

“NEW PELTON CONCEPT” UP TO SIX NOZZLES HORIZONTAL

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Abstract: Since the basic invention of the Pelton turbine more than 140 years ago, the developing underwent significant phases. It started from the one- and two jet horizontal turbine, up to the six-jet turbine 50 to 60 years ago, with the requirement to increase the power density of the unit. This could only be managed by turning the main axis into a vertical position to drainage the complied splash water to the outlet channel. Some manufacturers where then motivated to develop three jet horizontal units - with varying success.

A sudden inspiration gave me the kick to review the complete Pelton turbine from top to bottom. The result was a New Pelton Concept, now referred to as the Erlach Turbine.

1. Introduction

In a Pelton turbine the entire useful pressure energy is converted into kinetic energy in the nozzle. After the water is leaving, the free jet is in an ambient atmospheric pressure of the housing and hits tangential the double buckets of the runner. The free jet is cut by a central splitter into two equal parts and is deflected in the bucket by nearly 180° . Through the deflection almost all of the jet energy is converted into mechanical energy acting as an impulse force to the rotor. The remaining residual energy of approximate 2 to 4 % is still present as kinetic energy. This outlet spray water is - after leaving the buckets - divergent, and the entrainment of air is considerable, the ratio to water is about 40 to 70%. The direction from the buckets is mainly axial to the rotations axis and radial outwards. During the phase when the bucket hits the free jet and at the last part of dewatering the bucket, fine water spray, like foam, can be mixed with the rotation air, it is with low energy, non directed and can fill out the housing.

The housing shall be designed to guide this spray water in direction of the outlet channel, without a reflection to the runner. The runner itself has great air consumption, due to the ventilation effect of the buckets. These runner losses are about 1 to 1.3 %. Due to this fact, also water foam can be suctioned into the runner. At the beginning of the Pelton era, only horizontal Pelton turbines, with one or two nozzles were built. The dewatering of the spray water and foam to the outlet channel could be managed with a good housing, without spray water and foam to be rejected back to the runner.

Later on, to increase the energy density, Pelton turbines were built with up to six nozzles. In order to control dewatering, the runner in the housing and the runner's axis became vertical. Whereas the outlet spray water in direction to the channel, normally causes no problem, the above outlet water spray needs special care to avoid interference with the runner.

2. Realization of the invention for a New Horizontal Pelton

2.1. Study of investigation of the splash water in Pelton housings

The theoretical knowledge of the interaction between runner and housing, is still not in a status to follow the out coming splash water, independent of hydraulically design of the runner buckets and various housings constellations and frictions, as well different amount of air, makes it difficult for a complex calculation (Ray tracing). Almost two decades ago the first splash water distribution on a horizontal double-jet turbine was started as model test on the Institute of Waterpower and Pumps in Vienna [1], on the basis of visual documentation, qualified by efficiency measurements. A PIV measurement of three dimensional splash water flow distribution was started ten years later at the same Institute [1].

Measurements of the jet impact velocity in casings on a vertically six-jet prototype turbine, HPP Koralpe [2] was done by the University of Technology, Graz. The aim of this research project was getting a wider knowledge of the processes in the casing of Pelton runners in terms of velocity of the water flow and the transport of portion of air, their distribution over the base area of the casing. The amount of entrained air could be calculated by the using results. The target was to get information of aeration for the HPP Kops II, with the Pelton turbine running with back pressure in the outlet channel.

A video clip made by TIWAG of the 250 MW HPP Silz, gave me an impressive view of the splash water coming out of this vertically six-jet Pelton turbine runner buckets. The remaining energy in the splash water is still 3 to 4 % and is demonstrated in the velocity. As well the need of air of the divergent water spray can be seen in combination with the air ventilation of the runner. These impressions are really challenging.

2.2. Dewatering of the splash water → create a new housing

Again, for Pelton turbines it is essential, to have free jet, bucket design, gap angular between the nozzles, ventilation and aeration in a good matching with the housing. Up to two-jet horizontal Pelton turbine, the spray water can be good drained down to the channel. The gap angular can be selected up to 90 degrees for good dewatering the buckets. With a three jet-turbine this gap must be strongly reduced, to avoid spray water going upwards in the housing and fall down into the runner. A reducing of the gap angular shortens the time of dewatering and decrease the performance of the turbine.

