Engineering Calculation of Penstock in HPP Radove, Albania

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Abstract

Energy and economy in the global and regional plane, make an iseparable strategic binomial. These two problems are an essential part of regional and global development plans. To include these in the increasing trend, each country or region draw detailed designs, in order to operate with efficiency their resources and natural resources. The production of energy from renewable resources is the most envied manner in securing the energy.Many countries, towns and villages around the world have already implemented the partially or fully supply of their citizens with recondition energy, have implemented efficiency measures for energy in their buildings and industries as well as measures for the effective operation of the resourses

In this challenge, in the past two decades, is involved Albania as well, which fortunately is favored by its geographical position and natyral resourses. In Albania are build about 136 SHPP, during the past two decades, which produce abour 24.1% of the enery of the country. In the development of this important sector are involved not only policymakers but also the scientific institutions and the best specialists of that field. Such participation was necessary in order to solve many problems such as preserving and protecting the environment, flora and fauna, to increase buildings security, to increase the efficiency of rational use of water resources.

In the desgns for construction of small hydro power plants, special importance was given to the Penstock of HPP as it deals with its security, with losses in pipes and with the cost of construction, etc.

KEYWORDS: efficiency, engineering calculation, gate, hydraulic punch, hydropower plant, penstock, resourse, tube thickness, ventilation tube.

INTRODUCTION

In a comprehensive assessment , seeing the role and weight the energy has in all sectors of economic and social life, can be said to be a determining role, it becomes clear that managing the energfy with efficiency is a must to ensure a safe and progressive development of society [1]. Approching this issue in the framework of a workshop creates an opportunity to exchange experiences between personalities and actors, as well as entities in this area, to: Energy Efficiency, Energy Management, Security of Supply, renewable resourses of energy and its efficiency. New technologies in energy must be complementary to a very sensitive aspect as environmental protection [1].

Albania has huge reserves of energy and in this context, no water sources are excluded which are to be considerable. The efficiency of natural resources and energy, energy autonomy are factors that lead to economic growth, employment growth and sustainable development. As referred to above the Albanian government has drawn up detailed plans and oriented private business to invest in rational exploitation of all capacities of natural resources, mainly water resources by building several small hydro power plants. During these 15 years are built around 136 hydropower plants with an installed power of 1413 702 MWh or 24.1% of general production . It is foreseen to be build 160 HPP very close [1].

MATERIALS AND METHODS

All the data are part of the engineering assessment for HPP Radove. Part of it are the calculations of Penstock of HPP Radove. Catchment basin of Çarshovë, is located in the north-western city of Leskovik - Albania, and flows into Vjosa River. This basin is fed by waters coming from small streams in quote 500 to 900 meters (a.s.l) from the accumulation of rainfall and snow water, which reaches the value from 1000 to 1300 mm per year with an average of 1110 mm. For better use of this resource it is designed to build several hydropower plants, among them the HPP of Radova. Radova, where the HPP is built, is part of the suburban of Leskovik and it lies approximately 3.3 km to the northwest.

Actual technical data of HPP Radove

Quota of intake structure :	K1 = 632.0 m
Quota of HPP building:	K2 = 469.0 m
The height of the gross fall:	Hb =163.0 m
Total losses	Hw = 9.00 m
The height of the net fall:	Hn = 154.0 m
Installed power:	N = 2728 Kw
The energy produced	E = 10 656 590 Kwh (Annual production of HP Radove.Bussiness Plan)

