Diaphragm in pressure pipe: Steady state head loss evolution and transient phenomena

LABORATOIRE DE CONSTRUCTIONS HYDRAULIQUES
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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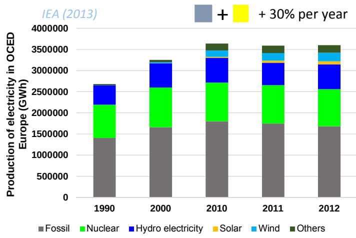
Introduction

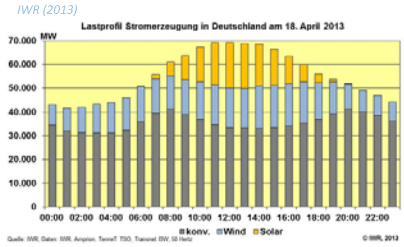
ELECTRICITY MARKET CONTEXT

Demand is still growing: expected to double by 2030

The part of renewable (wind + solar) is still increasing



Total production of electricity in OECD Europe

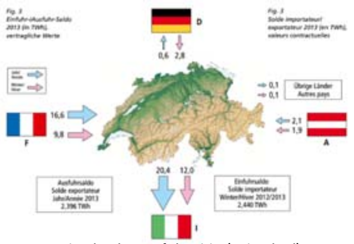


Evolution of electricity production in Germany

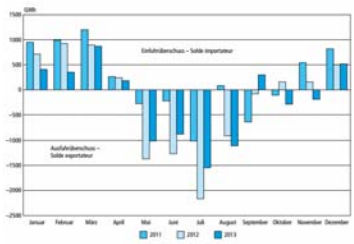
Liberalization of European electricity market

Introduction

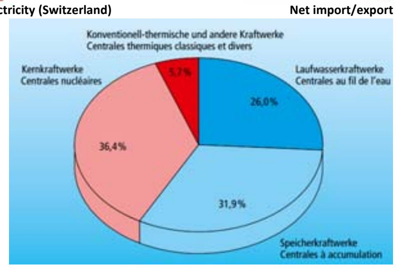
SWISS MARKET - HYDROELECTRICITY



International exchange of electricity (Switzerland)



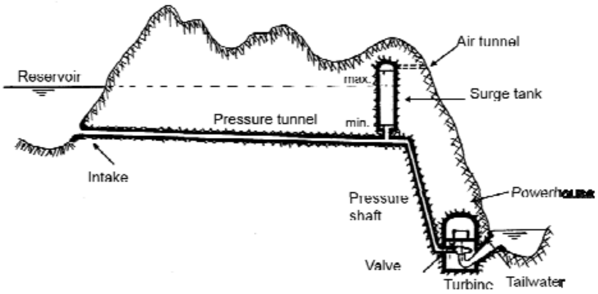
Net import/export blance in Switzerland (2013)



Total production of electricity in Switzerland
distributed by category (2013)

Introduction

HIGH HEAD POWER PLANT



Role of surge tank

- Reducing the water hammer
- Improve the regulation of turbines
- Damping of the acceleration and

deceleration of flow in the pressure tunnel

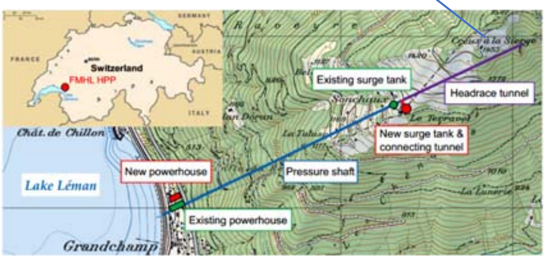
Forces Motrices Hongrin-Léman

©Swissdam

Lake Hongrin:

- Normal elevation: 1255 m.a.s.l
- Minimum elevation: 1205 m.a.s.l
- Water volume: 345'000 m^3
- Catchment area: 91 km^2

(natural: 46 km^2 + adduction: 45 km^2)