The target was to create a new housing which is able to protect the runner from down falling water to the runner and this with up to six nozzles.

Koralpe: Pelton turbine

6 jet vertically

$Q_N = 8 \text{ m}^3/\text{s}$

$H_n = 720 \text{ m}$

$P = 50 \text{ MW}$

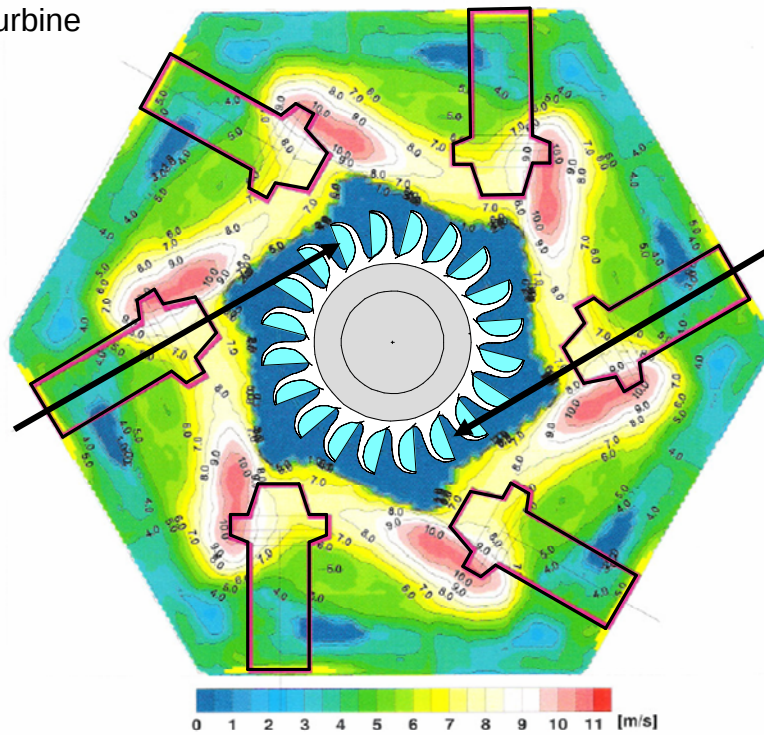


Abbildung 5.27: Vertikale Abstrahlgeschwindigkeit v_v [m/s]

Fig. 1. HPP Koralpe; View from the injectors and runner section, down to the main measuring section (velocity and flow distribution), positioned on the trash rack

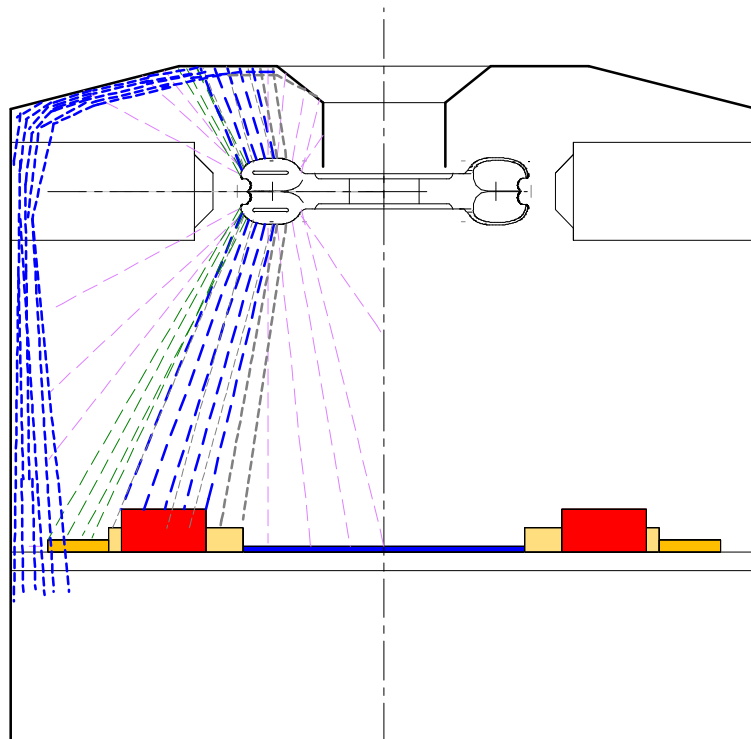


Fig. 2. HPP Koralpe; Cross section
Velocity and flow distribution of the splash water from the runner to the trash rack, transposed from the measurements, see Fig. 1

2.3. From the IDEA to the REALITY

Transposing a latent idea in combination with all my experience by studding various investigations of splash water in Pelton houses, especially [1, 2], the target came closer.