The object of this study

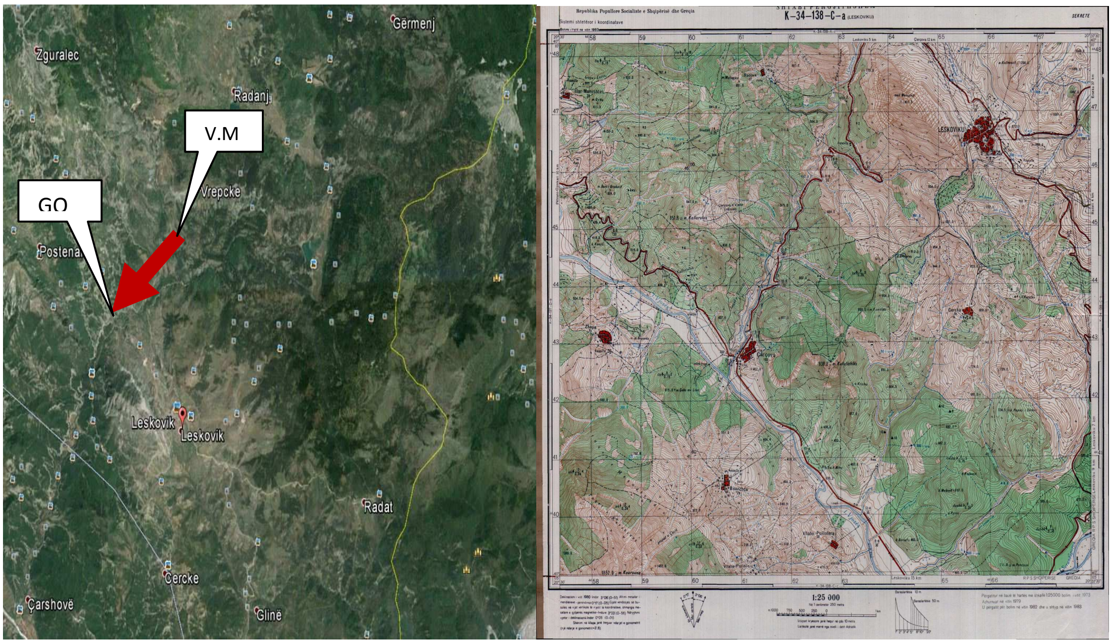

Figure 1. Map of location of the HPP Radove

Economic diameter of turbine pipeline

The turbine pipeline has been subject to the calculations to determine the diameter and its thickness . To determine the diameter it has to undergone a technical economic analysis, its subject is the annual cost and energy losses. The diameter is considered acceptable when the amount of the cost of the pipeline with an annual value of energy is minimal for a certain range of diameters review. Data for the analysis were taken as follows:

Maningut rate: 0.011
Flow in the pipeline: 2.1 m^3/sek
Length of pipeline: 2180 m
Cost of energy: 0.0535 Euro/kwh
Price of pipeline: 1600 Euro/Ton
Annual inflation: 2.5%
Reviewed diameters: (0.4 – 2.5) m

RESULTS AND DISCUSSIONS

Constructive calculations of penstock

1. **Selection of turbine diameter.** Calculations are made in Excel and are summarized in the following table which is generated by the respective graphical presentation (Chart 1).

