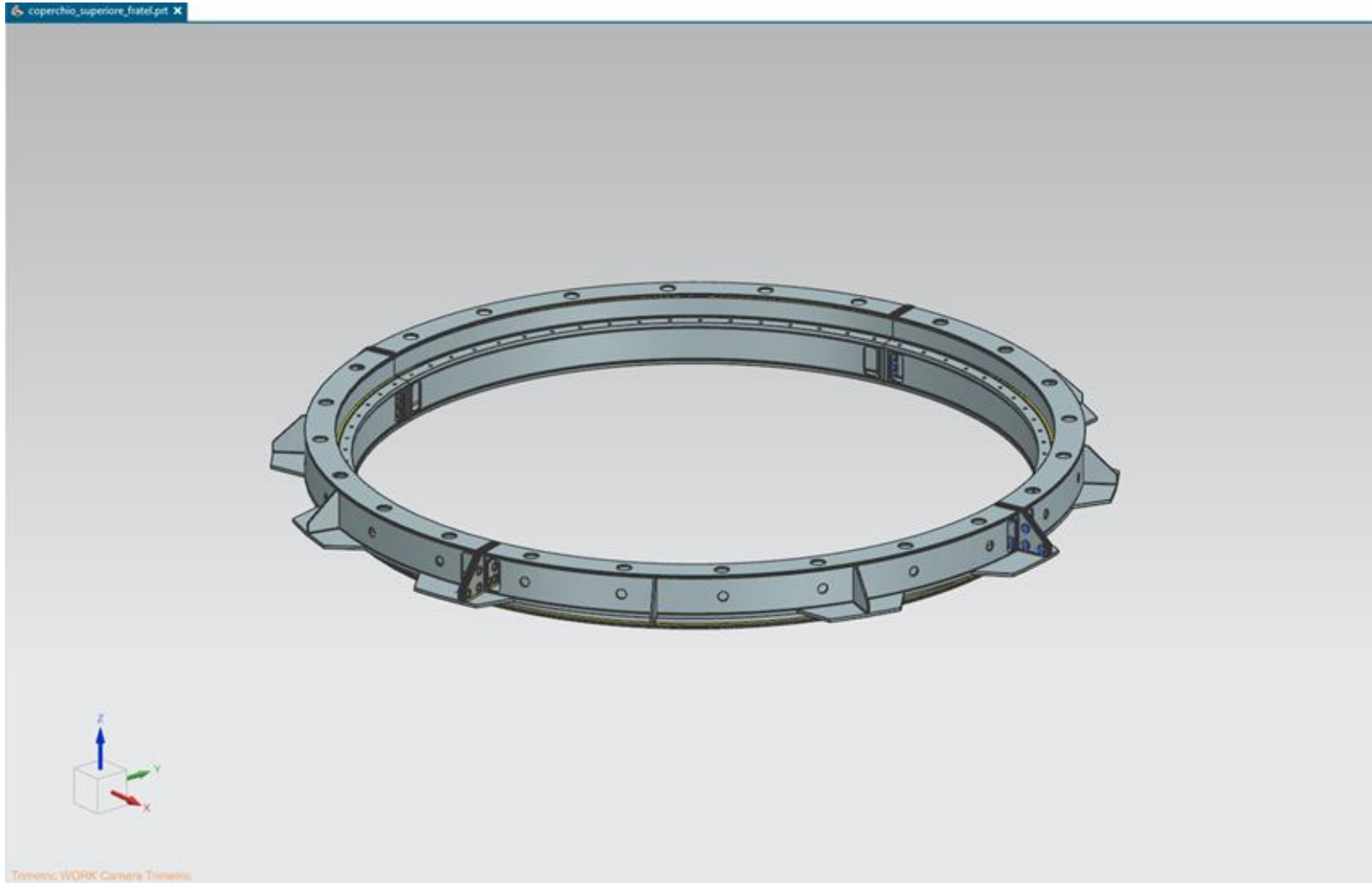
Hydraulic and Geometrical Data of the Pelton Turbine: PeltonETA	
General Layout Data:	
Turbine Category:	Prototype:
Project Name:	
Full Load Discharge at Rated Head:	Q_FL = 3,8 [m³/s]
Q Reference (FL=full load, OL=overload):	FL
Rated Net Head:	H_{n,rated} = 570 [m]
Minimum Net Head:	H _{n,min} = 550,23 [m]
Maximum Net Head:	H _{n,max} = 593,52 [m]
Maximum Static Head:	H _{stat,max} = 597,2 [m]
Turbine Type (selection):	h1R2N
Deflector Type (selection):	deflecting
Orientation of Turbine Shaft:	horizontal
Number of Active Injectors per Runner:	z0/n _{runner} = 2 [-]
Angle in-between 2 Neighbour Injectors:	alpha = 75 [°]
Frequency (16.667 Hz, 50 Hz, 60 Hz):	f = 50 [Hz]
Synchronous Speed (selection):	n _{syn} = 500 [1/min]
Actual Speed (overwrite if necessary):	n = 500,000 [1/min]
Latitude:	phi = [°]
Altitude of Runner Centerline:	z_CL = 672,8 [masl]
Pipe Roughness inside Distributor:	k_distr = 0,1 [mm]
Pipe Roughness inside Injector:	k_inj = 0,05 [mm]
Pipe Roughness at Nozzle Orifice:	k_orifice = 0,005 [mm]
Physical Properties:	
Average Water Temperature:	theta = 8 [°C]
Kinematic Viscosity:	nu = 1,39E-06 [m²/s]
Gravitational Acceleration:	g = 9,805 [m/s²]
Water Density at the Inlet Valve:	rho = 1002,5 [kg/m³]
Average Water Density:	rho_avg = 1001,2 [kg/m³]
Runner: Runner Layout	
Runner Bucket Profile (selection):	ALPHA
Category of Bucket Profile:	alpha
Manufacturing Type (selection):	Fully Forged
Pitch Circle Diameter:	D₁ = 1953 [mm]
Nominal Inside Bucket Width:	B₂ = 471 [mm]
Characteristic Specific Speed:	D₁/B₂ = 4,15 [-]
Admissible characteristic Specific Speed:	(D ₁ /B ₂) _{adm} = 3,20 [-]
Estimated maximum Stress Amplitude:	sigma_max = 16,2 [N/mm²]
Normalized Bucket Load at Full Load:	phiB2_{100%} = 0,1031 [-]
Max. normalized Bucket Load at S=S0:	phiB2_max = 0,1088 [-]