In consideration of the constellation of the six-jet vertical turbine and in knowledge of the main splash water flow distribution (see Fig.1, 2), the system was turned (main shaft) to 90 degrees in to horizontal axis (see Fig.3). The idea was to avoid now the splash water reflecting to the runner, a spray water guiding ring in a certain distance to the runner was placed. The outer guiding ring is designed in a manner following the main flow of splash water. With a second ring on inner side, the complied splash water and foam is focused in a way that the runner is protected from the spray water and vagabonded foam. Incident water particles mixed with air, hitting in a certain angle of attack at the side plates, will be reflected in more or less radial direction. There is still some kinetic energy in the drainage water, so the needed space will be moderate, the housing becomes small.

Preliminary semi homologue model tests, with different housing constellations, brought out encouraging results to continue.

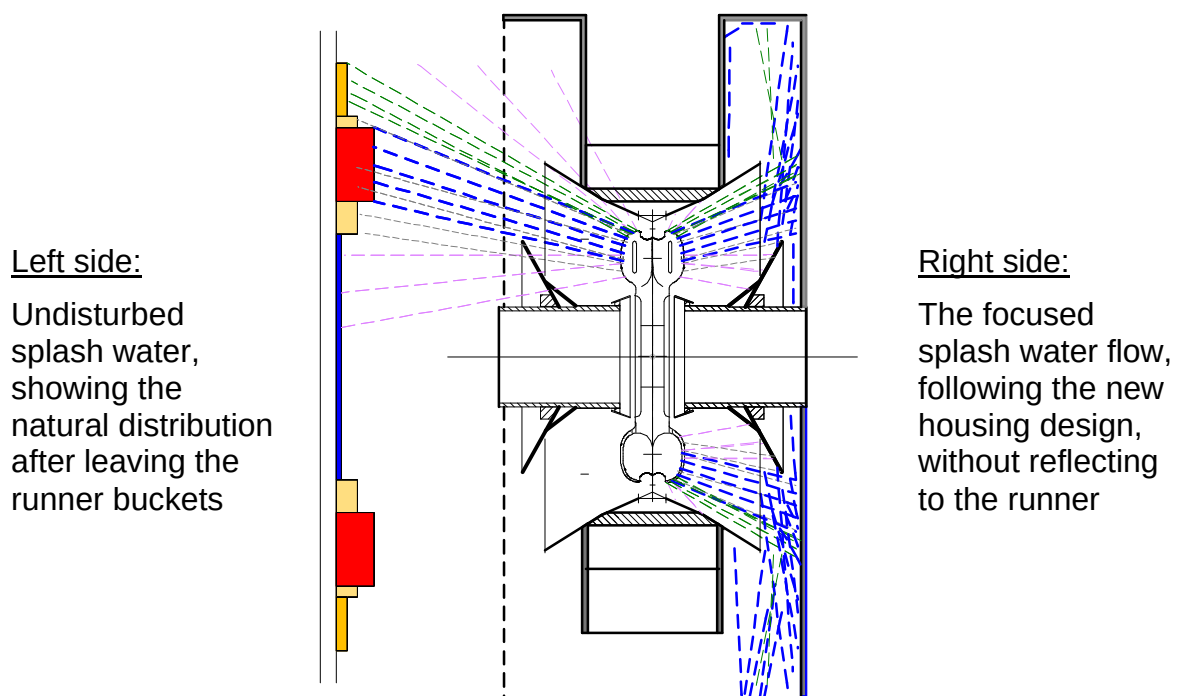


Fig. 3. Principle sketch of the new six-jet horizontal Pelton turbine housing
Drainage of full flow with six-jet in action down to the outlet channel