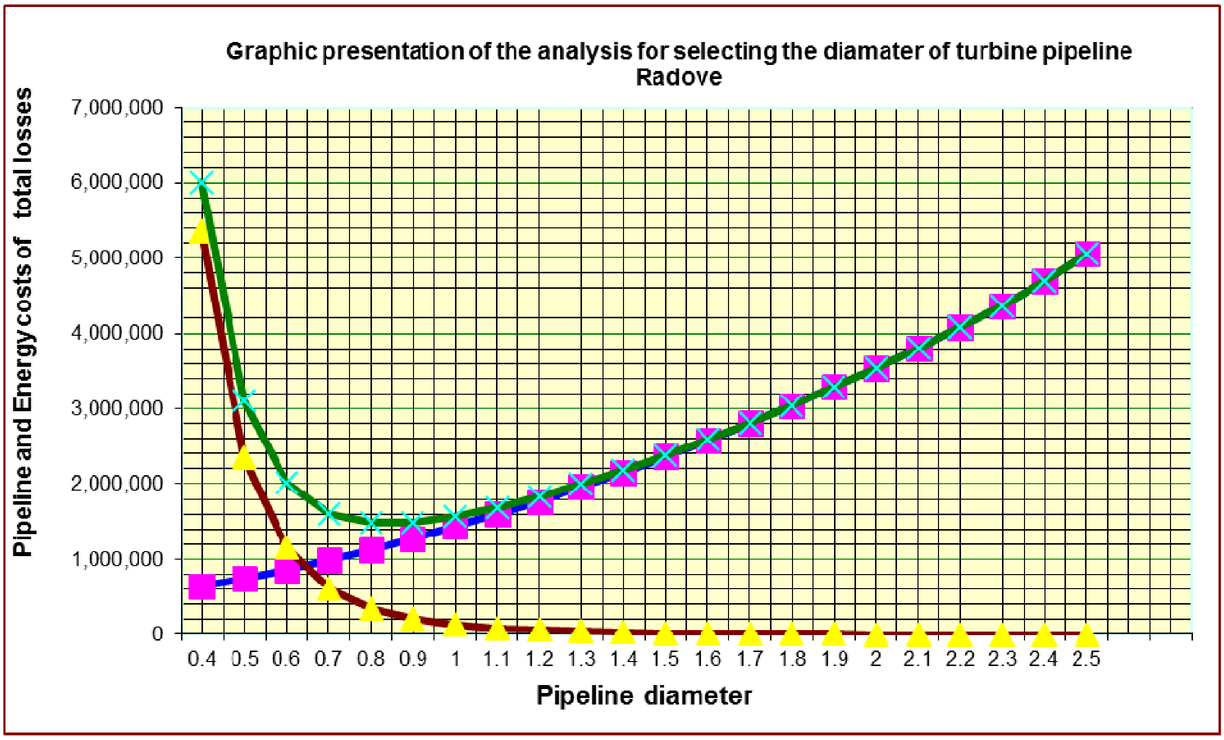

Chart 1. Graphic presentation of the analysis for selecting the diameter of turbine pipeline Radove.

By examinning several diameters we can conclude that the most economic diameter is that between diameters

D = 1.0-1.2 m.

D = 1000; losses = 11.98 m

D = 1100; losses = 7.207 m

D = 1200; losses = 4.532 m

The above calculation are made for steel pipes.

Based on the calculations made, the most optimal diameter of Penstock is diameter D = 1100 mm with losses 7.207 m.

2. Thickness calculation of turbine pipeline. Calculation of the wall thickness of the turbine pipe is made in accordance with the following requirements:**:**

- Selection of the pipeline material,
- Its maximal resistance in stretching,
- Pipeline diameter
- And pressure of work system

In the steady outflow , the flow is considered constant with the time and work pressure is calculatedd by the height of the water column above the point that is taken into consideration. In this case the thickness of the pipe wall is calculated:

$$e = \frac{P_j D}{\sigma_f}$$

where:

e = Pipe wall thickness (mm)
P_1 = Hydrostatic pressure (KN/mm^2)
D = Internal Diameter (mm)
σ_f = Allowed stress in stretching(drawing out) (KN/mm^2)

For steel pipes the above formula is transformed as follows:

$$e = \frac{P_1 D}{2\sigma_f k_f} + e_s,$$ where:

e_s – Extra thickness for corrosion in mm
k_f – welding coefficient; k=1 for seamless pipes and k=0.9 for controlled welding with NDT
σ_f – Allowed stress in stretching(drawing out) (1400 kN/mm^2)

The pipe must be rigid enough to cope with the risks of deformation during assembly. For that are given various thickness from different organizations. We shall present two of them:

a- e_{min}= 2.5*D_t + 1.2 mm (Pipe diameter in meters)
b- e_{min}= (D+508)/400 (Dimensions in mm)

For the first case the diameter selected results e_{min}= 2.5 x 1.1 + 1.2 = 2.75 mm
And fot the second case e_{min}= (1100 + 508)/400 = 4.02 mm
Rapid change of the water flow in the pipeline as a result of operating the system during opening or closing is associated with a considerable increase or decrease of the pressure due to the appearance of the hidraulic punch reaching values that exceed several times the value of the hydrostatic pressure of the system.
This possibility must be taken into account by calculating the walls thickness of the pipeline to meet the effect of hydraulic punch.
The velocity of wave propagation in the pipe during the hydraulic punch is calculated as:

$$c = \sqrt{\frac{10^{-3} K}{1 + \frac{KD}{Et}}}$$

where:
K = Module of elasticity of water 2.1x10^9 N/m^2

E = Module of elasticity of pipe material (N/m^2)
D = Pipe diameter (mm)
t = Thickness of the pipe wall (mm) aproved before
The time the wave return to the gate immediately after closing is atherwise called critical time andd is given by the formula:

$$T = 2L/c$$

Pressure arising in the closing gate when vales return after its immediate closure is calculated:

$$P = \frac{c\Delta_v}{g}$$

where: Δ_v = Change of water velosity
Applying the data in the above sentences to our pipe it results:

$$c = \sqrt{\frac{10^{-3} x 2.1 x 10^9}{1 + \frac{2.1 x 10^9 x 1100}{2.1 x 10^{11} x 10}}} = 1011.76 m/s$$

The pressures caused by the wave:

$$P = \frac{1011.76 x 2.21}{9.81} = 228.02 m$$

Critical time for our case is: T = 2 x 2180/1011.76 = 4.3 sek.