- Il draft tube (o condotto di scarico) è un componente fondamentale nelle turbine idroelettriche **Kaplan** e **Francis**.
- Quando si effettua il "draft tube comparison", si confrontano diversi condotti di scarico **geometricamente simili**, per determinare quale sia il più efficiente per una specifica applicazione.



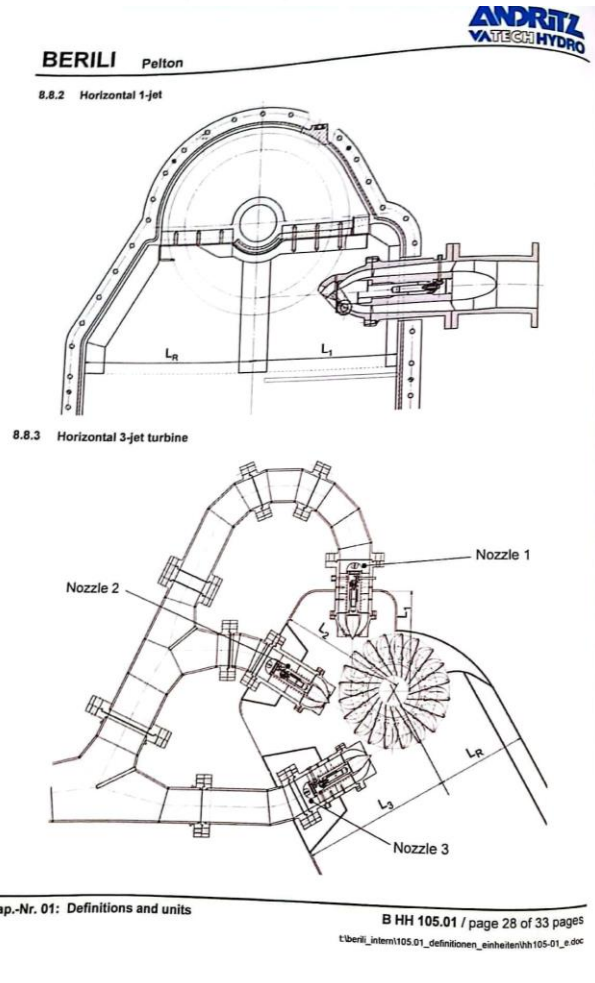
- Adimensionalizzazione
- Acquisizione dati