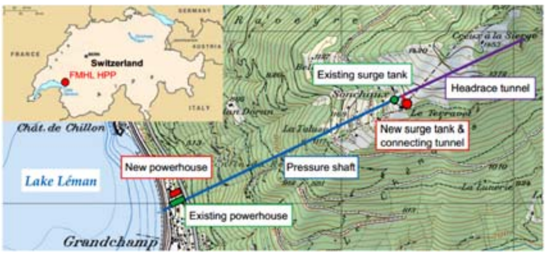


(Hachem et al., 2013)

Lake Geneva:

- Elevation: 372 m.a.s.l
- Water volume: 89 km^3

Forces Motrices Hongrin-Léman



(Hachem et al., 2013)

Existing powerhouse
- Commisionned in 1971
- Maximum head: 878 m
- Existing generation capacity: 4 x 60 MW
- Flow capacity (generation): 33 m^3/s
- Flow capacity (pumping): 24 m^3/s
- Annual generation: 724 GWh
  - Natural generation: 188 GWh
  - Pumped generation: 536 GWh

www.fmhl.ch

Veytaux I plant

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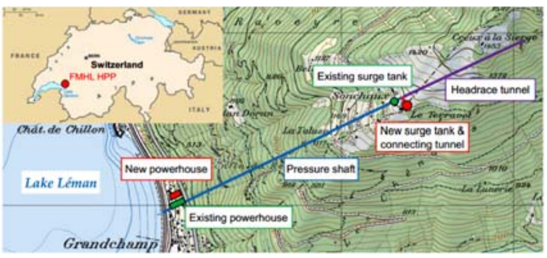
Forces Motrices Hongrin-Léman



(Hachem et al., 2013)

New powerhouse
- Under construction
- New generation capacity: 420 MW + 60 MW
- New flow generation: 57 m^3/s
- New flow pumping: 43 m^3/s

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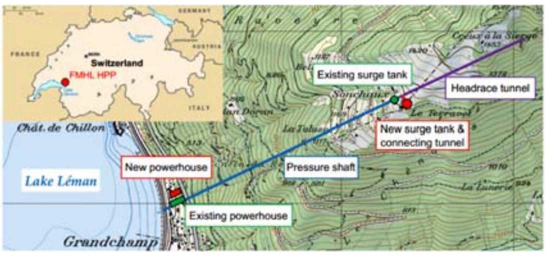
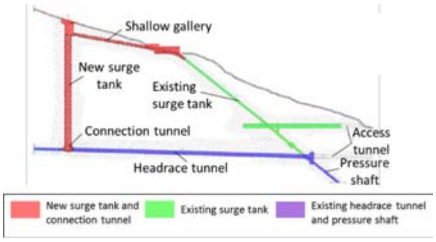
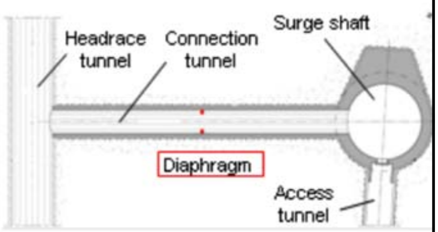
Forces Motrices Hongrin-Léman



(Hachem et al., 2013)



(Hachem et al., 2013)



(Hachem et al., 2013)

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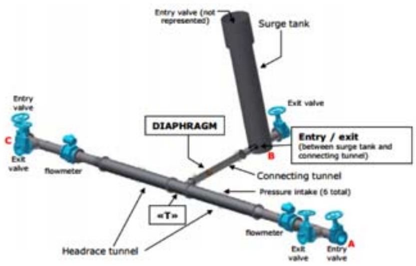
Experimental set-up



EXPERIMENTAL CHARACTERISTICS

Froude similarity
Scale: 1/18.2
Set of discharges: 6 – 8 discharges from 0 to 35 l/s
Determination of pressure: Linear relation between signal and piezometric value
Data acquisition: 100 Hz – 15 s