If the changee in velosity is more than 10 x T, the super-pressure is small or it does not exist and the case is ignored. When this time is more than 2L/c, the super-pressure will develop incomplete, in this case the Allievi's formula should be used to determine the super-pressure due to the phenomenon of hydraulic punch:

$$\Delta_p = P_0\left(\frac{N}{2} \pm \sqrt{\frac{N^2}{4} + N}\right)$$

where:
P_0 = Hydrostatic pressure

and

$$N = \left(\frac{LV_0}{gP_0 t}\right)^2$$

where:
V_0 = Water velosity (m/s)
L = Pipeline Length (m)
P_0 = Hydrostatic perssure (m)
t = closing time
The maximum pressure in the pipe will be: $P = P0 + \Delta p$

3. Determining the pipe thickness. Applying the above formula to our pipe we define the necessary thickness of turbine pipe to meet the hydraulic punch for a wide range of the closing time of turbines. The results of the above calculations are presented in tabular form below (Table 1 and 2, Chart 2):

Table 1. Llogaritja e presionit nga grushti hidraulik

Water flow in the pipeline (m3/s)	2.1
Pipeline diameter (mm)	1100
Pipeline Length (m)	2180
Normal level in upstream	632
Normal level in downstream	469
Module of water elasticity	$2.15*10^{9}$
Module of elasticity of pipe material	$2.0*10^{11}$
The initial velocity of water (m/s)	2.21
Acceleration of Gravity (g)	9.81
Hydrostatic pressure (m)	163
Allowed stress [σ] KN/mm^2	2800
Welding coefficient K	0.9
δ- corrosion mm	2

Table 2. Calculation of hydraulic punch

Turbine closing	N	Δ P + (m)	Δ P - (m)	P0 (m)	P+total(m)	P-total(m)	Thickness of pipe from	Thickness of pipe from	Thicknees of tube (full)	velocity of wave (m/s)	Critical time (sek)	Pressure of wave (m)
1	9.085	1629.04	-148.17	163.00	1792.04	14.83	39.11	8.46	41.11	1287.14	3.39	290.08
2	2.271	492.70	-122.48	163.00	655.70	40.52	14.31	8.46	16.31	1119.90	3.89	252.39
3	1.009	265.54	-101.00	163.00	428.54	62.00	9.35	8.46	11.35	1032.76	4.22	232.75
4	0.568	177.53	-84.98	163.00	340.53	78.02	7.43	8.46	10.46	1011.76	4.31	228.02
5	0.363	132.24	-73.01	163.00	295.24	89.99	6.44	8.46	10.46	1011.76	4.31	228.02
6	0.252	105.00	-63.86	163.00	268.00	99.14	5.85	8.46	10.46	1011.76	4.31	228.02
7	0.185	86.91	-56.68	163.00	249.91	106.32	5.45	8.46	10.46	1011.76	4.31	228.02
8	0.142	74.06	-50.92	163.00	237.06	112.08	5.17	8.46	10.46	1011.76	4.31	228.02
9	0.112	64.49	-46.21	163.00	227.49	116.79	4.97	8.46	10.46	1011.76	4.31	228.02
10	0.091	57.09	-42.28	163.00	220.09	120.72	4.80	8.46	10.46	1011.76	4.31	228.02
11	0.075	51.20	-38.96	163.00	214.20	124.04	4.68	8.46	10.46	1011.76	4.31	228.02
12	0.063	46.41	-36.12	163.00	209.41	126.88	4.57	8.46	10.46	1011.76	4.31	228.02
13	0.054	42.43	-33.66	163.00	205.43	129.34	4.48	8.46	10.46	1011.76	4.31	228.02
14	0.046	39.07	-31.52	163.00	202.07	131.48	4.41	8.46	10.46	1011.76	4.31	228.02
15	0.040	36.21	-29.63	163.00	199.21	133.37	4.35	8.46	10.46	1011.76	4.31	228.02
16	0.035	33.73	-27.95	163.00	196.73	135.05	4.29	8.46	10.46	1011.76	4.31	228.02
17	0.031	31.58	-26.45	163.00	194.58	136.55	4.25	8.46	10.46	1011.76	4.31	228.02
18	0.028	29.68	-25.10	163.00	192.68	137.90	4.21	8.46	10.46	1011.76	4.31	228.02
19	0.025	27.99	-23.89	163.00	190.99	139.11	4.17	8.46	10.46	1011.76	4.31	228.02
20	0.023	26.49	-22.78	163.00	189.49	140.22	4.14	8.46	10.46	1011.76	4.31	228.02
21	0.021	25.13	-21.78	163.00	188.13	141.22	4..11	8.46	10.46	1011.76	4.31	228.02

