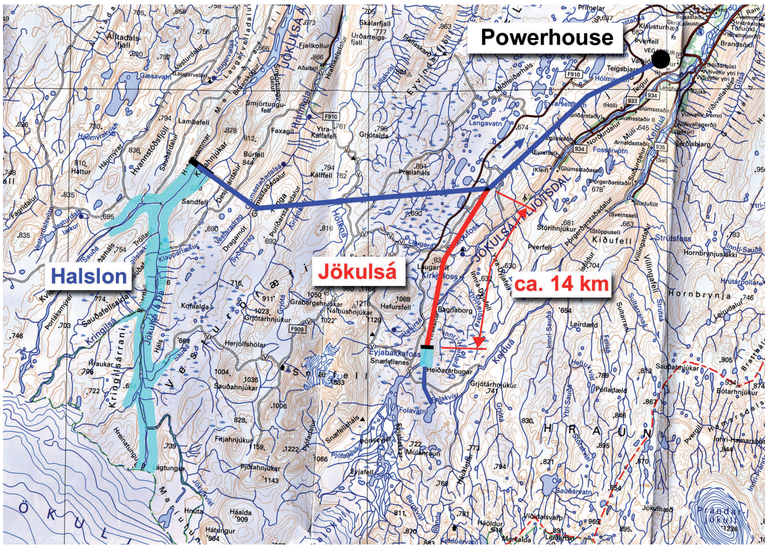
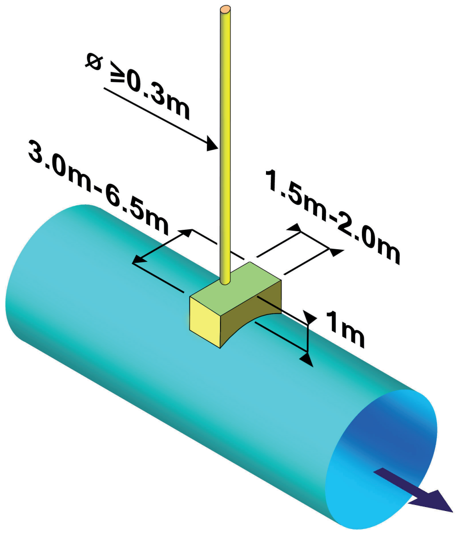
Jökulsá Tunnel – Kárahnjúkar Project (Iceland) (2003)

The Kárahnjúkar Master Plan contemplated the combination of a large Secondary Intake directly connected to the Hálslón low pressure system by means of the 13 km long Jökulsá Tunnel. However, due to the hydrological character of the rivers being harnessed and the associated large water level fluctuations in the Hálslón Reservoir, this tunnel had to operate with very large and variable discharges, as well as with very variable head conditions including free-surface flow in the tunnel upstream stretch. To reach this target in spite of such unfavorable conditions that basically ruled out any conventional hydraulic device (e.g. hydro-mechanical equipment, vortex shaft), the Project Engineer was compelled to invent a non-conventional concept. The governing idea was to minimize the air entrainment into the downstream pressure flow in order to facilitate its still speculative de-aeration. This was achieved by minimizing the slope of the tunnel stretch operating under free-surface flow conditions.



Overview of the project area. The Jökulsa Tunnel with its approx. 14 km length diverts water from southern catchment areas.



Final layout of the de-aeration device, consisting of a de-aeration chamber and a drill-hole, as proposed by VAW.

Practical experience during operation over the past decades has shown relevant discrepancies between measured and theoretically determined energy losses at intake trashracks of low head river power plants. On one hand not all loss-relevant parameters are taken into account by the usually applied equations and on the other hand, thorough comparison of field measurement data is prevented by rapidly changing flow conditions and widely varying geometrical parameters which all may have and influence on the quality of the obtained results. This research contribution tries to point out how this gap can be bridged and better prognosis of trashrack losses can be reached by applying a new equation in combination with numerical analysis of the flow field in the upstream vicinity of such Trashracks.

Obviously, such a concept implied Laboratory investigations, having moreover to be phased as possible negative initial results could induce their discontinuation. Therefore, 2 phases of investigations were defined:

- “Phase 1” aiming at assessing the general technical feasibility of the concept had to investigate the availability of any possible reference, past experience or even numerical modeling before carrying out general physical model testing at variable scales.
- “Phase 2” aiming at defining the design criteria ruling the de-aeration devices final design involved detail model testing at higher scale.

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The bottom line of the Phase 1 was a confirmation of the lack of references as well as the technical feasibility of the hydraulic design concept, thus justifying the contemplated “Phase 2” of laboratory investigations.

Main results and design criteria

“Phase 2” of the laboratory investigations could not only definitely ascertain the technical feasibility of the de-aeration concept but also demonstrate its efficiency, which is very close to 100 %. The de-aeration shafts can therefore be distributed according to the maximum pressure tolerated for the air bubbles and depending on the tolerable rise in water level in the drill hole due to air evacuation (maximum height of water level above tunnel soffit: approx. 5 times the local pressure head, see fig. 2). Furthermore, only one additional safety de-aeration shaft downstream of the lowest possible location of the free-surface flow is necessary (considering also transient conditions).

De-aeration chambers

The design of the de-aeration device can be very simple without requiring any particular constructional means as depicted on the right. The optimum location of the drill holes is at the upstream side of the de-aeration chambers on the tunnel axis and the minimum diameter was set to 300 mm.

Enlarging the spacing between two successive de-aeration points, initially assumed to be 1000 m, is not recommended. Exceptionally, the 1000 m can be exceeded in case of technical reasons prevent drilling in shorter distances. A distance larger than 2000 m is not to be reached in any case as it has to be kept in mind, that even if all measures are taken to prevent it, one drill hole might be blocked.

Increasing the distance between two de-aeration points increases also the rise of the water level in the downstream drill hole, as it is dependent on the local pressure head. An estimation of the total rise above the tunnel soffit can be given as ca. 5 times the local pressure head.

Project data and model tests boundary conditions of the Jökulsá Tunnel

Design (as eventually fixed by the Owner upon Contractor’s proposal):
- Linear cylindrical layout
- Internal diameter: 6.5 m
- Slope: 1.3 %
- Cross section: circular
- Surface roughness: natural TBM excavation in basalt (Kst ~ 55, e ~ 10 mm)

Operating conditions:
- Discharge: 0 – 100 m^3/s

Maximum pressure at the first fully pressurized de-aeration device: 13 m (approx. 1.3 bar, consistently with a de-aeration device spacing of 1000 m)

Keywords:	De-aeration, large conduits, air-water flow, high head scheme
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