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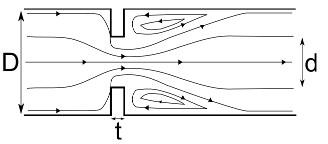
Experimental set-up

PREVIOUS STUDY

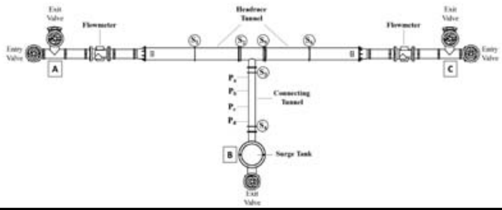
Determination of head losses to obtain the target head losses by varying β

- C0: none
- C1: β=0.70
- C2: β=0.77
- C3: β=0.74



GOAL OF THIS STUDY

1) Evolution of the head losses by varying the position in the connecting tunnel for C1 and C3
2) Temporal evolution of head losses during an emptying of the surge tank



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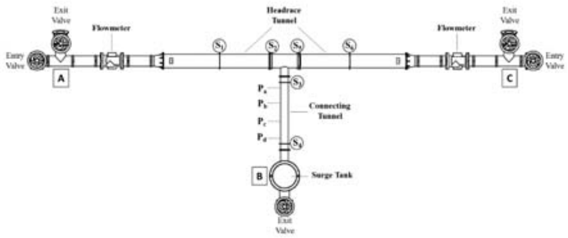
Head loss coefficient

DEFINITION

$$\Delta H = k \cdot \frac{v^2}{2g}$$

where: ΔH is the head losses, k the head loss coefficient, v the flow velocity and g the gravitational constant

$$Z_{Up} + \frac{p_{Up}}{\rho g} + \frac{v_{Up}^2}{2g} = Z_{Dn} + \frac{p_{Dn}}{\rho g} + \frac{v_{Dn}^2}{2g} + \Delta H$$



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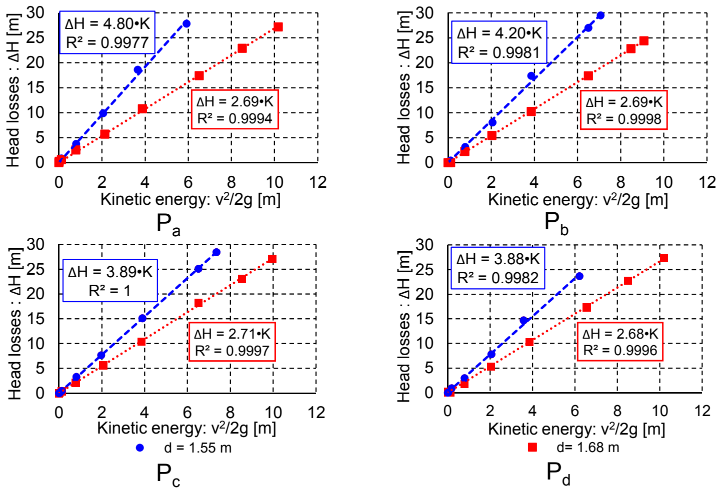
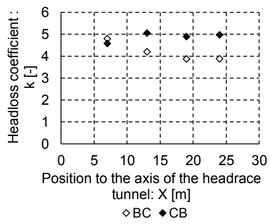
Steady head losses

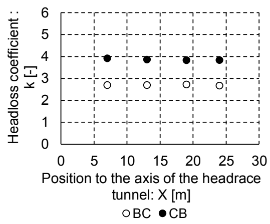
RESULTS



Steady head losses

RESULTS

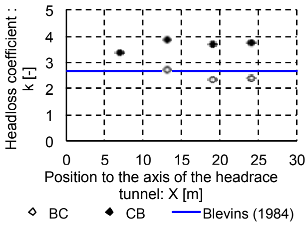


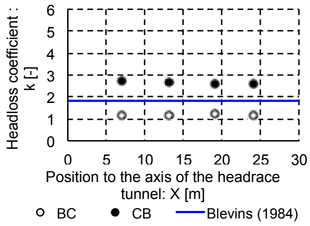


Comments:

- For the flow coming from the surge tank B:
  - More the orifice is close to the T-junction, higher is the head loss coefficient.
  - These is no effect for the bigger internal diameter.
- For the flow going to the surge tank B:
  - More the orifice is close to the T-junction, lower is the head loss coefficient.
  - Idem: No effect on the bigger orifice.