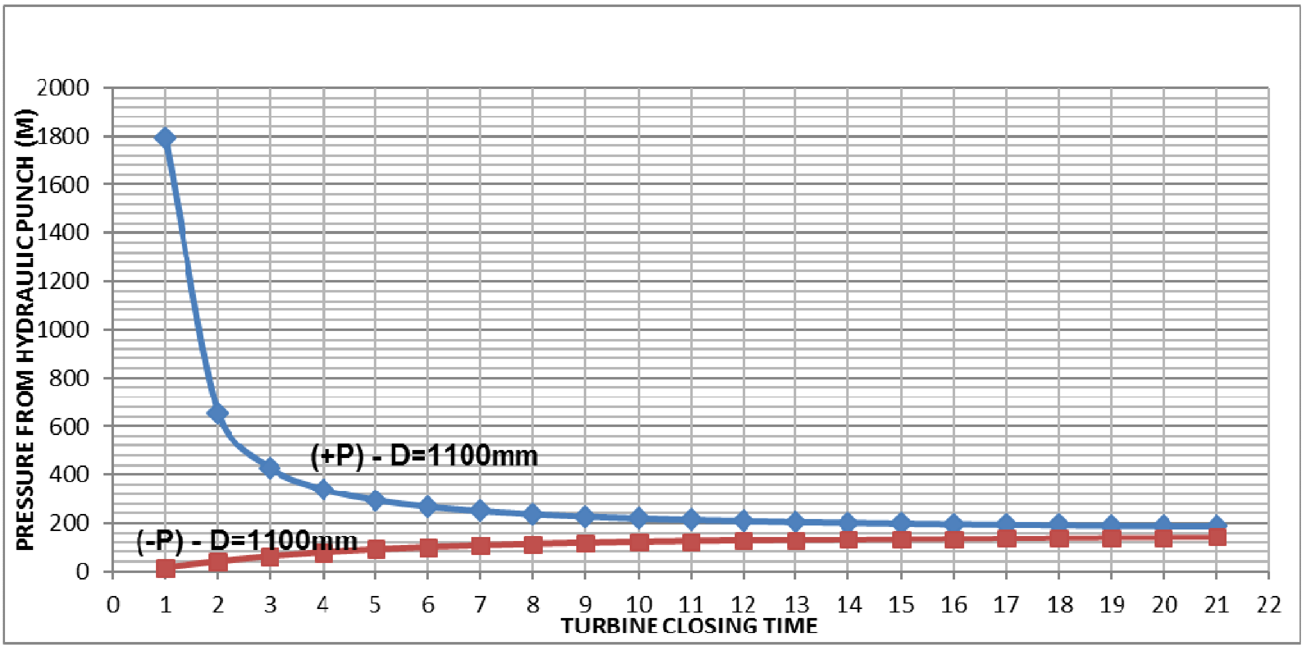

Chart 2. Positive and negative pressure from hydraulic punch, for the diameter of turbine pipeline

Knowing the closing time of the turbine about 6 seconds, requires the thickness of the pipe to be 10.46 mm, a thikness that meets the transport, instalation and rust conditions.

4. Losses in the turbine pipe (longitudinal losses). Turbine pipeline losses are a function of the water velocity, which itself is a function of flow and diameter of turbine pipeline.There are several methods for calculating losses in pipes. Despite their differences in their parameters, their results do not differ much from each other, to see this change, the calculations of losses are done according to three authors as shown in following table (Table 3):

Formula of Maningut $hw = \frac{10.3 \cdot L \cdot n^2 \cdot Q^2}{D^{5.333}}$

Formula of Darcy-Weisbah $hw = f \cdot \frac{L \cdot v^2}{D \cdot 2g}$

Formula of Hazen $hw = \left(\frac{151 \cdot Q}{C \cdot D^{2.63}} \right)^{1.85} \cdot L / 1000$