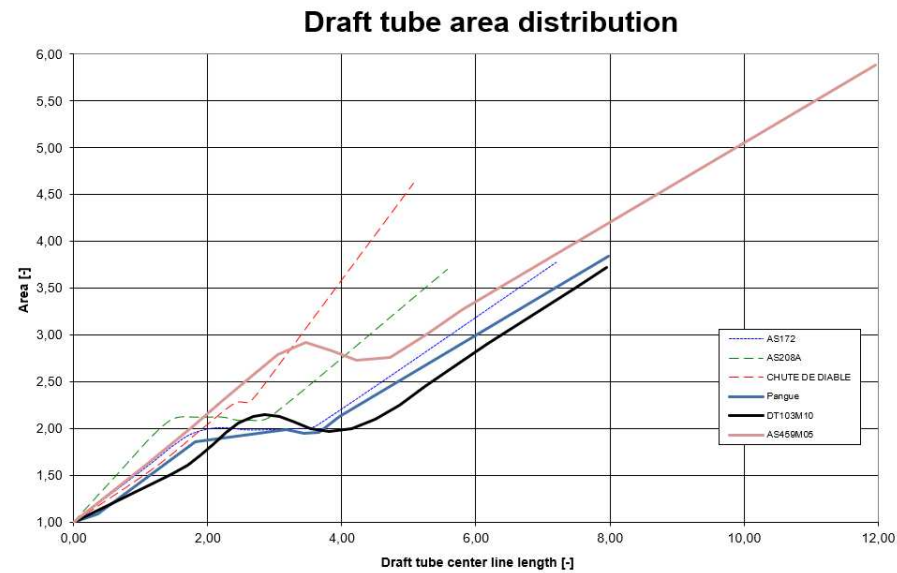


Obiettivi del lavoro

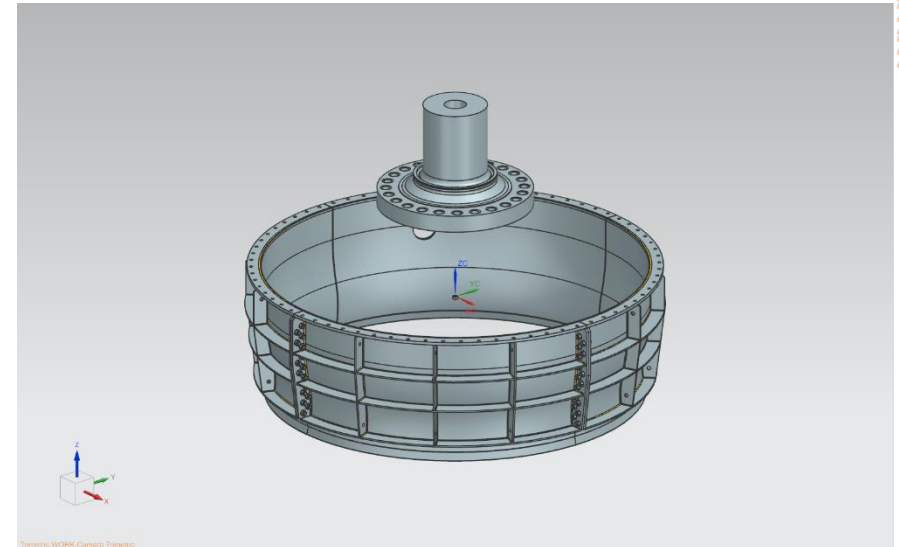
1.



2.



3.



**GRAZIE
PER
L'ATTENZIONE**

Giovanni Carlo Ruaro