Steady head losses





Comments:

- Literature relation does not predict correctly the head loss coefficient.
- Influence of the flow conditions

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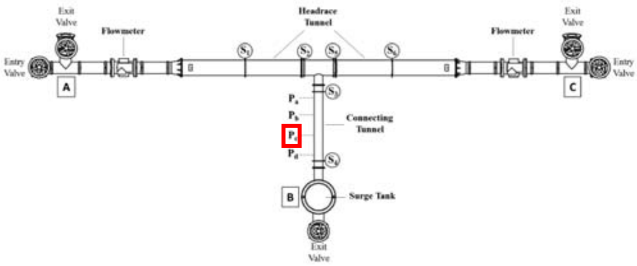
Transient head losses

EXPERIMENTS STEPS

1. The surge tank is filled.
2. The downstream valve is opened as quick as possible.
3. The transient pressures and discharge are recorded.

Duration of the experiments: 15 – 20 s



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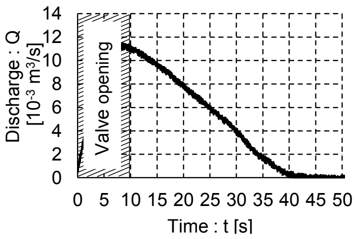
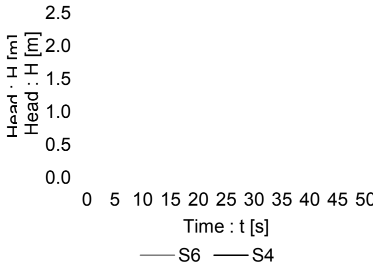
Transient head losses

RESULTS





Comments:

- First part of experiments are influenced by the valve opening.
- Discharge drops linearly.

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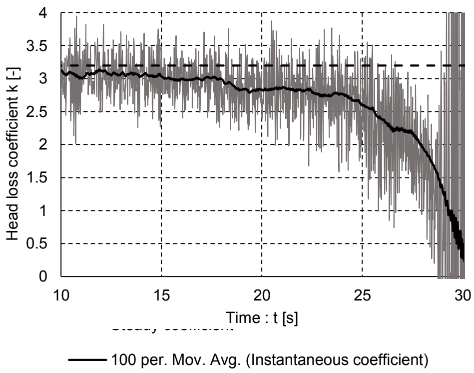
Transient head losses

RESULTS



Comments:

- For a decrease of discharge: Transient head losses is always under the steady one.
- There are 2 or 3 drop steps.

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Conclusions

STEADY HEAD LOSSES

The upstream and downstream flow condition influence the head losses through an orifice.

This induces more iterations to obtain the expected orifice.

Literature value are only used for long and straight flow conditions.

TRANSIENT HEAD LOSSES

For a decrease of discharge, the head loss coefficient is always under the steady one.

Next steps: Study a increase of head losses

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Conclusions

STEADY HEAD LOSSES

The upstream and downstream flow condition influence the head losses through an orifice.

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TRANSIENT HEAD LOSSES

For a decrease of discharge, the head loss coefficient is always under the steady one.

Next steps: Study a increase of head losses

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Outlooks for the thesis

SCIENTIFIC

- **Better understanding** of flow through a **throttle constriction**, orifice, in pressurized pipe
- **Influence** of **geometry** of throttles in pressurized pipes on **local head losses**
- **Interaction** between **flow behaviour** and **head losses** through throttles in pressurized systems

PRACTICAL

- Creation of a **catalogue summarizing** head losses as function of **different orifices** for a practical use.
- Establishment of correction factor as a function of flow conditions and junction geometries

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Thank you for your attention

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