Table 3. Calculation table of Manningut

Darcy-weisbah		**Maning**		**Hazen**	
Q (m^3/s) =	2.10	Q (m^3/s) =	2.10	Q (m^3/s) =	2.10
D_j(mm) =	1100.00	D_j(mm) =	1100.00	D_j(mm) =	1100.00
t (mm) =	10.00	t (mm) =	10.00	t (mm) =	10.00
L (m) =	2180.00	L (m) =	2180.00	L (m) =	2180.00
H_{st} (m) =	163.00	H_{st} (m) =	163.00	H_{st} (m) =	163.00
ε (m) =	0.000150	S =	0.950	S =	0.950
ν (m^2/s) =	0.000001006	R =	0.270	R =	0.270
v (m/s) =	2.210	n =	0.012	v (m/s) =	2.210
Re =	2372301.141	v (m/s) =	2.210	C =	120
f =	0.013				
$H_{w\text{-}long.}$ (m) =	6.735	$H_{w\text{-}long.}$ (m) =	8.577	$H_{w\text{-}long.}$ (m) =	9.048
$H_{w\text{-}Lok}$ (5%) =	0.337	$H_{w\text{-}Lok}$ (5%) =	0.429	$H_{w\text{-}Lok}$ (5%) =	0.452
$H_{w\text{-}Tot}$ (m) =	7.071	$H_{w\text{-}Tot}$ (m) =	9.006	$H_{w\text{-}Tot}$ (m) =	9.501
$H_{w\text{-}Tot}$ (%) =	4.338	$H_{w\text{-}Tot}$ (%) =	5.525	$H_{w\text{-}Tot}$ (%) =	5.829

5. Calculation of the diameter of ventilation pipe. The ventilation pipe serves for inserting or removing the air from the turbine pipeline and its protection by immediately filling or emptying.

When the pipe is filled with water, air in it is removed through the ventilation tube, and when the water is emptied from the pipeline the air is replaced through the ventilation pipe in order not to create vacuum.

Ventilation pipe section depends on the flow rate of the air passing in it, as well as from its velocity in the pipe, this is given by the formula:

$$F_a \geq \frac{Q_a}{V_a} \ (m^2),$$

from which we find the diameter of ventilation pipe:

$$D_a \geq \sqrt{\frac{4 \cdot F_a}{\pi}}$$

where:

Q_a = air inflow, which is accepted equal to the water flow in the pipe (m^3/s).

V_a = air velosity , for which the pressure difference between atmospheric pressure and the pressurein the pipeline should not exceed the allowed value.

$$v_a \leq 400 \cdot C \cdot \sqrt{\Delta p}$$

where:

c = coefficient that takes into account the flow supopression which is agreed for pipe 0.7 and for valves 0.5.

Δp – allowed drop of pressure, which depends on the the rigidity of the pipeline.

$$\Delta p = \frac{2 \cdot E}{k} \cdot (\frac{\delta}{D_0})^3 \ \text{kg/cm}^2$$

where:
E = module of elasticity of the walls material of the turbine pipeline, which in our case is of steel E=2.1*10^6 kg/cm^2.
δ = average thickness of walls of the turbine pipes 10 mm.
D_0 = The internal diameter of the pipeline D_0 = 800 mm.
K = safety coefficient was accepted for coated pipes 10 and uncoated pipes 5 , in our case most of the length of the pipeline is coated. The calculations are presented in Table 4.

Table 4. Calculation of diameter of ventilation pipes

D (mm)	δ (mm)	E (kg/cm^2)	K	ΔP (kg/cm^2)	C	V_a (m/s)	Qa (m^3/s)	Fa (m^2)	Da (mm)
800.00	10	2.10E+06	10	0.820	0.700	253.599	0.400	0.002	44.814

The diameter of the ventilation pipe will be agreed more or equal to d ≥ 44.814 mm.

CONCLUSIONS

- In this study we have taken into consideration all the design principles, focusing specially on:
- Knowledge of base material of tube formation
- Selection of electrode adapted to the base material
- Choice of temperature at which welding will be carried
- Choosing the optimal parameters of the welding equipment
- Alignment of joints welded with define space
- NDT testing of the welding seam
- Avoiding at the maximum the thermal stresses during welding and manage the cooling of the seam
- After welding, special parts of the Penstock must be subject to thermal treatment e.g. biffurcation
- Joining with welding , better realization by chemical corrosive and controllable requires among others alignment and care to the root layer.
- In cases where the penstock is on the surface, the relative extension must be solved by temperature fluctuations with expansion the places where it is claps with anker must be free moving.
- The interior and the external surfaces of the pipe are waterproofed.

References

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