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Energy efficient fish attraction

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EFFISHENT ENERGY EFFICIENT FISH ATTRACTION

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Vattenfall: selected facts (2017)

- Power Company owned by the Swedish State
- Electricity generation: 31 200 MW (127 TWh)
- Whereof hydro: 11 700 MW (36 TWh)
- >100 hydro power plants
- Hydro mostly in Sweden
Two straight 25 m test sections
Cross section: 2×4 m
Max flowrate: 16 m³/s (2 m/s)
Fish ladder:
- 77 steps
- 350 m long

Attraction water:
- May 20 – Sept. 30
- 10 – 23 m³/s
- Corr. to 7-17 MW

STORNORRFORS
599 MW, 75 m head

Perforated floor
Fish ladder with additional 8 m³/s attraction water (0.6 MW)

Lilla Edet HPP (46 MW, 7.3 m head)
Better use of water for attraction?

**Case Lilla Edet**
- Head 7.3 m
- 8 m³/s
- Velocity <1 m/s

**Typical Swedish HPP**
- Head 25 m
- 8 m³/s
- Velocity <1 m/s

0.6 MW

0.6 MW

2.0 MW

-99.3% <4 kW

-99.8% <4 kW
**Ejector**

- **Q2** Suction fluid (low pressure, higher flowrate)
- **Q1** Motive fluid (high pressure, low flowrate)

- **Nozzle**
- **Mixing chamber (throat)**
- **Diffuser**
- **Outlet**

- **Q1 + Q2**

- **No movable parts**
- **High pressure flow may be used to accelerate low pressure flow**
Use reservoir head to accelerate water below dam
Ejectors in Lilla Edet HPP?

Free surface
From fish ladder
Perforated floor

2+8 m³/s

Q₁
Q₂
Q₁+Q₂
Losses after Ejectors?

Hydraulic losses were estimated with CFD to 0.3 m head over the domain above (dotted line).

Velocities (speed) at a plane parallel with the perforated bottom just downstream fish ladder (at grey arrow heads)

2+10 m³/s
Efficiency of ejectors: Flume experiments
Civil Engineering design of “ejector house”

Flow rate: $Q_1$ 20/36 l/s ($U_{vena\,contracta} = 4/7 \text{ m/s}$)
Throat length: TL 400/1000 mm
Throat height: TH 80/100/200 mm
Diffuser angle: $\alpha$ 2°/4°
Also "no roof"
Example of experimental results

"Lift height" ($\Delta H$) vs. flow

\[
\frac{\Delta H}{\frac{U_{\text{jet}}^2}{2g}}
\]

Efficiency $\eta$ (%)

1D theory:
See Cunningham equations in Karassik et al. (2001) or ESDU (1985)

1D theory, typical loss coeff
1D theory, adjusted loss coeff

- 2018-02-21, TL=1000: Q1=20
- 2018-02-21, TL=1000: Q1=36
- 2018-03-13, No roof, Q1=20
- 2018-03-13, No roof: Q1=36

See Cunningham equations in Karassik et al. (2001) or ESDU (1985)
CFD validation (symmetry plane in mid channel, volume of fluid, standard k-ε)
Conclusions

Savings
• Even a non ideal "civil engineering" design of ejectors still gives major savings of spill for attraction water
• Ejectors may be used to reduce spill flow for attraction water by 67-70%
• By better design of ejector and/or in-feeding of attraction water: 80% is reachable…
• Lower investment in tunnel/tube from reservoir correspondingly (smaller dimensions)

Design
• CFD may be used in design (close to experimental results)
• Primarily design of diffusor part of ejector could be improved
• Technique best suited when downstream main river is adjacent to fish ladder
• Pump for $Q_1$ may replace spill entirely (or be used for entire attraction flow)

Typical Swedish and Lilla Edet HPP case
• For a typical Swedish HPP (25 m head) savings of 1.5 – 1.6 MW is possible
• For Lilla Edet HPP with complex attraction water in-feeding savings of 0.4 MW is possible
References


Report on results from experiments, etc. Contact main author for possible pdf-copy: johan.westin@vattenfall.com (or presenter patrik.andreasson@vattenfall.com )
Reserve:
Hydraulic test
"attraction raft"
Reserve:
Pictures of components