2.4. New Axial Distributer

A water supply system in axial direction to the nozzles (optional) was in the focus as well. As it is known, that in a conventional six nozzle distributor, different flow conditions are existing. Deviation can be with individual nozzle operation ± 0.3 to 0.6 % of over all efficiency. It is known that the last nozzle have the best inflow

condition. This nozzle feeding pipe design was taken as basic design and was only to multiply for the others up to six. The commercial aspects are the production-oriented components. The design can be seen in Fig. 10

A special application (Fig. 4) is the distributor from the cone to the individual elbows and pipes for the feeding water to the injectors. The aim was to have the same inflow condition to every branch independent of the active nozzle combination as well a low friction coefficient, low swirls and to keep the diameter of the cone small.

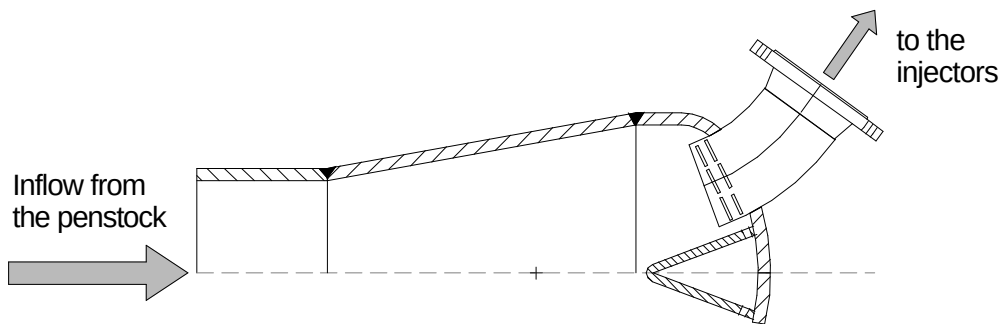


Fig. 4. Inflow cone of the axial distributor
Special application (see also patent EP 2 035 689)

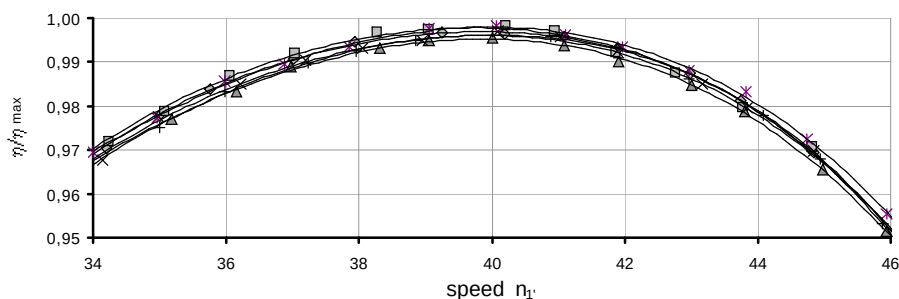


Fig. 5. Axial distributor, efficiency deviation
with the individual nozzles operation from 1 to 6, at full load

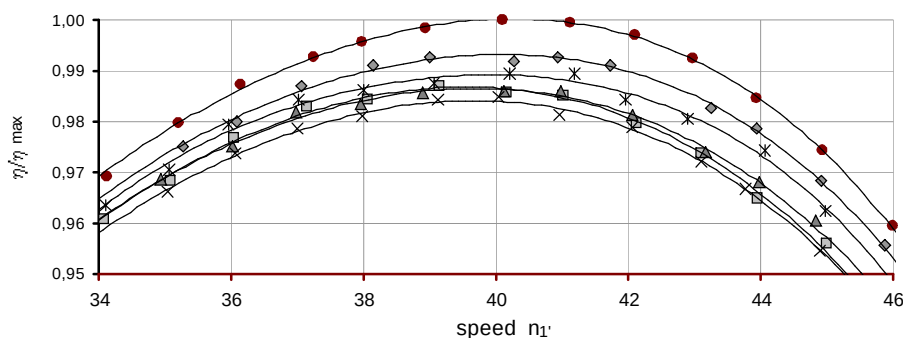


Fig. 6. Conventional distributor, efficiency deviation
with the individual nozzles operation from 1 to 6, at full load

2.5. Model Tests

In consideration of a substantial reform of the complete Pelton turbine, extended full homologue model tests had been made over the complete water way from the main closing device up to the drainage to the outflow channel, concerning inflow condition to the nozzles with different distributors, nozzle tests, jet quality, and ventilation losses of the runner, runner displacement, splash water from the buckets, as well different housing constellations and aeration. This was done with various nozzles opening and combinations over the full operating field.

As basis to compare the new Pelton concept with a conventional Turbine, a well known standard vertical six-jet turbine from the research partner VOITH Hydro was taken with the components and data from vertical measurement. The complete Model Turbine (state of art) with distributor, injectors and runner was turned in horizontal position and adapted with the new housing. Later on with the same basic constellation, the axial distributor was changed with the conventional one.

A good equipped and certificated Laboratory (HSLU – Luzern), with high accuracy flow calibration (mass and volume) could be found. The crew could demonstrate an absolute overall measurement accuracy of 0.25 %, with the repeatability of 0.1 %. This was the back ground of a seriously test campaign.

The evaluation of the hydraulically efficiency was made in accordance to IEC 60103. Some extracts of the result can be seen in:

One jet in operation; Fig. 5, 6. It demonstrates the inflow effect of the new axial system versus the conventional distributor, tested with the same conditions. The data are normalized by taking $\eta_{\max}$ for both diagrams the same value.

Three jets in operation; Fig. 7. Shows the increasing of the performance due to the new possibilities to extend the angular separation between the nozzles over the complete circumference. For a three-jet horizontal Pelton in prior art the gap is about 60 to 70 degrees. In the case of the new Pelton Turbine, the gap becomes 120 degree and enables time enough to empty the runner buckets. Fig. 8. Shows the vertical six-jet Pelton turbine (state of art) at full load as basis, versus to the new horizontal Pelton turbine conventional distributor and as well the new axial distributor.

Six jets in operation; Fig. 9. Shows the vertical six-jet Pelton turbine (state of art), at full load as basis, versus to the new horizontal Pelton turbine with the conventional distributor

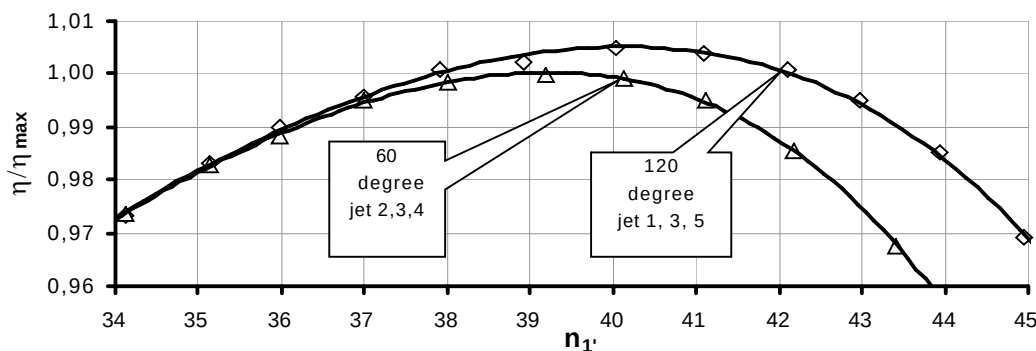


Fig. 7. Six-jet Horizontal Pelton, with axial distributor, three-jet in operation, at full load
Increasing of the efficiency with 120 degree versus 60 degree

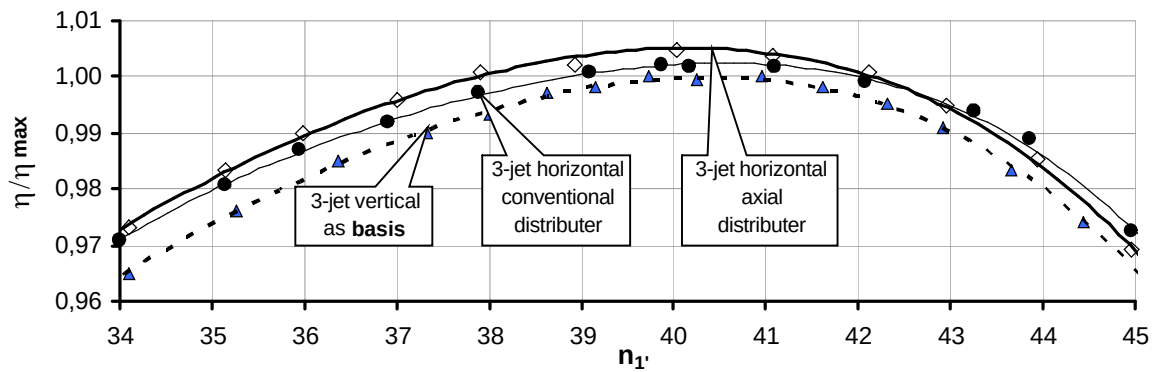


Fig. 8. Six-jet Horizontal Pelton with three-jet in operation at full load
Vertical axis versus horizontal axis

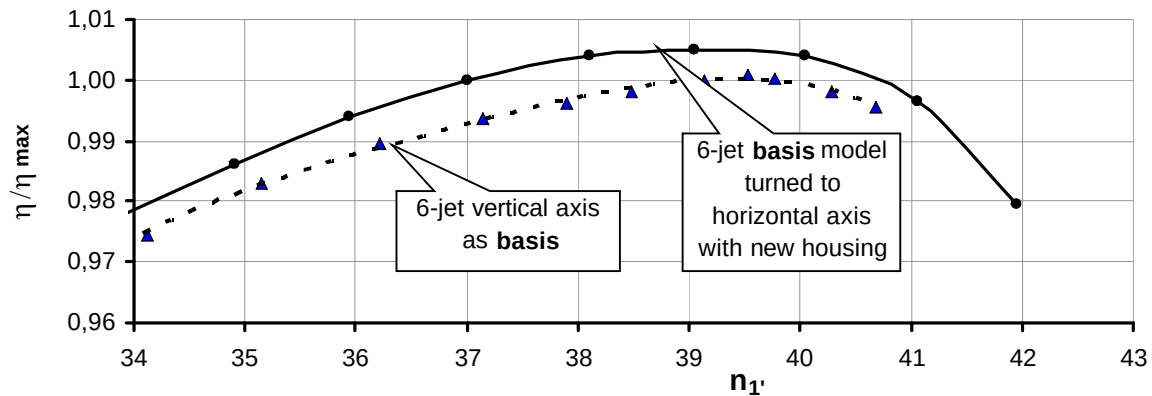


Fig. 9. Six-jet Horizontal Pelton with six-jet in operation at full load
Vertical axis versus horizontal axis

3. Main functions & advantages of the “New Horizontal Pelton”

3.1. Basic concept:

- Increasing the power density of the unit by using up to six jet per unit instead two (three) jets
- Flat turbine efficiency characteristic, good operation condition down to 5% of discharge. (summer and winter operation with one unit)
- Better performance due to an extension of the gap angular between the nozzles over the complete circumference.
- Outflow conditions from the runner buckets are left and right symmetric, so the conditions become better then in a vertical Pelton.
- Specially at full load condition, a clearly increasing of the performance
- Reduction of costs, especially of the generator because of higher speed opportunity.
- No additional baffle blades to avoid splash water and foam.
- Involving all advantages of a horizontal unit, now using up to six jets

The basic concept can be used with the conventional distributor, see Fig. 11 and as well as option with the axial distributor, see Fig. 10.

3.2. Option: Axial distributors

- Complete inflow arrangement, from the main closing device to the injectors, standard components (off store, good value) can be used; short work shop duration time can be realized.
- Weight reduction about 20 %, reduction of welding can be reduced up to 50 % compared to a six jet conventional distributor.
- Good for standardisation and parametric design, easy to adapt to different runner diameters. Axial bearing forces are better balanced.
- The housing concept is created in such a way, that for all nozzle combination (2 to 6), the basic configuration is the same.
- All nozzle inflow condition are nearly equal, therefore they have the same efficiency condition, independent of the active nozzle combination.
- Easier to extend the gap angular between the nozzles.

4. New Pelton Concept, schematic sketch → Erlach Turbine

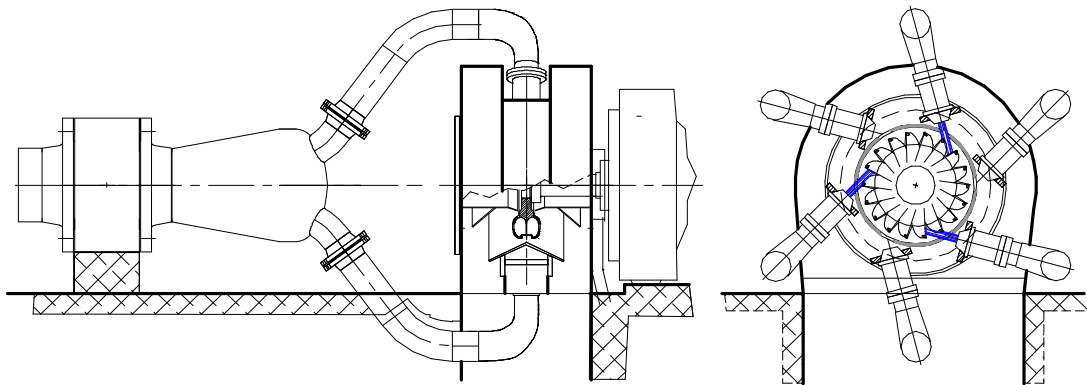


Fig. 10. Relates to the configuration with an axial distributor (six jet)

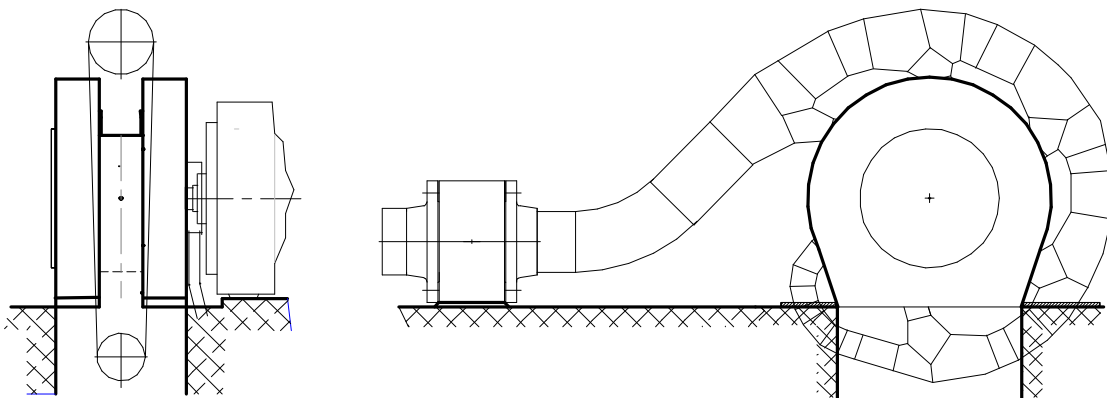


Fig. 11. Relates to the configuration with an conventionally distributor (six jet)

5. Status

Preliminary, semi homologue model tests was made at the University of Stuttgart (Prof. Dr.-Ing. E. Göde), seen as function test, brought out encouraging results.

Full homologue model tests carried out at the University of Luzern (Prof. Dr.-Ing. Th. Staubli), validated full the function of the first six nozzles horizontal Pelton turbine.

In cooperation with the research partner VOITH Hydro, this concept was brought to commercial use. As the first license partner VOITH Hydro is on the way to realize the New Pelton Concept.

Concerning the new Pelton turbine, three patents are granted worldwide for the design of housing and the water supply system.

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C.V.

I was born in Austria (AT). Start of my career was HPP Kaprun, AT. In 1963, I joined Andritz Hydro (Escher Wyss) for 40 years. I am experienced in commissioning, mechanical design, specification and site testing, for all types of hydraulic machines, plants and components for new and refurnished projects, until 2003. After retirement I started as an independent consultant, specialized in advising for pumped storage power stations (VIW, Kops II AT / GNFE, ES). In 2010, I was honored with the IEC "1906 Award".